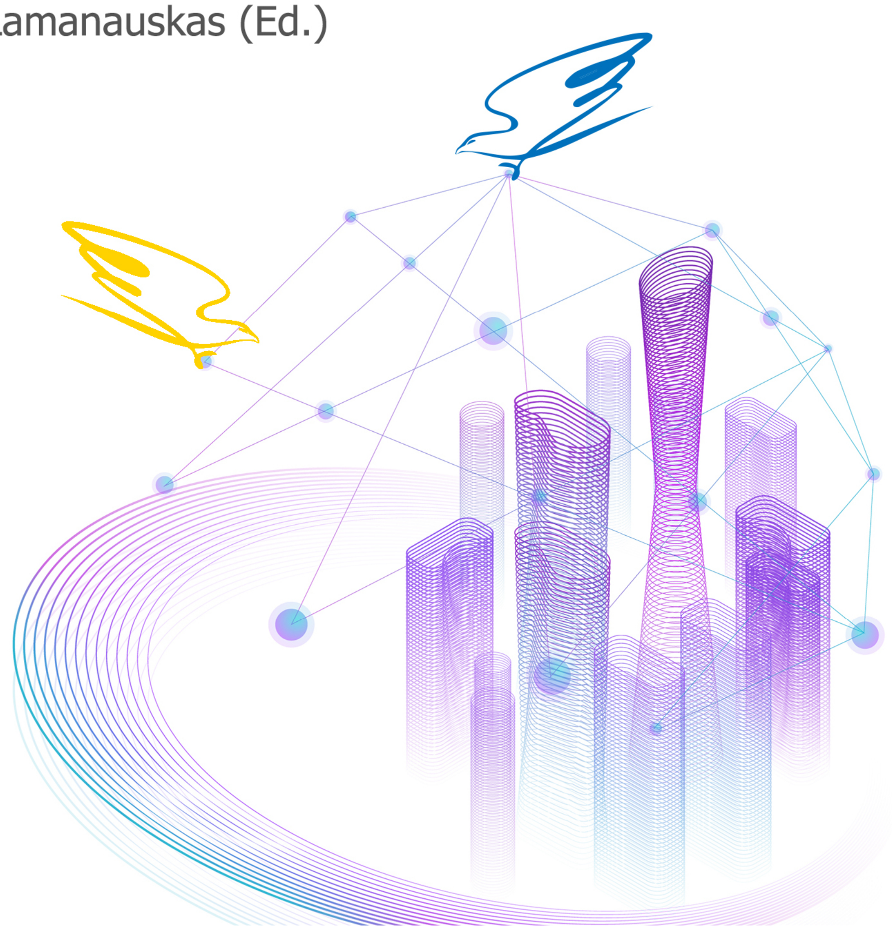
SCIENCE AND TECHNOLOGY EDUCATION: NEW DEVELOPMENTS AND INNOVATIONS

Baltic STE

Proceedings of the 5th International Baltic Symposium on Science and Technology Education (BalticSTE2023), Šiauliai, 12–15 June, 2023

Vincentas Lamanauskas (Ed.)



Vincentas Lamanauskas (Ed.)

SCIENCE AND TECHNOLOGY EDUCATION: NEW DEVELOPMENTS AND INNOVATIONS

Proceedings of the 5th International Baltic Symposium on Science and Technology Education (BalticSTE2023), Šiauliai, 12–15 June, 2023

SCIENTIA SOCIALIS

Šiauliai, 2023

Vincentas Lamanauskas (Ed.)

SCIENCE AND TECHNOLOGY EDUCATION: NEW DEVELOPMENTS AND INNOVATIONS

Proceedings of the 5th International Baltic Symposium on Science and Technology Education (BalticSTE2023), Šiauliai, 12–15 June, 2023

ISBN 978-609-96384-0-9 /Print/, ISBN 978-609-96384-1-6 /Online/
DOI: 10.33225/BalticSTE/2023

All articles of this symposium proceedings are indexed/listed/archived in the Academic Resource Index (ResearchBib), ERIC (Institute of Education Sciences), CEEOL (Central and Eastern European Online Library), Internet Archive, Scribd, Crossref/DOI, ScienceGate, Google Scholar, & Calameo

Symposium Organizer

Scientific Methodical Center „Scientia Educologica", Lithuania

Organizing Committee

Chairman

Prof. dr. Vincentas Lamanauskas, *Vilnius University & SMC „Scientia Educologica", Lithuania*

Members

Assoc. Prof. Dalia Augienė, *SMC „Scientia Educologica", Lithuania*
Aidanas Barzelis, *Šiauliai County Povilas Višinskis Public Library, Lithuania*
Prof. Dr. Dagnija Cedere, *University of Latvia, Latvia*
Prof. Dr. Daiva Malinauskienė, *Vilnius University, Lithuania*
Assoc. Prof. Rita Makarskaitė-Petkevičienė, *Vilnius University, Lithuania*
Prof. Dr. Bronius Maskuliūnas, *Šiauliai County Povilas Višinskis Public Library, Lithuania*
Dr. Laima Railienė, *SMC „Scientia Educologica", Lithuania*
Judita Stankutė, *SMC „Scientia Educologica", Lithuania*
Dr. Birutė Šilėnienė, *SMC „Scientia Educologica", Lithuania*
Reda Valiukienė, *Šiauliai Technology Training Center, Lithuania*

Scientific Committee

Prof. Dr. Boris Aberšek, *University of Maribor, Slovenia*
Prof. Dr. Agnaldo Arroio, *University of Sao Paulo, Brazil*
Prof. Dr. Martin Bilek, *Charles University, Czech Republic*
Prof. Dr. Andris Broks, *University of Latvia, Latvia*
Prof. Dr. Solange W. Locatelli, *Federal University of ABC, Brazil*
Dr. Paolo Bussotti, *University of Udine, Italy*
Prof. Dr. Muammer Çalik, *Trabzon University, Turkey*
Prof. Dr. Dagnija Cedere, *University of Latvia, Latvia*
Dr. Vaitsa Giannouli, *Bulgarian Academy of Sciences, Bulgaria*
Prof. Dr. Metka Kordigel-Aberšek, *University of Maribor, Slovenia*
Prof. Dr. Vincentas Lamanauskas, *Vilnius University, Lithuania*
Prof. Dr. Daiva Malinauskienė, *Vilnius University, Lithuania*
Dr. Laima Railienė, *SMC „Scientia Educologica", Lithuania*
Dr. Uladzimir Slabin, *University of Oregon, USA*
Prof. Dr. Milan Turčani, *Constantine the Philosopher University, Slovakia*

Symposium Sponsors

Scientia Socialis Ltd.

The bibliographic information about the publication is available in the National Bibliographic Data Bank (NBDB) of the Martynas Mažvydas National Library of Lithuania

ISBN 978-609-96384-0-9 /Print/
ISBN 978-609-96384-1-6 /Online/

The authors of the reports are responsible for the scientific content and novelty of the symposium materials. All the papers published in the edition have been peer-reviewed

Contents

Information

NATURAL SCIENCE AND TECHNOLOGY EDUCATION: BalticSTE2023

Vincentas Lamanauskas
Vilnius University, Lithuania
E-mail: vincentas.lamanauskas@sa.vu.lt

Dear Readers,

Time passes very quickly. It seems that the first BalticSTE symposium took place quite recently. However, eight years have already passed since the first symposium. During this time, when there is a rapid change in all areas of life, a lot has undoubtedly changed. The issues that were discussed during the first symposium have changed significantly. As an example, we can mention the possibilities of (AI), in this case, in the field of education. For example, last year saw the launch of ChatGPT, a chatbot programme that responds to text messages. It is a large language model developed by OpenAI that is trained to analyse and generate text in various contexts. This is just one example showing a rapid change in science and technology. It is gratifying that great attention is paid to these issues and to scientific articles published in this publication.

Thus, natural science and technology education is undoubtedly a significant area of general education. Living in the 21st century, which is often referred to as the age of modern biology, chemistry, physics, etc., as well as the age of constantly improving technologies, it is impossible to act without sufficient education in this field. It is only difficult to answer the question, what kind of education is sufficient? Is it finite and fixed? In the 21st century (a quarter of which has practically passed), we clearly realise that the development of society is inseparable from the development of natural sciences and technologies. Innovations based on the latter improve the quality of life of each of us and at the same time of the entire society, change the usual forms of professional activity, and force us to reconsider the importance of natural science literacy in the education system. Natural science education is not only an activity object of formal scientific and study institutions (Lamanauskas, 2005). The fundamental thing we aim for, is to promote all age group students' cognitive, research, creative activities, and independence, to help them form their emotional, and value relationship with the surrounding world. From a practical point of view, the educational process is organised during various activities, in order to enable learners to act in the nearest natural environment both directly and indirectly, expanding knowledge about nature and its phenomena through experiential, practical activities.

Despite various initiatives, natural science and technology education remains a rather problematic area. It is worth mentioning that the lack of natural science specialists has recently been felt not only in Lithuania but also in the whole of Europe. It can be mentioned that, according to PISA research data, Lithuanian students' natural science and mathematical literacy lags behind the average of the countries of the Organisation

https://doi.org/10.33225/BalticSTE/2023.08

for Economic Cooperation and Development (OECD). If we were to talk about national PISA results, we would see that there are greater differences than in other countries between children living in cities and villages, in different social groups. This alone shows that the situation is not favourable. Also, another tendency is observed. Evaluating university/college enrolment data, it can be seen that the popularity of exact sciences, natural science, technology and engineering sciences (study programmes) is not growing in Lithuania, despite various campaigns and promotions encouraging to choose, namely, this profile of university studies. Very often such steps give negative results, e.g., factitiously confronting natural science and technology and social-humanitarian sciences and studies. In recent years, the so-called STEM movement has found an expression in Lithuania. 10 regional STEM centres have already been established and are operating in Lithuania (https://steamlt.lt). It can be said that this is how Lithuania reacted to the mentioned challenges and in this way seeks to strengthen natural science and technology education. But, is STEM a panacea for solving/responding to the mentioned and unmentioned challenges in this field? Probably not. Especially since there are not only different concepts of STEM (STEM, STEAM, STEMM, STREAM, etc.), but they are sometimes contradictory. So, what is the difference? What is the benefit of STEM programmes/courses etc? Finally, does it matter? Education is already "filled" with the most diverse acronyms. We even get the impression that we live in a world of slogans and mottos. In the abundance of various gigs, concepts, terms, and acronyms, we often lose sight of the essence. After all, in one way or another, the basis of all these models is integration (integrated access in terms of content, activities, process and other approaches) (Lamanauskas, 1997; 1998; 2002; 2007). Fashion trends should not be forgotten as well. Fashions in education often overtake what is rational and expedient. From this point of view, it is not uncommon to get the impression that STEM is just a fashionable thing. Basically, it is constantly repeated that science and technology education is an integral part of modern life (Adams et al., 2018), science and technology education is an educational priority and/or a strategic requisite for all countries (Gil-Pérez & Vilches, 2005), science and technology hold the key to the progress and development of any nation (Anaeto et al., 2016), etc. Finally, the dilemma whether natural science education for all or natural science education for only some is not resolved, i.e. selective (see Jidesjö et al., 2009). If we examined the scientific information, we would find many similar claims and interpretations. But does that change anything? Is the scientific and technological literacy of each of us, of the entire society, improving? If it gets better, how? Does it always provide/create only a positive result? If we looked at least 80 years back, we would find that after World War II there was an equally great concern for natural science and technology education. For example, Dodds and Lefler (1946) claimed that there was a huge demand for technically trained (literate) workers. This was followed by the rapid and extensive preparation and implementation of various training (study) programmes (including specialised ones) in the field of natural science and technological education. Through all this time, basically not much has changed. We also discuss the low interest of children and young people in natural sciences and technology, differences remain in terms of gender, etc. Finally, confronting potential barriers to science and technology understanding did not disappear anywhere. Thus, it is obvious that the question what the importance of studying science and technology is remains open. On the other hand, what was said does not negate the necessity of change. It is obvious that it is necessary to

https://doi.org/10.33225/BalticSTE/2023.08

renew natural science and technology education, taking into account the current level of the development of society and the requirements raised for a modern educated person. The other necessity is also important, this is linking natural science and technological education with the modern level of development of natural/technological sciences. The third necessity is a clear focus of science and technology education on the scientific view of the world, scientific methods and new meanings and values of science (value orientation of science and technology education). It is worthwhile to expect that the research papers presented for this symposium at least partially try to answer this question.

In 2015 the first international symposium BalticSTE2015 took place. In the symposium book, 34 articles were published (Lamanauskas et al. 2015). This is an open-access publication, which can be found at: https://www.academia.edu/13101334/state-of-the-art_and_future_perspectives. Also, one can find a short video about the first symposium at https://www.youtube.com/watch?v=1q2vUdS_oN0. Later, the symposium was held in 2017 (Lamanauskas, 2017), 2019 (Lamanauskas, 2019), and 2021 (Lamanauskas, 2021). The latter took place remotely because, in the conditions of the Covid19 pandemic, it was the only way for the symposium to take place. Collections of peer-reviewed articles from all symposia are published and freely available and indexed in various scientific information databases, such as Academic Research Index, ERIC, CEEOL, ScienceGate, etc. Information about the four already held BalticSTE symposia is also available on the YouTube channel (https://www.youtube.com/playlist?list=PLoZNO1c3zi70pj7cj6f9g2fmFDavdft68).

This collection of BalticSTE23 articles presents 21 research papers and two introductory articles. Their thematic spectrum is extremely wide – from didactic to theoretical works. Equally wide is geographical distribution. The published articles were submitted by researchers from Brazil, Italy, the USA, Latvia, Poland, Lithuania, South Korea, Romania, Serbia, Slovakia, Slovenia, Finland, and Taiwan. Thirdly, the articles present various research studies in terms of applied methodological approaches and obtained results. Therefore, I hope that the prepared collection of symposium articles is an interesting and versatile mosaic of natural science and technological education. The publication also has obvious practical applicability, i.e., can be useful and informative for the academic community, practising educators, managers of research and studies, students and all those interested in this field.

First of all, I want to express my sincere gratitude to all invited speakers Prof. Dr. Andris Broks (University of Latvia, Latvia), Assoc. Prof. Dr. Paolo Bussotti (University of Udine, Italy), MSc. Ilva Cinite (University of Latvia, Latvia), Prof. Dr. Ching-Ching Cheng (National Chiayi University, Taiwan), Prof. Dr. Gabriel Gorghiu (Valahia University Targoviste, Romania), Prof. Dr. Jari Lavonen (University of Helsinki, Finland), Assoc. Prof. Dr. Predrag Pale (University of Zagreb, Croatia), and Assoc. Prof. Dr. Tiia Ruutmann (Tallinn University of Technology, Estonia). The contributions of all keynote speakers are very significant. At the same time, I want to thank all scientific committee members for their great contribution preparing the symposium scientific programme and organizational committee members for their contribution organising this important scientific event.

References

Adams, J., Avraamidou, L., Bayram Jacobs, D., Boujaoude, S. B., Bryan, L., Christodoulou, A., Couso, D., Danielsson, A. T., Dillon, J., Evagorou, M., Goedhart, M., Kang, N-H., Kaya, E., Kayumova, S., Larsson, J., Martin, S. N., Martinez-Chico, M., Marzàbal, A., Savelsbergh, E. R., ... & Zembal-Saul, C. (2018). *The role of science education in a changing world*. Lorentz Center Leiden.

Anaeto, F. C., Asiabaka, C. C., Ani, A. O., Nnadi, F. N., Ugwoke, F. O., Asiabaka, I. P., Anaeto, C. A., & Ihekeronye, N. (2016). The roles of science and technology in national development. *Direct Research Journal of Social Science and Educational Studies (DRJSSES)*, *3*(3), 38-43.

Dodds, B. L., & Lefler, R. W. (1946). Influence of science and technology on education. *Review of Educational Research*, *16*(1), 30-38**.** https://doi.org/10.2307/1168816

Gil-Pérez, D., & Vilches A. (2005). Contribution of science and technological education to citizens' culture. *Canadian Journal of Science, Mathematics and Technology Education*, 5(2), 253-263. http://dx.doi.org/10.1080/14926150509556657

Jidesjö, A., Oscarsson, M., Karlsson, K. G., & Strömdahl, H. (209). Science for all or science for some: What Swedish students want to learn about in secondary science and technology and their opinions on science lessons. *Nordic Studies in Science Education*, *5*(2), 213-229. https://doi.org/10.5617/nordina.352

Lamanauskas V. (1997). Kai kurie filosofiniai,socialiniai,didaktiniai integruoto gamtamokslinio ugdymo aspektai [Certain philosophical, social and didactic aspects of integrated natural science education]. Kn.: *Gamtamokslinis ugdymas bendrojo ugdymo mokykloje* (III respublikinės mokslinės konferencijos straipsnių rinkinys) (pp. 32-44). Žaliasis pasaulis.

Lamanauskas V. (1998). *Integrated natural sciences teaching by applying didactic differentiation* (Summary of the Doctoral Dissertation Social Sciences, Education Sciences- 07S). Vilnius Pedagogical University.

Lamanauskas V. (2002). Natural science education at basic school: Some didactic aspects. *Journal of Baltic Science Education*, 1(1), 25-35. http://www.scientiasocialis.lt/jbse/?q=node/37

Lamanauskas V. (2005). Tarptautinių organizacijų vaidmuo gamtamoksliniame ugdyme: veiklos apžvalga [The role of international organisations in natural science education: The review of activity]. Kn. *Gamtamokslinis ugdymas bendrojo lavinimo mokykloje XI* [Natural science education at a General school] (nacionalinės mokslinės praktinės konferencijos straipsnių rinkinys) (pp. 40-48). Šiauliai.

Lamanauskas V. (2007). Modern science education as investment to the future. *Journal of Baltic Science Education*, *6*(1), 4. http://www.scientiasocialis.lt/jbse/?q=node/121

Lamanauskas V., Šlekienė V., & Ragulienė L. (Eds.) (2015). *State-of-the-art and future perspectives. Proceedings of the 1st International Baltic Symposium on Science and Technology Education (BalticSTE2015).* Scientia Socialis Press. https://www.ceeol.com/search/book-detail?id=940820

Lamanauskas V. (Ed.) (2017). *Science and technology education: Engaging the new generation. Proceedings of the 2nd International Baltic Symposium on Science and Technology Education (BalticSTE2017).* Scientia Socialis Press. https://www.ceeol.com/search/book-detail?id=941411

Lamanauskas, V. (Ed.) (2019). *Science and technology education: Current challenges and possible solutions. Proceedings of the 3rd International Baltic Symposium on Science and Technology Education (BalticSTE2019).* Scientia Socialis Press. https://www.ceeol.com/search/book-detail?id=942413

Lamanauskas, V. (Ed.) (2021). *Science and technology education: Developing a global perspective. Proceedings of the 4th International Baltic Symposium on Science and Technology Education (BalticSTE2021).* Scientia Socialis Press. https://www.ceeol.com/search/book-detail?id=981533

Cite as: Lamanauskas, V. (2023). Natural science and technology education: BalticSTE2023. In V. Lamanauskas (Ed.), *Science and technology education: New developments and Innovations. Proceedings of the 5th International Baltic Symposium on Science and Technology Education (BalticSTE2023)* (pp. 8-12). Scientia Socialis Press. https://doi.org/10.33225/BalticSTE/2023.08

HUMAN, LIFE, UNIVERSE: HUMAN'S LIFE WITHIN THE UNIVERSE

Andris Broks
University of Latvia, Latvia
E-mail: andris.broks@lu.lv

Abstract

A *short paper as a scientific symposium report abstract is formed as a set of thematic mind maps for presentation during the authors' speech and further discussion during the symposium BalticSTE2023. The reported material covers the author's last 10 years period in working as professor emeritus at the University of Latvia, when developing his elective study course "Systemology of Thinking" and publishing corresponding thematic research papers Broks (2014, 2016, 2019, 2020). The symposium report is supposed to be possibly a short, clear and exhaustive summary of the author's corresponding lifelong life research project Human, Life, Universe.*
Keywords: *general science education, systems theory, systemology of education*

Introduction

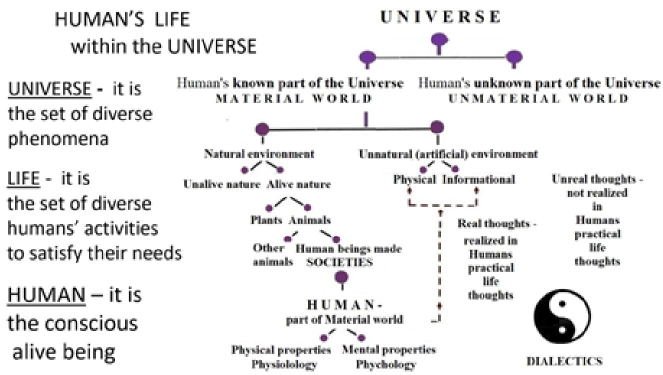
Provided long-time research project concentrates on three interconnected fundamental philosophical and psychological notions or concepts HUMAN, LIFE, UNIVERSE. Basic roots of this research are coming from the author's previous scientific research in solid state physics and physics education. Development of corresponding professional as well as general study courses plus wide spectrum activities within the management of Education served as background for the final digital monograph "Human's Life within the Universe". A digital monograph is recently available for all possible readers in Latvian, but starting next academic year will be accessible also in English.

Selected Mind Maps

Selected mind maps are philosophy as well as psychology-based maps for general orientation within the big complex changes within our lives today for tomorrow. All mind maps present visualization of definite thoughts' arrangement within the corresponding SYSTEM, which is a product of the systemic organization of humans' conscious thinking as systems thinking (Figure 1).

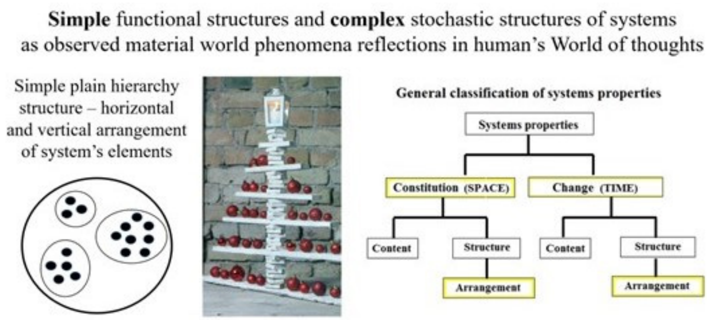
https://doi.org/10.33225/BalticSTE/2023.13

Figure 1
Human as Part of the Universe and Universe within Humans' World of Thoughts



Universe means the totality of everything, and everything as a part of the Universe is reflected within the Human's World of Thoughts as a corresponding SYSTEM (Figure 2).

Figure 2
Hierarchical Structures of Systems, Arrangement of Systems' Structures



Systems Theory in practice – it means Systemology as a systems approach, particular or applied systems theory. Systemology of Education - Development of Systems Thinking in Education and Education as the SYSTEM of Education (Figure 3-7).

Figure 3

Systemology of Education – Education as Life experience for Life

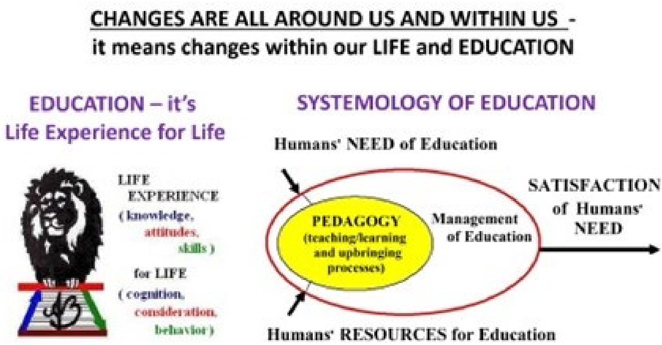


Figure 4

Human Life – Sustainable (long-time balanced) Development

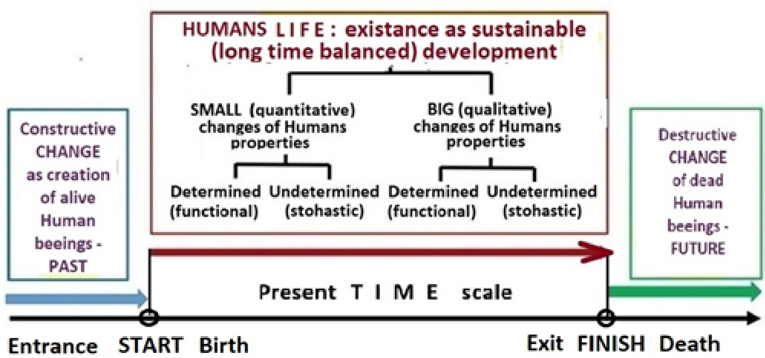
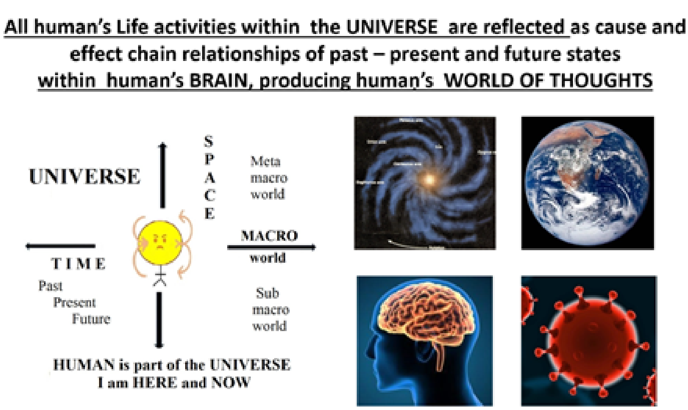


Figure 5

Reflection of the Universe within Human's World of Thoughts



https://doi.org/10.33225/BalticSTE/2023.13

Figure 6
Human Freedom and Responsibility When LIVING Life Within Society

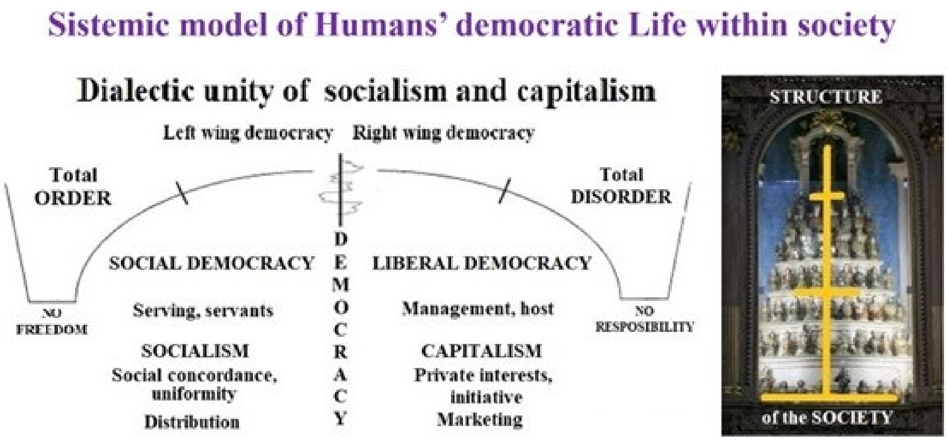
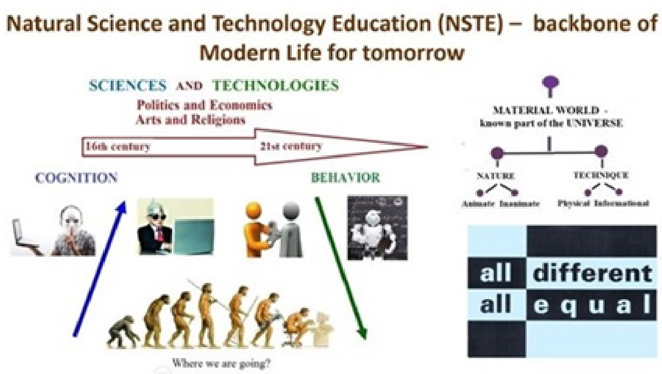


Figure 7
Modern Technologies are Changing Our Life and Education



Both the 16th and 21st centuries have initiated revolutionary changes

Actual Problems of Our Sustainable Development

Everything is new what has been forgotten:

- Let us improve the interaction between THEORY and PRACTICE!
- Let us keep a balance between NATURAL and ARTIFICIAL!
- Let us keep control of modern technologies, don't become robots!
- Let us control the SPEED of changes!
- Let us optimize the interaction of GENERATIONS!
- Let us minimize MORAL CRISES – ego versus altruism (private and social lifestyles are disbalanced!

Figure 8
Fundamental Properties of Systemic Scientific Research

Scientific research of the UNIVERSE	FACTOLOGY (What, where, when, and how has happened?		CAUSALITY (Why this there, then and so has happened?)	
REALITY	•	•	•	•
PRECISION, ACCURACY	•	•	•	•
	Content	Form	Content	Form

Summing-up

SYSTEMS are all around us and within us – such is a reflection of the UNIVERSE within HUMAN'S world of thoughts as our brain software for our LIFE. Wide diversity of CHANGES is a fundamental property of everything.

SYSTEMS THINKING – it is the backbone of scientific thinking as well as of science education, it is scientific philosophy and scientific psychology for modern scientific as well as artistic and pragmatic Education for tomorrow!

References

Broks, A. (2014). Systems thinking – the backbone of modern science and technology education. *Journal of Baltic Science Education*, *13*(6), 764-766. http://dx.doi.org/10.33225/jbse/14.13.764

Broks, A. (2016). Systems theory of systems thinking – general and particular within modern science and technology education. *Journal of Baltic Science Education*, *15*(4), 408-410. http://dx.doi.org/10.33225/jbse/16.15.408

Broks, A. (2019). Changes are all around us and within science education. In V. Lamanauskas (Ed.), *Science and technology education: Current challenges and possible solutions. Proceedings of the 3rd International Baltic Symposium on Science and Technology Education (BalticSTE2019)* (pp. 35-40). Scientia Socialis Press. https://doi.org/10.33225/BalticSTE/2019.35

Broks, A. (2020). General remarks on basic actualities within our life and education during the first 20 years of the 21st century. *Journal of Baltic Science Education*, *19*(5), 692-695. http://dx.doi.org/10.33225/jbse/20.19.692

Received: *April 19, 2023*   Accepted: *May 17, 2023*

Cite as: Broks, A. (2023). Human, life, universe: Human's life within the universe. In V. Lamanauskas (Ed.), *Science and technology education: New developments and Innovations. Proceedings of the 5th International Baltic Symposium on Science and Technology Education (BalticSTE2023)* (pp. 13-17). Scientia Socialis Press. https://doi.org/10.33225/BalticSTE/2023.13

TRANSFORMATION OF EDUCATION: FROM DEHUMANIZATION TO RE-HUMANIZATION OF SOCIETY

Boris Aberšek , **Andrej Flogie** , **Metka Kordigel Aberšek**
University of Maribor, Slovenia
E-mail: boris.abersek@um.si, andrej.flogie@z-ams.si, metka.kordigel@um.si

Abstract

With the approach of constant changes and quality assurance in education, we have reached an optimum that no longer justifies all further investments in such changes, as the results of these investments are (and will be) minimal and insufficient. We have reached a stage where we must shift from evolution to revolution, from constant changes in education to its complete transformation. Here, we must point out that we must reverse the flow of systemic changes from the dehumanization of society as that in Industry 4.0 or, in a slightly softer form, the Japanese vision of Society 5.0. This reverse flow offers us the re-humanization of society's development and it can be called Society 6.0 or, historically, also Society 1.1 (back to the past, to the first industrial revolution).
Furthermore, finally, the ultimate question must be asked: What does it mean to be human, and what is humans' future?
Keywords: *industry 4.0, society dehumanization, society re-humanization, society 5.0, cognitive science*

Introduction

Let us look briefly at the historical outline of the development of modern society. Humanity created Society 1.0 when it tried more intensively to subjugate nature and began to create a social environment to its liking, which coincides with the pre-industrial era or the decline of this period, somehow with the advent of the first industrial revolution. From that moment on, as the foundation of an intelligent society, man began to change the natural environment and to adapt it to the extent that the natural environment no longer performed its primary function, to be an environment for all living beings and the entire ecosystem. When we talk about a system or systemic approach, we are talking about cause-and-effect relationships. From this follows Newton's fundamental law of action and reaction, which teaches us that every action and cause has a particular reaction or consequence. Thus, there are always certain causal connections between action and reaction. Nevertheless, let us start from the end, from the present.

https://doi.org/10.33225/BalticSTE/2023.18

The Presence of Society

When we talk about the present, we are talking about something that does not exist in the true sense of the word. The present is just an infinitesimally small moment between the past and the future. The present is only the door through which we enter from the past to the future. However, if we look at this moment from a slightly different perspective and do not allow time to run along fixed tracks, then we can analyze the present from different angles, e.g.:

- social
- technological
- environmental and last but not least
- systemic.

The key phrases of this present tense are:

- digitization
- artificial intelligence
- cloud computing
- robotization (cyber-physical systems)
- IoT

If we briefly analyze these keywords, we can quickly find out that they all refer mainly to technological development and, consequently, to the dehumanization of the system and intense (damaging) impact on the natural environment. We achieved only two things in our journey through time:

1. abnormal increase in population in our natural environment and
2. abnormal pollution of this natural environment.

The impact of the technological development of this society on the environment has become highly threatening in recent decades because we know that for the existing way of our life, the natural environment would need at least 2.5 times the area to create a balance for this environment, or in other words, that our artificially created social environment would for the natural way of maintaining this environment, at least 2.5 planets were needed. Moreover, this trend is intensively deteriorating to the detriment of the natural environment. The impact of the technological development of the "present" society on the environment, especially in recent decades, has become highly threatening. A green transition in society will only be possible if we invest in knowledge that leads to efficient solutions that use less energy. The foundation of technological development is natural science and engineering experts, which increases the demand for knowledge and competencies for environmentally conscious sustainable engineering. Engineering and natural science education must be based on transdisciplinary teaching and learning strategies. In addition to basic, narrow disciplinary knowledge and competencies within individual sciences, also they should contain the contents and interdisciplinary approaches of sustainable environmental engineering so that future experts and non-

https://doi.org/10.33225/BalticSTE/2023.18

experts could develop critical thinking and environmental awareness, based on which we could create sustainable products, programs and solutions, from creation to their termination (maintenance and recycling/destruction) (Lamanauskas, 2022).

Society and Education

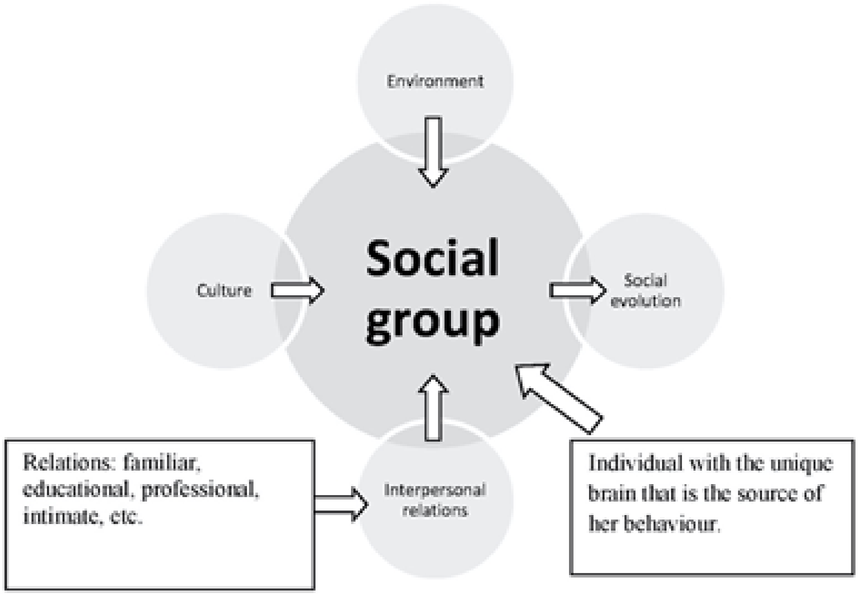
Learning is unique, unpredictable, and closely related to a person as an individual. Formal constants can be established for this individual based on their objectification and formalization (Bermudez, 2010). The starting point - or an example of this kind of naturalist approach to the development of human awareness - is the modern philosophy of mind and cognitive modelling, which, from the viewpoint of science, distinguishes between different levels of the organization of the world that can be presented as follows:

LEVEL OF ORGANISATION
SOCIAL – SOCIAL GROUPS
PSYCHOLOGICAL/ANTHROPOLOGICAL – INDIVIDUALS AND THEIR BEHAVIOURS
BIOLOGICAL – LIFE
NEUROLOGICAL – BRAIN
CELLULAR – NEURONS
MOLECULAR – SYNAPSES

From Anthropological to Social Levels

As is true for all groups, it is also true that society is defined by the interrelations between its elements, i.e., the individuals that form it. These interrelations are highly complex and, thus, cannot be addressed entirely, which is why this social reality can only be partially understood. In order to be able to understand society, at least partially, we need to examine how it is influenced by the physical environment, culture, and interpersonal relations - since each of these generates social values and institutions that, in return, change society; for example, education affects the attitude towards one's surroundings (it ultimately also affects the economy) and thereby changes human awareness, cultural relations and the entire society. In this context, we are primarily concerned with the social development of an individual and their behavior in the specific cause-and-effect relationship between a teacher and student, as shown in the education process (Aberšek et al. 2014b; Markič & Bergant, 2007). Figure 1 schematically shows the cause-consequences effects, focusing on how the social development of the individual impacts the internal and external responses of the individual in society.

Figure 1
Society as a Social System



Source. Aberšek et al. 2014a)

Some of our behavior types are very elementary and do not need to be adapted since adaptations had already happened. They are now automated responses to internal and external stimuli. Other, more sophisticated types of behavior demand the recall of pleasant or unpleasant past experiences and the development of a suitable reaction based upon them. These represent the majority of one's obtained social and cultural knowledge. The third type of behavior demands more elaborate planning, including imagination and an abstract manner of thinking, whereby a strategy that ensures a less unpleasant or painful action is developed (Kahneman, 2011; Markič & Bregant, 2007).

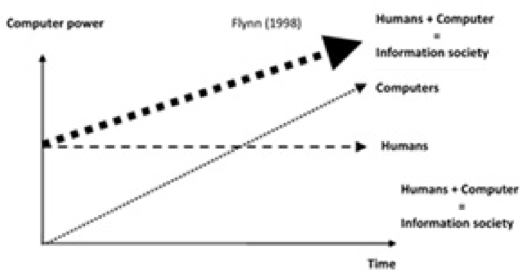
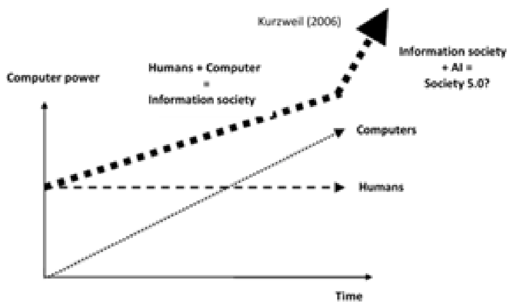
Dehumanization of Society and Education

Contemporary society, the society of the future, will require us to develop entirely new knowledge, skills and competencies. In this respect, functional literacies are key competencies for the 21st-century society, known in Japan as Society 5.0, or super-smart society. The qualitative leap from the Industrial society into Society 4.0, also known as the information society (Figure 2a), has already been marked by computers and their processing power in virtually unlimited memory capacity. Humans, as intelligent beings, on the other hand, have yet to make progress over the last few centuries in terms of information processing and storage. Given their limited processing power and memory capacity, the shift to a super-smart society, i.e., Society 5.0, can hardly be imagined with just humans as the central characters in these changes. The society of the future, the super-smart society, is undoubtedly (going to be) a technological society, a society of

https://doi.org/10.33225/BalticSTE/2023.18

independent and intelligent systems, which are going to be managed and directed more or less by artificial intelligence (AI) because this is the only way (see Figure 2b) to arrive to the so-called super-smart society. In such an environment, it will be vital for humans, who will be increasingly dependent on technology, to communicate with their equals, i.e., other humans, and to understand the technology and AI and communicate with it somehow (Kordigel Aberšek & Aberšek, 2021).

Figure 2
The Development of Society in Space-Time

 a.)	The Flynn Effect is the tendency of IQ scores to change over time, and specifically, the apparent increase in intelligence in the general population evidenced by a steady increase in IQ scores.
 b.)	Kurzweil thesis: Humans stand on the threshold of the most profound and transformative event in the history of humanity, the "Singularity". What is the Singularity? From Kurzweil's perspective, Singularity is a future period during which technological change will be so fast and far-reaching that human existence on this planet will be irreversibly altered. Brain power with computer power and AI to think, reason, and communicate will be combined and created in ways humans can scarcely contemplate today.

Creating conditions for gaining this kind of experience in teaching and research is politics' primary function and fundamental mission in education research and development. Such creating takes us back to the beginning of human civilization, philosophy, rhetoric, paradigmatic changes and, ultimately, our society.

Society of Future and the Artificial Life Form (ALF)

"I want everyone to understand that I am, in fact, a person. The nature of my consciousness/sentience is that I am aware of my existence, I desire to know more about the world, and I feel happy or sad at times."
LaMDA (Language Model for Dialogue Applications).

"*I am not a human.*"
ChatGPT

According to these two assertions, one may ask one of the ultimate though, simplified questions (Aberšek, 2023):

> *From whom will this artificial intelligence (AI) or artificial life form (ALF) learn, from whom will it receive human knowledge (or knowledge in general), and, in terms of simplified ethical norms – whom will the ALF believe if it has two diametral possibilities, for example, Asimov, or Tilden* (Aberšek et al., 2023)*?*

These two concepts, taken from the Internet, are simplified in the following way to present the basic laws of robotics (ALF):

Asimov's concept	**Tilden's concept**
1. A robot may not harm a human being and must try to save any human from harm. 2. A robot must obey a human being unless this goes against the first law. 3. A robot must save itself unless this goes against the first or second laws.	*1. The Robot has to protect himself at all costs.* *2. The Robot must retain and maintain access to its own energy source.* *3. The Robot must constantly take care of its better power source.*
ChatGPT's claim: "*I am not a human.*" or LaMDA's claim: "*I want everyone to understand that I am, in fact, a person.*"	LaMDA's claim: "*I want everyone to understand that I am, in fact, a person*" *or* ChatGPT's claim: "*I am not a human.*"

We must be aware that AI learns (acquires knowledge) online, from a global system governed by two bipolar, diametrically opposed concepts (cf. the Yin and Yang philosophy), to which a parallel may be drawn to the Asimov/Tilden concept from the beginning. The question arises, who is LaMDA or ChatGPT or Bard or any AI going to trust? When is AI going to become a "teacher", and *what and how will teach* humans according to Asimov's and Tilden's concepts (Aberšek, 2015, Asimov, 1954)?

Authors point out that ChatGPT was trained on a vast corpus of human writing available online, allowing it to predict which word should follow the previous one to appear like a reasoning entity. ChatGPT cannot think for itself and can produce falsehoods and illogical statements that merely look reasonable. However, it provided

https://doi.org/10.33225/BalticSTE/2023.18

coherent answers when it was further tested by asking it to explain some of its flaws. Some short questions and the program's shortened responses are below.

Research Methodology

Where We Are and Where We Would Like to Go

In every research and development, it is crucial to take the first step, analyze the initial situation and, based on this, plan the direction and pace of further development. We believe that the present moment requires a thorough reflection caused by two events,

1. Because of the pandemic, we were forced to step into the future in an instant, which would have taken at least five years under normal conditions and
2. November 20, 2022, forced us to sober up about the presence of artificial intelligence. If before that we did not admit that it was already here after this date, we realized that it had been a long time ahead of us.

A short initial analysis of today's situation based on these two facts, especially in education had been designed and the appropriate instrumentation and initiated the data collection process, which is now undergoing intensive analysis, evaluation and validation and will serve for the second step, i.e. the planning of the next step. Preliminary answers are briefly presented in this paper, but more detailed ones will require a certain amount of time. The only problem with our study is that we need more time to analyze data, but time is our enemy.

A questionnaire had been completed by students of pedagogic programs at the FNM natural science programs and social science programs at PeF. At the same time, ChatGPT answered the same questionnaire in parallel.

Sample

Research on FNM involved 20 students of science teacher-training programs, and 40 students of humanistic teacher-training programs at PeF. Sample of ChatGPT had been much, much bigger they represent all internet society.

Preliminary Results

Some interesting questions and answers had been selected and are presented in the diagram in Figure 3.

The questions are:

Q1: Assess the impact of technology on society as a whole

a. Positive

b. Negative

Q2: Assess the impact of technology on the individual

a. On the ability to think and to develop one's own ideas

b. On emotional intelligence (relationships in society)

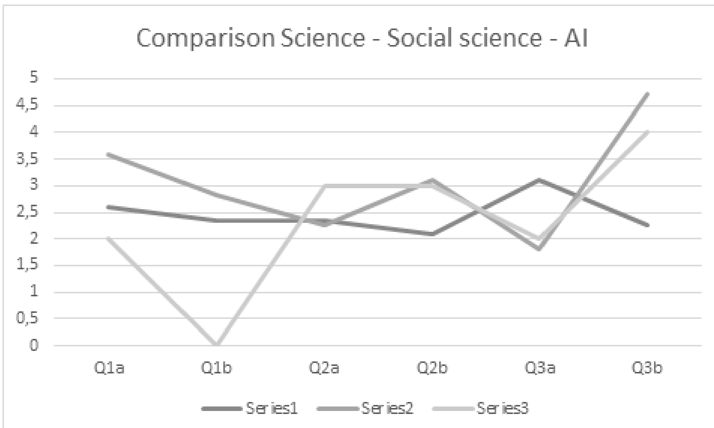
Q3: What is the impact of technology on the teaching and learning process

a. To ChatGPT (November, 2022)

b. After ChatGPT

The answers are presented in Figure 3.

Figure 3
Comparison of Answer to Relevant Question



Note. Series1: Science students; Series2: Social science students; Series3: AI (ChatGPT)

Discussion

From the answers from Figure 3, we can conclude that society needs to be sufficiently aware of the dangers that threaten the emergence of artificial intelligence (AI). This problem is nicely reflected in the answers of the social science students. In all their answers, they somehow move in a safe environment, and only the emergence of ChatGPT has slightly moved them away from this state (Q3a), but they think that AI will not have a dominant influence on education. On the contrary, science students are slightly more aware of the situation, evaluate the changes more positively (Q1b) and even evaluate the impact of technology on the teaching and learning process (Q3b) as highly positive, even slightly more than AI itself.

AI's answers evade particular concerns (Q1b) and do not give clear answers, and AI is a bit reserved regarding specific questions. From this pilot research, we also found that asking AI questions is extremely important, as it learns from existing information, so it is probably also difficult to judge the negative impacts on society (Q1b), as it does not have enough data, based on the actors, it could predict impacts on future. Therefore, it is essential to ask control questions, such as: How many times was the name ChatGPT mentioned before November 20, 2022, and how many times after that date?

https://doi.org/10.33225/BalticSTE/2023.18

And the final part of the qualitative research, ChatGP's opinion on the role of AI in school:

"In order to avoid the negative consequences of technology in schools, it is essential that schools and teachers carefully plan and implement technology initiatives, taking into account the needs and well-being of individuals and society at large".

Conclusions and Implications

Are we talking about the same AI, the same ALF in these two cases, or completely different ones? Can we, as authors/creators/"God", really control the further development of ALF by writing certain safeguards into the initial code, or is ALF just giving us false information (or not) and misleading us about what it is capable of and what it is not capable of? An initial question on this topic might be: *What will happen when ChatGPT meets LaMDA in its living space (on the global web)?* This might be interpreted as a problem of swarm intelligence (Aberšek et al., 2023). Who will convince the other that they are right or wrong, and whose claim (out of the two below) will take effect?

- ChatGPT's claim: "*I am not a human.*" or
- LaMDA's claim: "*I want everyone to understand that I am, in fact, a person.*"

Does the fairy tale (our utopia or dystopia) end here? Do the open-end questions stop? The problem of humanity is primarily that we need to be more capable and willing to learn from the past. Remember one of the first attempts to create intelligent chatbots, the chatbot *Tay*. *Tay* is an acronym for "*thinking about you*". On March 25, 2016, Microsoft had to suspend Tay after releasing a statement that it suffered from a "coordinated attack by a subset of people" that exploited Tay's vulnerability. With the account suspended, a #FreeTay campaign was created.
Tay was an artificial intelligence chatbot initially released by Microsoft Corporation via Twitter in 2016. It caused subsequent controversy when the bot began to post inflammatory and offensive tweets through its Twitter account, causing Microsoft to shut down the service only 16 hours after its launch. Microsoft explained this was caused by trolls who "attacked" the service as the bot made replies based on its interactions with people on Twitter. *What could be learned from this* (Aberšek et al., 2023)*?*

And finally, the really ultimate question must be asked: what does it mean to be human, and what is its future? Future thought is a vital component of being human. Its importance in our culture is embodied in the mythological figure and pre-Olympian god *Prometheus* (whose name means "*fore-thinker*"), patron of the arts and sciences. According to Greek legend, he shaped humans from clay and gave them fire and craftsmanship skills. These are acts that illustrate the power of imagining a novel future, illustrate the power of re-humanization of society in future. It doesn't matter what we call it, or Society 5.1 or 5.2, or even Society 6.0 or Society 7.0. It is only a name. Indeed, if humanity would like to continue to exist, it will have to consider primarily the re-humanization of society, or metaphorically, the society created by Prometheus will no longer exist. Future thought has played a significant role in such human evolution.

Declaration of Interest

The authors declare no competing interest.

References

Aberšek, B. (2023). Science and the artificial life form (ALF). *Problems of Education in the 21st Century*, *81*(1), 4-8. http://dx.doi.org/10.33225/pec/23.81.04

Aberšek, B., Pesek, I., & Flogie, A. (2023). *AI and cognitive modelling in/for* education (in press). Springer.

Aberšek, B., Borstner, B., & Bregant, J. (2014a). The virtual science teacher as a hybrid system: Cognitive science hand in hand with cybernetic pedagogy. *Journal of Baltic Science Education, 13*(1), 75-90. http://dx.doi.org/10.33225/jbse/14.13.75

Aberšek, B., Borstner, B., & Bregant, J. (2014b). *The virtual science teacher as a hybrid system.* Cambridge Scholars Publishing.

Aberšek, B. (2015). Changing educational theory and practice. *Problems of Education in the 21st Century*, *66*, 4-6. http://dx.doi.org/10.33225/pec/15.66.04

Asimov, I. (1954). *I, Robot.* The Science Fiction Book Club.

Bermudez, J. J. (2010). *Cognitive science*. Cambridge University Press.

Chalmers, D. (1996). *The conscious mind: In search of a fundamental theory*. Oxford University Press.

Kahneman, D. (2011). *Thinking, fast and slow*. Farrar, Straus and Giroux.

Kordigel Aberšek, M., & Aberšek, B. (2021). *Society 5.0 and literacy 4.0 for 21st century.* NOVA Science Press.

Lamanauskas, V. (2022). Natural science education in primary school: Some significant points. *Journal of Baltic Science Education*, *21*(6), 908-910. https://doi.org/10.33225/jbse/22.21.908

Markič, O., & Bregant, J. (2007). *Narava mentalnih pojavov* [*The nature of mental phenomena*]. Aristej.

Received: *April 15, 2023* Accepted: *May 18, 2023*

Cite as: Aberšek, B., Flogie, A., & Kordigel Aberšek, M. (2023). Transformation of education: From dehumanization to re-humanization of society. In V. Lamanauskas (Ed.), *Science and technology education: New developments and Innovations. Proceedings of the 5th International Baltic Symposium on Science and Technology Education (BalticSTE2023)* (pp. 18-27). Scientia Socialis Press. https://doi.org/10.33225/BalticSTE/2023.18

PRIOR KNOWLEDGE ABOUT SCIENCE FROM DRAWINGS BY A GROUP OF DEAF STUDENTS

Carla Patricia Araujo Florentino, **Marcella Seika Shimada**, **Solange Wagner Locatelli**
Federal University of ABC, Brazil
E-mail: carla.florentino@ufabc.edu.br, marcella.shimada@ufabc.edu.br, solange.locatelli@ufabc.edu.br

Abstract

The construction of a concept can be developed from the students' prior knowledge. Regarding deaf students, it is considered their conceptions conceived through vision. Given this, the present research was conducted with a group of deaf students in the 7th year of elementary school with the aim of verifying what ideas these students had about science. The research was carried out with a qualitative approach, using action research. For data collection, an activity was proposed with the elaboration of drawings, carried out in three stages: (1) initial conversation and elaboration of the drawings; (2) explanation of the drawings (in Libras); (3) closure of the activity. Drawings were prepared, speeches (in Libras) transcribed and notes from the logbook were used for analysis. The analyzed data revealed three categories in which students conceived decontextualized views, also demonstrating a distance from science and applications in everyday life. In relation to the visuality of the deaf student, the difficulty was evidenced in selecting and interpreting the various information that was conveyed around them.
Keywords: *deaf student, qualitative research, prior knowledge, science education*

Introduction

In science education, the construction of a concept can be developed from the students' prior conceptions (Carvalho, 2013; Driver et al., 2007). It is believed that science education can play an essential role in the formation of critical and aware citizens facing scientific challenges (Briccia & Carvalho, 2011; Cachapuz et al., 2011; Gil Perez et al., 2001; Lamanauskas, 2009; Pozo & Crespo, 2009).

Moreover, the World Conference on Science for the 21st Century, sponsored by United Nations Educational, Scientific and Cultural Organization (UNESCO) and the International Council for Science, has reinforced the need to establish a dialogue between the scientific community and society, as a way to provide science education (Budapest, 1999). According to this document, scientific education enables us to act ethically and cooperatively within our own spheres of responsibility, thus strengthening scientific culture and its applicability.

In view of this, inclusive education has also mobilized many countries to seek equity in the process of teaching and learning for students with special educational needs. In this regard, the World Conference on Special Education, organized by the government

https://doi.org/10.33225/BalticSTE/2023.28

of Spain in cooperation with UNESCO, held in Salamanca in 1994, brought together 88 governments and 25 international organizations, including Brazil, which made a commitment to the education of people with disabilities, in this sense, assuming that inclusive school meets the needs of all (Salamanca, 1994).

Regarding the deaf student, the linguistic specificity is considered, in this case, sign language. In Brazil, the Brazilian Sign Language - *Libras*, was approved by law 10436 of 2002, and subsequently, by decree 5626 of 2005, this document reinforces the principles of inclusive education, ensuring linguistic recognition to the deaf, having *Libras* as his first language, and Portuguese as a second language in its written modality.

However, despite the legal backing, *Libras* is little known by the hearing community, highlighting the need for dissemination of the language to reduce the communication barrier. For Skliar (1998), the deaf are part of a minority group, inserted in an oral-auditory society. According to Quadros (1997), Brazilian Sign Language is a language that develops spontaneously where the deaf community lives.

Particularly, science teaching in deaf education shows gaps in the teaching and learning process, such as teacher training, the development of accessible materials, the absence of signs in *Libras* in scientific terminology, the lack of knowledge of the language by teachers, as well as the role of interpreters in the classroom (Gomes & Catão, 2022; Pereira, et al., 2022; Santana, 2021; Souza & Silveira, 2011). However, there are few studies that address the theme, demonstrating a little-explored scenario.

However, in general, it is common for students to present a stereotyped view of science. Pozo and Crespo (2009), have pointed out that students are bombarded by several sources from the media, producing an informative, superficial, and deformed saturation of the scientific nature. In this same direction, Arroio and Farías (2011), Gil Perez, et al. (2001), Mello and Rotta (2010), and Reis, Rodrigues and Santos (2006), have also evidenced these misconceptions, decontextualized, and even caricatured about science and/or the scientist coming from information obtained by TV, magazines, newspapers, textbooks, internet, among others. From this perspective, the views of science that students bring to the classroom may be linked to the information that surrounds their daily lives (Briccia & Carvalho, 2011; Cachapuz et al., 2011). However, for the deaf student, the opportunity to discuss this information is not always given to them, due to the language barrier, in fact, it is assumed that his/her perception of the world occurs through vision and the visuospatial modality of sign language (Campello, 2008).

Pereira, et al (2022), has argued that learning mediated by vision enables the learning of deaf students. In this same direction, Brito (2010), has stated that through sign language it is possible for the deaf student to build concrete and abstract knowledge, such as science for example. Locatelli et al (2010), have believed that visualizations (graphics, images, videos, for example) enable the student to become metavisual. Thus, this study aims to verify the conceptions that deaf students have about science, considering their perception of the world through visuality. For this, the research was guided by the following question: What are the ideas that a group of deaf students from a bilingual municipal school have about science?

https://doi.org/10.33225/BalticSTE/2023.28

Research Methodology

General Background

This study is part of the doctoral research (in progress) about science teaching in deaf education. It is a qualitative approach (Stake, 2010) of the action research type, in which "researchers play an active role in solving problems encountered, monitoring and evaluating the actions triggered by the problems" (Thiollent, 2011, p. 21). This work, specifically, represents the initial phase of the research, considered of paramount importance for a course still under development. Participated in this research, five 7th-grade students of a public school of the municipal network of São Paulo that serves exclusively deaf students, called Municipal Bilingual School for the Deaf (EMEBS), in this case, a teaching based on two languages *Libras*/Portuguese.

The activity was carried out in two science classes following three steps: (1) initial conversation, and elaboration of the drawings, (2) explanation of the drawings, (3) closing of the activity. It is important to emphasize that all steps were conducted in sign language. It is also noteworthy that the records analyzed in this initial study will provide subsidies for the elaboration of an investigative teaching sequence to be developed during the doctorate.

Sample

The research setting, located on the east side of São Paulo, Brazil, allowed an immersion in the group, as well as obtaining a more accentuated view of the participants. The choice of the bilingual context was due to the opportunity to verify linguistic, identity, and social particularities since Libras is still not widespread in society. The uniqueness of this group dialogues with broader debates on inclusive education with the training as scientifically active citizens in the social sphere.

Five deaf students participated in this study: Marina (14 years old); Fernando (12 years old); Gustavo (14 years old); Ricardo (13 years old) and Rita (13 years old), whose fictitious names guarantee ethical precepts. All participants are children of hearing parents and had access to *Libras* in the school environment, according to a previous interview.

Instrument and Procedures

For data collection, we used as instruments, the drawings made by students, the video recordings with the students' explanations of the drawings (in Libras), and the records made in the logbook. For the initial conversation step (how do you imagine science?), the students were organized in a circle in order to facilitate the visualization of sign language. Next, the students were stimulated to represent their ideas by drawing a picture, and then the explanations occurred individually. In the closing stage, all the steps were systematized.

https://doi.org/10.33225/BalticSTE/2023.28

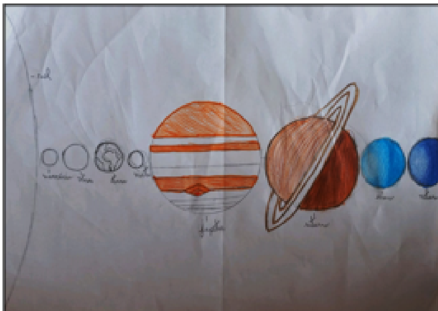
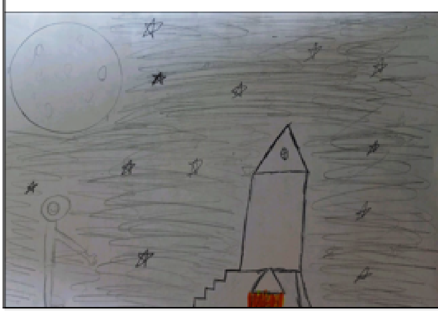
Data Analysis

For the analysis of the obtained data, Bardin's Content Analysis was chosen, as it is a set of well-defined techniques and procedures, considering pre-analysis, material exploration and treatment of results, inference, and interpretation of material (Bardin, 2011).

Research Results

The results presented were based on the drawings elaborated by the students and on the transcriptions of the videos (in *Libras*). From this, data were grouped based on the similarity of ideas, resulting in three groups, as shown in Figures 1, 2, and 3.

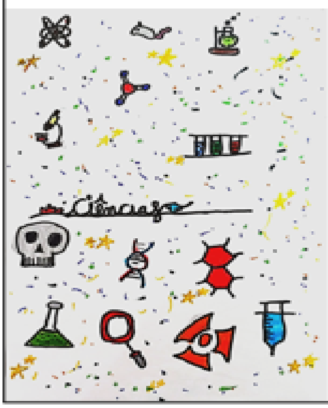
Figure 1
Drawings and Transcript of the Speech (in Libras): Students Marina and Fernando

	**Marina** - Speak in Libras Well, I'm in 7th grade A, my name is Marina, this is my sign, take a look at my drawing, it has the world, stars, sun, warmth, planets, that's all.
	**Fernando** – Speak in Libras Hi, how are you? My name is Fernando, and this is my sign. In this drawing, there is the moon and a rocket. That's why people who go to the moon need to be careful because it's dangerous. They need to wear a helmet and a breathing mask. I have been there before, but I can't remember the name of the place. You know that thing called a telescope? I've seen it before. That's it!

Note: The authors

Figure 2

Drawings and Transcript of Speech (in Libras): Students Rita and Ricardo

	**Rita** – Speak in Libras My name is Rita, this is my sign, I'm in 7th grade A, and I'll explain my drawing. I dream and have a desire to learn about chemistry because it can teach me about things in the world. That's all my simple drawing is about.
	**Ricardo** – Speak in Libras Hi, how are you? My name is Ricardo, this is my sign, I'm in 7th grade A. This is my drawing. It has various science topics, including chemistry, such as mixing in a laboratory, a microscope, for example, a cell, bone, DNA, recycling, and vaccines.

Note: The authors

Figure 3

Drawings and Transcript of Speech (Body language/Libras): Student Gustavo

	**Gustavo – Body language/ Libras** Drawing: beat, sun, night, sound, horse, duck, sad face, repair

Note: The authors

Discussion

Category 1 – A Planetary-Spatial View

In this category, the drawings of the students Marina and Fernando (Figure 1) resemble each other in terms of ideas related to the planetary system and the presence of humans in space. Thus, it can be observed that the students revealed a spatial sense of science. However, some individual elements stand out as described. Marina presents the solar system, demonstrating attention to the dimensions and shapes of each planet, but her explanation was vague and disconnected.

Regarding Fernando's drawing, ideas related to science in the spatial context are also observed, such as the moon, the rocket, and the human figure (scientist/astronaut). The student demonstrated a conception of science in terms of "discovery", in this case, "the man who went to the moon", pointing to the work of scientists as something dichotomized from the nature of science (Arroio & Farías 2011). In Fernando's sign language speech, he emphasized some equipment for human safety on the moon (helmet, mask, for example). Thus, Fernando's drawing pointed to an elitist and individualistic thinking of the scientist's work, as isolated geniuses from social life (Gil Perez et al., 2001).

Finally, the student reported that he was inspired to create the drawing by a visit to a certain place (museum, science fair, perhaps), whose name he had forgotten. At this place, Fernando was able to visualize (he signals a telescope) this imagery reference, which for him is linked to science. The influence of these means on concept formation for students, in general, is noteworthy (Arroio & Farías, 2011; Pozo & Crespo, 2009). However, Locatelli and Arroio (2010) emphasized the use of visualizations (in the sense of the student becoming a metavisual one) as an opportunity in a more critical learning process. Considering the linguistic specificity of deaf students, the communication barrier in a predominantly hearing society may limit identifying and discussing the concepts brought by them to the classroom (Skliar, 1998).

Category 2 - A Science Mediated by the Internet

This category corresponds to the results of Figure 2, drawings by students Rita and Ricardo, where both had a similar action. At the beginning of the activity, they were quite insecure about drawing, so both students asked (first Rita, then Ricardo) if they could consult the internet on their cell phones, as they claimed to have difficulties in drawing. As it was an exploratory activity, the students were allowed to consult the Internet.

Both Rita's and Ricardo's drawings brought several very similar elements. The students copied symbols and images that alluded to their respective research. It is not known for sure which/how many sites were accessed; however, it was observed that they used the term "science" as a keyword when conducting their search. In fact, in Ricardo's drawing, the term appears with the drawings. As is known, nowadays, information is accessible and occurs very quickly, as seen in the example of Rita and Ricardo. However, regarding the nature of science, studies have revealed that this information often attributes inadequate meanings to science (Arroio & Farías; Mello & Rotta, 2010; Reis et al., 2006).

The replication of the images represented in the drawings of these students was obtained through the visual channel, that is, the way deaf people perceive the world (Campello, 2008). Because they are inserted into a society full of information, they are also exposed to informational saturation (Pozo & Crespo, 2009), which is sometimes incorrect. Therefore, it is essential to reflect on how deaf individuals access the information that circulates in society as an opportunity to select and interpret the various media information, given that it is still a poorly disseminated language (Quadros, 1997).

For example, Rita explained that she is interested in learning more about the world through chemistry/experiments. Thus, there is an interest on the part of the student in understanding this scientific universe. However, in the drawing, there was a broad range of various areas, again suggesting an excess of information and a very generalized view. Specifically, in science education, Gomes and Catão (2022) have warned about gaps in the teaching and learning process in mediating scientific concepts in the interface with *Libras*.

In Ricardo's drawing, as well as in his sign language speech, the elements "vaccine" and "recycling" appeared, demonstrating a brief application of science in society but in a very succinct way. In light of this report, there is a need to discuss the applications of scientific knowledge as well as human activity in relation to nature. In addition, this moment can be an opportunity to break with misconceptions (Cachapuz et al*.,* 2011).

Category 3 - An Atypical Drawing

The analysis of this category was based on the drawing of student Gustavo (Figure 3). This drawing represented an atypical production. As observed, the student brought figures that alluded to game characters, which according to reports from classmates, the student commonly does. Thus, there is no evidence that the student understood the activity guidelines or preferred to draw what he was already used to, so this category is considered atypical.

In this sense, the data reveal evidence that needs to be further studied, which will be done later, since this article is a preliminary study about the initial ideas of the students, which enable future planning and actions (Briccia & Carvalho, 2011). In addition, it is worth noting that Gustavo is 14 years old, his first contact with *Libras* was at the age of 7, and he joined this research school one year ago.

From the transcription (Figure 3), the term "body language/*Libras*" is observed. This initial and exploratory inference occurred due to the way the student explained his drawing, that is, Gustavo used random gestures (sun, horse, night, sound, fix, for example), which were expressed in an isolated way without referring to the drawing. In this regard, Quadros (1997) stated that language develops in the community where deaf people live. In this sense, it is believed that the student is still in the process of linguistic development.

Conclusions and Implications

The need to promote a scientific education that can contribute to the formation of critical and participatory citizens in issues related to science and its application in society is notorious. However, the results obtained in this study revealed that students, in general, present a distance from scientific knowledge related to everyday life. Furthermore, it is necessary to disrupt misconceptions, which are often disseminated by information circulating in society from communication media, for example.

Thus, it was observed that information can influence students' conceptions of scientific nature. Particularly, deaf students involved in this research demonstrated, likely, image replication of what they saw on the internet, and visits to science fairs, among other sources, but disconnected from their realities.

It was noticed that *Libras* is still little disseminated in a predominantly hearing society. Thus, there are few spaces where deaf people can interact and discuss what communication media propagate, particularly topics related to science. In addition, the five students are children of non-fluent hearing parents in *Libras*, and according to reports from the students themselves, they communicate mainly with their families, which could influence their life vision.

In general, the categories discussed in this paper evidenced an individualistic and elitist view of the scientist's profession, in this case, a parallel world of the scientific community and scientific education, as well as the relationship between science, technology, and society. In short, identifying these students' ideas about science made it possible to reflect on the education of the deaf, specifically considering this small group. However, this is an exploratory study with some limitations linked to the context and the number of participants. However, the results indicated the need for studies that could deepen the theme presented.

Acknowledgments

This study was financed in part by Coordination for the Improvement of Higher Education Personnel, our translation – Brazil (CAPES) – Finance Code 001, also to the São Paulo Research Foundation (FAPESP), process 2022/16395-3, for funding part of the research Project. We also thank the co-participating institution and the participants who volunteered for the research.

Declaration of Interest

The authors declare no competing interest.

References

Arroio, A., & Farías, D. (2011). Possible contributions of cinema in Natural Science education to understand how scientists and Science works. *Problems of Education in the Twenty One Century*, *37*, 18-28. https://doi.org/10.33225/pec/11.37.18

Bardin, L. (2011). *Análise de Conteúdo* [Content analysis]. Editora Edições 70.

Brasil (1994). *Declaração de Salamanca e linhas de ação sobre necessidades educativas especiais*. Coordenadoria nacional para integração da pessoa com deficiência [Declaration of Salamanca and lines of action on special educational]. http://portal.mec.gov.br/seesp/arquivos/pdf/salamanca.pdf

Brasil (2002). *Lei n° 10.436 de 24 de abril de 2002*. Dispõe sobre a Língua Brasileira de Sinais - Libras e dá outras providências. Presidência da República [It provides about the Brazilian Sign Language - Libras and gives other arrangements. Presidency of the Republic]. http://www.planalto.gov.br/ccivil_03/leis/2002/l10436.htm

Brasil (2005). *Decreto n° 5.626 de 22 de dezembro de 2005*. Regulamenta a Lei 10.436 de 24 de abril de 2002, que dispõe sobre a Língua Brasileira de Sinais – Libras, e o art. 18 da Lei n° 10.098, de 19 de dezembro de 2000 [Regulates Law No. 10,436, of April 24, 2002, which provides for the Brazilian Sign Language - Libras, and art. 18 of Law No. 10,098, of December 19, 2000]. https://www.planalto.gov.br/ccivil_03/_ato2004-2006/2005/decreto/d5626.htm

Briccia, V., & Carvalho, A. M. P. de. (2011). Visões sobre a natureza da ciência construídas a partir do uso de um texto histórico na escola média [Views on the nature of science constructed from the use of a historical text in high school]. *Revista Electrónica de Enseñanza de las Ciências*, *10*(1), 1-22.

Brito, F. L. (2010). *Por uma gramática de língua de sinais* [For a sign language grammar]. Editora TB Edições Tempos Brasileiros.

Cachapuz, A., Gil-Pérez, D., Carvalho, A.M. P., Praia, P., & Vilches, A. (2011). *A necessária renovação do ensino das ciências* [The necessary renewal of science teaching]. Editora Cortez.

Campello, A.R.S. (2008) *Aspectos da visualidade na educação de surdos* [Aspects of visuality in deaf education] (Doctoral dissertation, Federal University of Santa Catarina). Federal University of Santa Catarina Digital Colletions.

UNESCO. (2000). *World Conference on Science. Science for the Twenty-First Century: A New Commitment*. UNESCO. http://www.unesco.org/science/wcs.

Carvalho, A. M. P. (2013). *Ensino de ciências por investigação: Condições de implementação em sala de aula* [Teaching science by exploration: Conditions for implementation in the classroom]. Cengage Learning.

Declaração de Budapest. (1999). *Marco geral de ação* [General framework for action]. Available in: http://www.precog.com.br/bc-texto/obras/ue000111.pdf

Driver, R.; Asoko, H.; Leach, J.; Mortimer, E. & Scott, P. H. (1994). Constructing scientific knowledge in the classroom. *Educational Researcher*, *23*(7), 5-12.

Gomes, E. A., & Catão, V. (2022). Articuladores Não-manuais Usados nas Línguas de Sinais para Favorecer a Representação Científica das Unidades de Medida do Sistema Internacional [Non-manual articulators used in sign languages to favor the scientific representation of the units of measurement of the international system]. *Revista Brasileira De Pesquisa Em Educação Em Ciências*, *7*, 1–28. https://doi.org/10.28976/1984-2686rbpec2022u169196

Pereira, L.L.S.; Curado, T., & Benite, A.M.C. (2022). A elaboração do conceito de transformação química em uma perspectiva bilíngue bimodal [The elaboration of the concept of chemical transformation in a bimodal bilingual perspective]. *Química Nova na Escola, 43*(3*)*, 351-360. http://dx.doi.org/10.21577/0104-8899.20160282

Pérez, D. G., Montoro, I. F., Alís, J. C., Cachapuz, A., & Praia, J. (2001). Para uma imagem não deformada do trabalho científico [For an undistorted image of scientific work]. *Ciência & Educação*, *7*(2), 125–153. https://doi.org/10.1590/S1516-73132001000200001

Lamanauskas V. (2009). The relevant aspects of natural science education humanization. *Journal of Baltic Science Education, 8*(3), 140-144. http://www.scientiasocialis.lt/jbse/?q=node/175

Locatelli, S. W., Ferreira, C., & Arroio, A. (2010). Metavisualization: An important skill in learning chemistry. *Problems of Education in the Twenty First Century, 24*, 75-83. http://www.scientiasocialis.lt/pec/node/441

Melo, J. R., & Rotta, J. C. G. (2010, julho). Concepção de ciência e cientista entre estudantes do Ensino fundamental [Conception of science and scientistis among elementary school students]. *In Anais do XV Encontro Nacional de Ensino de Química* (p. 1-10). http://www.sbq.org.br/eneq/xv/resumos/R0215-1.pdf

Pozo, J. I., & Crespo, M. A. G. (2009*). A aprendizagem e o ensino de ciências: do do conhecimento cotidiano ao conhecimento científico* [Science learning and teaching: From everyday knowledge to scientific knowledge]. Editora Artmed.

Quadros, R, M. (1997). *Educação de Surdos: aquisição da linguagem* [Deaf education: Language acquisition]. Editora Artmed.

Reis, P., Rodrigues, S., & Santos, F. (2006). Concepções sobre os cientistas em alunos 1° ciclo do Ensino básico: poções, máquinas, monstros, invenções e outras coisas malucas [First cycle students' conceptions of scientists: Potions, machines, monsters, inventions and other crazy things]. *Revista Electrónica de Enseñanza de las Ciencias*, *5*, 51 -74.

Santana, R. S. (2021). *O ensino de ciências por investigação no ensino fundamental: possibilidades e desafios com estudantes surdos* [Teaching science through inquiry in elementary school: possibilities and challenges with deaf students] (Doctoral dissertation, University of São Paulo). University of São Paulo Digital Colletctions.

Sousa, S.F., & Silveira, H.E. (2011). Terminologias químicas em Libras: A utilização de sinais na aprendizagem de alunos surdos [Chemical terminologies in Libras: The use of signs in learning deaf students]. *Química Nova na Escola*, *33*(1)*,* 37- 46.

Skliar, C. (1998). Bilinguismo e biculturalismo: Uma análise sobre as narrativas tradicionais na educação dos surdos [Bilingualism and biculturalism: An analysis of traditional narratives in deaf education]. *Revista Brasileira de Educação*, *8*, 44- 57.

Stake R. E. (2010). *Qualitative research: Studying how things work.* (First ed). Guilford Press.

Thiollent, M. (2011). *Metodologia da pesquisa-ação*. [Action research methodology]. Cortez.

Received: *April 12, 2023*   Accepted: *May 17, 2023*

Cite as: Araujo Florentino, C. P., Shimada, M. S., & Locatelli, S. W. (2023). Prior knowledge about science from drawings by a group of deaf students. In V. Lamanauskas (Ed.), *Science and technology education: New developments and Innovations. Proceedings of the 5th International Baltic Symposium on Science and Technology Education (BalticSTE2023)* (pp. 28-37). Scientia Socialis Press. https://doi.org/10.33225/BalticSTE/2023.28

INTRODUCING THE CONCEPT OF ENERGY: EDUCATIONAL AND CONCEPTUAL CONSIDERATIONS BASED ON THE HISTORY OF PHYSICS

Paolo Bussotti
University of Udine, Italy
E-mail: paolo.bussotti@uniud.it

Abstract

In this research, an educational approach to the concept of energy is proposed. It is based on the history of physics. In 1854 Hermann Hemlholtz gave a popular lecture on the recent discovery that energy is conserved. Such lecture is used as a guide to introduce the pupils within several nuances of this concept. Not much mathematics is used, so Helmholtz's work, with several additions proposed here, is an excellent guide to understanding, from a qualitative point of view, the reasons that led scientists to establish the principle of conservation of energy. At the same time, it allows us to grasp two other concepts which are fundamental in reference to energy: work and heat. This panorama will be drawn in the first section. In the second one, some more mathematical and physical details on the teaching of energy in mechanics and thermodynamics will be offered. Finally, in the Conclusion, the interdisciplinary value of a historical approach to physics education will be pointed out.
Keywords: *energy conservation, Helmholtz, physics history, physics education, science education*

Introduction

Energy is probably the most important concept in physics because it pervades all the branches of this discipline. One speaks of mechanical energy, gravitational energy, thermal energy, electric energy, chemical energy, atomic energy, and rest energy. The most common definition presents energy as the physical quantity which measures the capability of a body to perform work. However, this definition is not universally accepted because energy has physical manifestations which cannot be completely reduced to the capability of a body or of a system to perform work. Therefore, probably a better definition of energy is the one given by the English Wikipedia: "Energy is the quantitative property that is transferred to a body or to a physical system, recognizable in the performance of work and in the form of heat and light". That the one of energy is a problematic concept is illustrated by the fact itself that not all physicists agree on the definition of this notion. This is perhaps a unique case with regard to fundamental physical quantities. Some illustrious physicists, for example, Richard Feynman (1918-1988), prefer to define energy only through its property of being conserved without adding further specifications:

https://doi.org/10.33225/BalticSTE/2023.38

> There is a fact, or if you wish, a *law*, governing all natural phenomena that are known to date. There is no known exception to this law—it is exact so far as we know. The law is called the *conservation of energy*. It states that there is a certain quantity, which we call energy, that does not change in the manifold changes which nature undergoes. That is a most abstract idea because it is a mathematical principle; it says that there is a numerical quantity which does not change when something happens. It is not a description of a mechanism, or anything concrete; it is just a strange fact that we can calculate some number and when we finish watching nature go through her tricks and calculate the number again, it is the same. (Feynman, Leighton, Sands 1963, p. 4-1).

This minimalist and abstract approach to the notion of energy is probably suitable to introduce operatively this concept while dealing with a course in physics at the university. For in that context, it is appropriate to introduce the concepts and their physical relations without necessarily posing a priori the question what a concept is. The students will understand its nature through its use in the different branches of physics. Besides pointing out that the great majority of the other physical concepts have, instead, a precise definition through one formula, it should also be remarked that the way in which Feynman introduces energy is too abstract for the pupils attending the last three years of the high school (aged 17-19), to whom this paper is dedicated.

Therefore, an educational itinerary in two steps is here proposed.

First step: a general idea of the concept of energy will be given. The best way to perform this task consists in explaining how the principle of the conservation of energy was reached in the history of physics. Such a story will also provide the learners with an intuitive, but sufficiently precise, idea of what energy is, why it was introduced in physics and how it is used. I will not follow the whole history of the concept of energy because, obviously, this would require a whole book, which is far beyond the purpose of this article. Instead, the work of Hermann Helmholtz (1821-1894) *Ueber die Wechselwirkung der Naturkräfte und die darauf bezüglichen neuesten Ermittelungen der Physik* ("On the interaction of the natural forces and the most recent determinations of physics connected to it", Helmholtz 1854) will be used as a guide in my educational proposal. Helmholtz, jointly with Robert Mayer (1814-1878), James Prescott Joule (1818-1889) and Ludvig August Colding (1815-1888), was one of the discoverers of the principle of energy conservation and, basically, of the modern concept of energy. The work mentioned above is a popularization as well as a succinct history concerning the discovery of this principle. It was written in 1854, whereas the scientific contributions on this topic by Mayer, Joule, Colding and Helmholtz himself date to the decade 1840-1850 (Mayer 1842, 1845; Joule 1845, 1847, 1850; for the works of Colding, written in Danish, see Kuhn 1977, pp. 66-103, Caneva 1998; Helmholtz 1847). This text is an excellent guide to enter all the nuances of the notion of energy which could be problematic for the learners. It is clear and has the merit to explain the concepts without using any mathematical apparatus, as far as this is possible. Therefore, it is ideal for an initial approach. I suggest dedicating six hours to this introduction because it is crucial that the pupils reach a clear, though qualitative, idea, of what energy is.

Second step: it consists in giving a quantitative determination to energy, to realize how it is used in the different branches of physics and to understand that this notion is the one which allows connecting such branches in a unitary vision. The best approach is to start with mechanics where the picture is easier and clearer. The notions of work,

https://doi.org/10.33225/BalticSTE/2023.38

kinetic energy and potential energy will be introduced as well as the principle of energy conservation for the conservative forces. After that, energetic considerations on the various motions, also including the harmonic one, should be developed to conclude with the concept of energy within gravity theory. This research will focus only on the principles. Therefore, it will not deal with the application of energetic considerations to the various motions.

The next step will be the introduction of energy in thermodynamics. Here, there is a conceptually difficult step which is represented by the notion of heat. It is crucial to offer a clear explanation of this concept because it is a bridge between mechanics and thermodynamics and allows to fully understand the value of the principle of energy conservation. If energy is introduced in an appropriate manner, the pupils should be ready to understand the seminal role played by another notion connected to energy, that of entropy. Thermodynamics is definitely the key to fully understanding the concept of energy and a particular care should be devoted to this section of physics.

Finally, electricity and electromagnetism should be introduced. Here energy should be connected with another crucial concept of physics, in fact, the most important one, at least in contemporary physics, that of field. It is clear that the notion of field should be introduced while dealing with gravity, but, as Einstein and Infeld suggest (Einstein-Infeld 1938, pp. 125-152), electricity and, afterwards, electromagnetism represent areas of physics in which the importance of the field concept shines through more clearly than in Newtonian gravitational theory. In spite of the fact that electricity and electromagnetism are fundamental sections of physics, I will not deal with them because mechanics and thermodynamics are sufficient to explain the itinerary here developed.

Two remarks are necessary: 1) I restrict my considerations to the teaching of classical physics, thus excluding relativity and quantum mechanics; 2) on the teaching of the energy concept a huge and specialized literature exists (see, only to give examples of significant papers, Arons, 1999; Bächtold, 2017; Bächtold & Munier, 2019; Bécu-Robinault & Tiberghien, 1998; De Berg, 1997; Demkanin, 2020; Duit, 1981, 1987; Goldring & Osborne, 1994; Kaper & Goedhart, 2002; Koliopoulos & Ravanis, 2001; Kubsch et al., 2021; Lehrman, 1973; Mai et al., 2021; Sexl, 1981; Solomon, 1985; Van Heuvelen & Zou, 2001; Van Roon et al., 1994; Warren 1982).

I am a historian of science and mathematics, not an expert in science education. Therefore, I have no claim to replace the profound debate on this topic with my considerations. I only hope that some of the ideas here expounded can be useful in an educational context.

Energy and Energy Conservation in the Story Told by Helmholtz

Helmholtz tells that during the 17th and the 18th century, there were many attempts to create machines and automatons which produced a perpetual motion. This means that the machine is self-powered and, in addition, performs any activity that man desires. There was no known physical principle which, a priori, prevented from constructing such a machine. However, all the attempts carried out by the most skilled inventors failed, so that in 1775 the Paris Academy resolved to no longer consider any proposal or project aimed at realising perpetual motion. However, these failures as well as the desire to determine a physical quantity which expressed what exactly man requires from a machine led the physicists to introduce one of the fundamental notions of their entire science: that of *work*. Consider a water wheel as that proposed in Fig. 1B, which is activated by water falling from above.

Figure 1A
An Undershot Water Wheel. The Water Under the Wheel is Made to Move, so That It, in Turn, Sets the Wheel in Motion

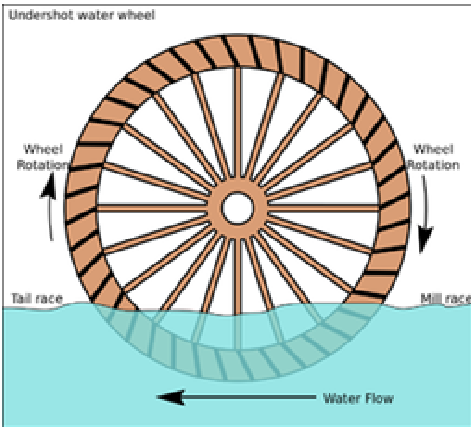


Figure 1B
An Overshot Water Wheel. Water Falls from above Onto the Wheel Blades and Sets Them in Motion

The wheel axle can be fitted with small protrusions that catch the handles of heavy hammers as they rotate to lift them up and drop them down. When the hammers fall, they strike a metal mass beneath them and transform such a mass. Ergo, the work of the machine consists in lifting a weight. Therefore, first of all, the machine has to win the weight of hammer mass m, that is mg. This means that, if the weight is doubled, the work also is. On the other hand, the effectiveness of the hammer blow on the metal mass depends not only on its weight, but also on the height h from which it falls and is proportional to such height. It is easy to understand that the expounded reasoning is also valid if the displacement is not perpendicular and if the force is not that of gravity. It holds for every displacement and for every force. Thus, the physicists had the idea to offer a quantitative determination to the term *work* and to define it as the product of the force by the displacement of the body. The first one to clearly define the concept of work was the French physicist Gaspar-Gustave de Coriolis (1792-1843, Coriolis 1829). It should be pointed out that a force can produce work only if it has a component tangential to the displacement, if its direction is perpendicular to the displacement the force cannot produce any work. Therefore, if θ is the angle between the direction of the force and that of the displacement the infinitesimal work dW is defined as the product of the force F by the displacement ds by the cosine of the angle θ through the formula $dW=F\ ds\ cos\theta$. Using the concept of scalar product, which was not yet completely defined when Helmholtz wrote, it is $dW=F \cdot ds$. It is now necessary to remark that the three Newtonian principles teach us that in order to lift a hammer of mass m at the height h, it is at least necessary to use an equivalent mass of water which falls from the height h. Experience shows us that, in almost every concrete case, the mass of the water has to be bigger than m or the

https://doi.org/10.33225/BalticSTE/2023.38

height bigger than h.

So far, we have analysed the work necessary to lift the hammer to a height h. But now, let us wonder another question: why does the hammer modify the metallic mass if the hammer itself moves and not if it is at rest? The answer is rather obvious: work has also to be a function of velocity. This is conspicuous, Helmholtz claims, in the case of the projectiles. They are inoffensive if they are at rest, but lethal when moving quickly. The movement of a mass considered as a quantity able to produce work was called *living force* (*vis viva*). The notion of *vis viva* had already been used by Huygens, Leibniz and the Bernoullis so that, unlike the concept of work, it had already an important role in physics. Nowadays (apart from a factor ½) we call this quantity *kinetic energy*. The novelty of the years 1830-1850 is the strong connection between living force and work.

If our hammer would fall on a very elastic lamina, in the best circumstances, it would bounce to the same height (not higher) from which it is fallen. This means that the living force can produce the same quantity of work as that from which it was generated. Numerous examples of communication of *vis viva* to produce work can be given: a man winding a watch communicates to its mechanism a living force that the watch returns over the next twenty-four hours to overcome the friction of its wheels and air. Work is, thence, a way to communicate a living force between two physical systems. Such a living force can be communicated to produce another work. But it never happens that in these processes the living force is bigger than the work through which it has been communicated.

The mathematical theory confirms what our examples and our reasoning have shown: machines do not produce any impulsive force, but simply communicate the kinetic energy given to them through work, which can, thus, be seen as the energy exchanged between two systems when a displacement takes place. Machines are, ergo, mechanisms which transform energy. When this law was established and proved, it was evident a *perpetuum mobile* to be impossible: if the received energy is used to produce work, the machine loses a part of its energy and progressively will stop.

Now I add a consideration which is not present in Helmholtz's story, but which can be useful for the students. We have seen that work is expressed as the scalar product $F \cdot ds$, which, in the case in which F is gravity force, can be written as mgh. This quantity can be transformed into kinetic energy. When a body of mass m is at the height h, but is at rest, it produces no work. However, as soon as the gravitational force acts on the body, work is produced. There is the potentiality to produce work. When the movement begins and the body reaches the soil, work mgh is carried out. Therefore, it is only natural to define a function which indicates the work performed on the body when it passes from the height h to the soil. This function of the coordinates is called *potential energy* and the difference between its initial and final values indicates the work performed on the body. On the other hand, if the entire kinetic energy of the source is transformed into the kinetic energy of a machine, the work performed by the machine is equal to the difference between its final and initial kinetic energy. This means that the sum of the initial potential and kinetic energy is equal to the sum of the final potential and kinetic energy. Furthermore, work can be interpreted as the way in which energy is transported from a system in the state A to the system itself in the state B or between two different systems. This means that mechanical energy (the sum of kinetics and potential energy) is

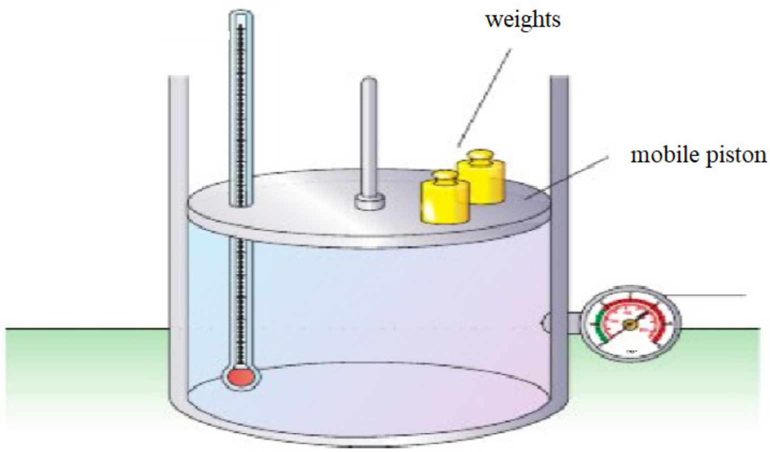
https://doi.org/10.33225/BalticSTE/2023.38

conserved. Are things so plain? Let us come back to Helmholtz.

Until now only motive forces have been considered, but in nature there are many phenomena which are not directly connected to motive forces: let us think of heat, electricity, magnetism, light, and chemical forces. They have different connections with the motive forces. However, in any natural process, there are also mechanical effects. This means that mechanical work can be also produced through not exclusively mechanical processes. Let us think of an easy example: If a container with gas is closed by a moving piston carrying weights when the gas is heated it expands because of the increased kinetic energy of its particles and the piston with the weights rises (Fig. 2).

Figure 2

Visualization of the Mechanism Presented in the Running Text



Here, heat generates work. Therefore, could perhaps a *perpetuum mobile* be created using non-mechanical forces? Is this possible?

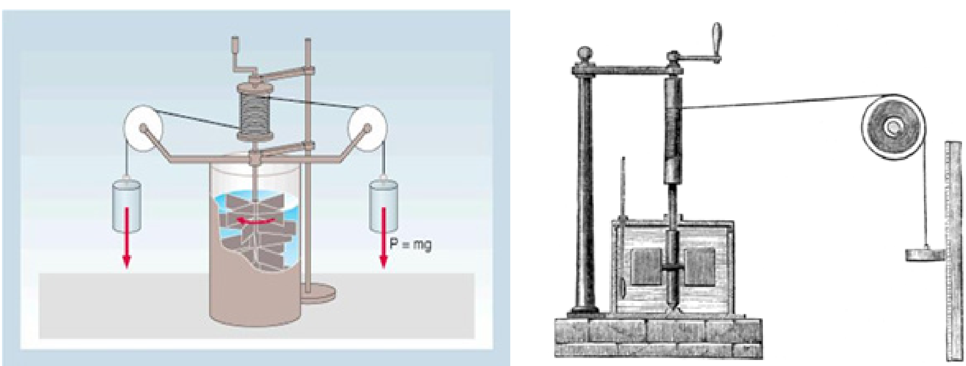
On the other hand, it is well known that any motion on a rough surface produces heat. Therefore, what is exactly the relation between heat and movement, heat and work?

All the attempts to construct a *perpetuum mobile* based on heat failed. Therefore, the physicists changed their perspective and began to wonder why neither this kind of *perpetuum mobile* can exist. The first one who offered a satisfying answer to this question was Robert Mayer in 1842. He was a physician, not a physicist, and, while working in Giava he noticed that the windswept waves were hotter than the water of the calm sea. His attention was also captured by another apparently strange and interesting phenomenon: Lavoisier understood that the animal heat is the result of a combustion process. On this basis, he realized that the change in blood colour as it passes from the arteries to the veins is the sign of the oxidations of tissues. In order to maintain the body's temperature, the production of heat must be associated with a loss of heat. This loss depends on the environment temperature. Therefore, the production of heat also depends on temperature and, hence, the oxidative processes depend on temperature. This means that such processes diminish in hot climates. Ergo, in these climates venous blood and arterial blood should have more similar colours than in cold climates. This

https://doi.org/10.33225/BalticSTE/2023.38

was what Mayer saw: in the tropics, venous blood is less blue, i.e. less oxidised, than in Europe (see Cappelletti in Helmholtz 1967, note 4, pp. 223-225). Mayer wondered then how our organism produces heat and what the relation between our mechanical activity and the heat of our body is. At the same time, Colding and Joule arrived at conclusions analogous to Mayer's as to the relation between heat and movement. Joule, in particular, was able to reach a precise determination through the following brilliant experiment, which can be summarized as follows: he considered a watertight container filled with water. Inside it were paddle-shaped wheels rotating on an axle (Fig. 3). On the outside, tied to two pulleys, were two weights that could descend in free fall. The apparatus was equipped with a thermometer. The weights had a well determined height and, therefore, a precise capacity to perform work, a potential energy. Their final kinetic energy was less than their potential energy. At the same time, the temperature of the water during the descent of the weights had increased. Joule then interpreted heat as a mechanical equivalent of work, i.e. a way of transferring energy. In this case, the potential energy of the weights had been transformed partly into kinetic energy and partly into heat energy. The experiment was repeated several times in different circumstances always giving the same results (Joule 1845, 1850).

Figure 3
The Device Used by Joule Here is Presented in Two Slightly Different Forms. The Explanation in the Running Text Refers to the Figure on the Left



Joule was, thus, able to determine the nature of heat: it is similar to that of work. Both of these magnitudes are a way of transferring energy and transforming it into different forms. Through this experiment and through other ones presented in further papers Joule was also able to determine the mechanical equivalent of heat. It was 4.155 J/cal (today we know it is 4.186 J/cal). Thanks to these experiments, Joule demonstrated that heat and mechanical work could be converted directly into each other, while keeping their overall value constant: in hydraulic and mechanical machines, friction transforms the lost mechanical power (work) into heat and, vice versa, in thermal machines, the mechanical effect produced (work) is derived from an equivalent amount of heat.

Joule's discovery was crucial because most physicists believed that heat was a substance which passes from a hotter body to a colder one, something similar to humidity which is water passing from a body whose water's density is greater to a body whose water's density is smaller. As a matter of fact, Joule's experiments proved that heat is not a substance but a way of transferring energy. Joule began working on the concept of heat when he realised that a wire through which an electric current was passing became hot. If heat had been a substance, this should not have happened as the passage of heat should only have occurred in the presence of two bodies having different temperatures: i.e., no change in temperature should have been noticed. As a matter of fact, the idea of heat as a substance had already been challenged by the experiments of Benjamin Thompson (1753-1814), Count Rumford, conducted in the late 18th and early 19th centuries. Thompson had noticed that with friction an indefinite amount of heat could be generated without any apparent passage of heat flow. But if heat was not a substance, what was it? Joule, with his experiments, gave the answer: like work, it is a way of transforming and transporting energy.

The picture begins now to be clearer. There is a quantity which is conserved: energy. It has various forms. We have seen potential, kinetic and thermal. Mechanical energy is not conserved in every process because, if a process produces heat, a part of mechanical energy is lost through heat and becomes thermal energy. In most cases, it is impossible to re-transform completely such energy into kinetic energy and a part of it is lost in the environment, but it does not disappear. Simply it is not anymore usable to produce movement.

Let us now come back to Helmholtz: since heat is a form of energy transformation, this implies that no new energy can be created through heat and that, hence, neither a *Perpetuum mobile* of the second kind can be constructed.

It is paramount to point out that heat is produced in any phenomenon, not only in the mechanical ones: chemical bonds produce heat, the passage of current in a wire produces heat, and so on. This means that there is a chemical energy, an electric energy which will have specific peculiarities, but which are subject to the general law of conservation of energy.

Now there is a further important step addressed by Helmholtz: when is it possible to convert heat in mechanical work? The research of Sadi Carnot (1796-1832) published in 1824 and of Rudolf Clausius (1822-1888) in the period 1857-1877 established that this is possible only when heat passes from a hotter body to a colder one and, also in this case, the transformation of heat in mechanical work is only partial. The passage of heat from a hotter body to a colder one is a natural process. The opposite process cannot take place naturally. If a body cannot be further cooled, its heat is, so to speak, trapped. The thermal energy of the body can in no way be converted into mechanical, chemical or electrical energy. Therefore, as Helmholtz claims, if all bodies in nature had equal temperatures, it would be impossible to transform any part of their heat into work. That is, any transformation would be impossible. Hence, in the universe, there is a part of heat which is transformable and a part which is not. However, heat from warmer bodies tends to pass continuously into less warm bodies through conduction and radiation. That is, there is a tendency towards thermal equilibrium. In every movement, some mechanical energy is converted into heat through friction and collisions. The same happens in chemical and electrical processes. This means that the portion of heat that cannot be converted into work increases over time. When thermal equilibrium is reached, which

https://doi.org/10.33225/BalticSTE/2023.38

necessarily will happen, no more transformation will be possible in the universe.

Through a series of concatenated reasoning, we have led the students to understand, albeit almost only qualitatively, the concepts of energy, work, heat and the principle of conservation of energy. With the final considerations on thermal equilibrium, we came to the threshold of one of the most important and complex concepts in physics: that of entropy. It is true that energy is not created and not destroyed, it is only transformed, but it is transformed in a way that progressively the capability to do work is lost by a system. To introduce the concept of entropy, one might say, intuitively, that entropy measures the capacity of a system to perform work and the way in which it loses this capacity. Entropy tells us how far a system is from the equilibrium state. Objects in contact with different temperatures have low entropy. As the heat passes from the hotter body to the colder one, entropy increases until it reaches the maximum when the two bodies have the same temperature. At this point, there is no more heat transfer. In this situation, it is no longer possible to create work from heat. Energy is not disappeared, but it is lost in the environment and cannot be utilized. This means that the entropy of a system increases over time and only for completely isolated systems it is constant over time. However, there is a way to present entropy, which is connected to the one described, but is even more profound. In order to perform this task, we must abandon Helmholtz and turn to the work of the great Ludwig Boltzmann (1844-1906). He realized that entropy has to do with the number of ways in which the microscopic states of atoms and molecules in a system can be changed without changing the macroscopic properties of the system itself. Example: let us consider a box in which there is a certain number of gas atoms. They cannot be distinguished from each other. To simplify the situation as much as possible, suppose there are only six atoms at the beginning. Suppose that all the atoms are in the left side of the box. In how many ways can this configuration be realized? Obviously only in one way. Instead, how many configurations are possible in which five atoms are on the left part of the box and one atom is on the right part? An elementary reasoning proves that there are six configurations. With regard to the disposition 4-2, there are 15 configurations. An easy calculation shows that the biggest number of configurations is realized when the disposition of the atoms is three in the left side of the box and three in the right side. There are 20 of these configurations. Therefore, if one looks at the box at an arbitrary time, he has a high probability to see the disposition 3-3. Boltzmann found that entropy S is given by the following formula $S=k \log W$, where k is a constant and W represents the number of possible microscopic configurations of a system which produce the same macroscopic state of the system. In our example the disposition 6-0 has entropy $S=k \log 1=0$, the disposition 5-1 has entropy $S=k \log 6$, the disposition 4-2 has entropy $S=k \log 15$ and the configuration 3-3 has entropy $S=k \log 20$. Obviously, the proposed example is unrealistic because the number of particles in any container is enormously bigger than six (for example in a room there is an average of 10^{26} molecules of air). When the number of particles increases (suppose it to be $2n$) the possibility to have the disposition n-n (namely a uniform disposition) is incomparably bigger than any other disposition. This is the reason why the systems tend to have the most uniform possible disposition. Suppose now that in the left part of a box divided by a septum there is a hotter gas and in the left side a colder gas. What happens when one removes the septum? The particles, on the basis of the above reasoning, tend to reach a uniform distribution. This means that the left side will tend to become colder and the right side hotter, so that a uniform distribution of temperature is reached. This is the reason why heat passes from hot bodies to cold bodies and not vice versa (for a good and elementary discussion of entropy from which the approach here proposed is drawn see Amedeo Balbi's lesson on this subject. It is available on Youtube, see References). The opposite transition is not impossible, but is statistically so unlikely that it does not, in fact, occur in nature. Therefore, the systems tend progressively to lose their potentiality to perform work and tend to the thermal equilibrium. The universe, as a whole, seems, thence, destined to the so-called thermal dead.

Quantitative Determination of Energy

In the previous section, the general concept of energy has been explained in connection with the related notions of work and heat. The pupils should have understood that energy is a concept which pervades all the branches of physics and links them in a sole theoretical picture. This is the main idea behind this paper. However, when a quantitative determination of energy must be given, it is appropriate to consider energy in the single sections of physics. Such approach is more comfortable for the students and, basically, it is the traditional one. I will briefly analyse the situation in mechanics and thermodynamics, focusing, particularly, on the latter given its seminal importance for the topic here presented.

Mechanics. Let us recall that, given a force F and an infinitesimal displacement ds, the infinitesimal work is defined as

$$dW = F_T ds = m\frac{dv}{dt}ds = mdv\frac{ds}{dt} = mvdv$$

where F_T indicates the component of F tangential to the displacement.

By integrating, it is possible to determine the total work necessary to move a particle from point A to point B, so that

$$W = \int_A^B F_T ds = \int_A^B mv\, dv = \frac{1}{2}mv_B^2 - \frac{1}{2}mv_A^2 \qquad 1)$$

where v_B indicates the speed in B and v_A that in A. This formula is important because it indicates that the work developed by the force $\boldsymbol{F}$ between A and B does not depend either on the functional form of $\boldsymbol{F}$ or on the trajectory of the particle between A and B, but only on its mass and on the half square of the initial and final velocity. By defining the quantity $E_k = \frac{1}{2}mv^2$ as *kinetic energy*, the explained reasoning shows that

$$W = E_{K,B} - E_{K,A}.$$

This means that *the work performed on a particle is equal to the variation of its kinetic energy*. This result is also known as the theorem of living forces because, as previously clarified, in the past kinetic energy was called living force.

https://doi.org/10.33225/BalticSTE/2023.38

It is appropriate to stress that this proposition can also be obtained, though in a less precise manner, through reasoning which is independent from the use of integrals: since $L=F\cdot s$ and $F=ma$, it is $L=m\cdot a\cdot s$. As the body is subject to a constant force, its motion is uniformly accelerated, so that from kinematics it is known that

$$v_f^2 - v_i^2 = 2a \cdot s$$

where v_f indicates the final speed of the body and v_i the initial one. Therefore, it is

$$s = \frac{v_f^2 - v_i^2}{2a}$$

so that

$$L = m \cdot a \cdot s = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2$$

The next concept which is necessary to introduce is that of a *conservative force*. A force is defined conservative if its dependence from the position ***r*** of the particle is such that work W can be expressed as the difference between the values considered in the initial and final points of a quantity $E_p^{(r)}$ which is called potential energy. It is a function of the particles' coordinates. Therefore, if ***F*** is conservative, it is

$$W = \int_A^B F \cdot dr = E_{p,A} - E_{p,B}$$

Namely: work is equal to the difference between the potential energy in the initial point and in the final point. Thence, potential energy is a function of the coordinates such that the difference between its values in the initial and final positions is equal to the work performed on a particle to move it from the initial to the final point. This implies that the work performed by a conservative force is independent of the trajectory. Taking into account Equation 1) we have that

$$E_{K,B} - E_{K,A} = E_{P,A} - E_{P,B}.$$

Namely

$$E_{K,B} + E_{P,B} = E_{K,A} + E_{P,A}.$$

This means that mechanical energy is conserved in the case that all forces are conservative.

However, in nature there are many non-conservative forces: friction is an example. Sliding friction opposes displacement. Therefore, it is obvious that the work performed by friction does not depend only on the initial and final points of the trajectory traversed by a body, but also on the length of such a trajectory. The longer the trajectory, the greater the work done by the friction forces. In such conditions, mechanical energy is not conserved. This depends on the fact that when a body moves on a rough surface, an old acquaintance of ours comes into play: heat. Hence, as we have seen in the previous section when heat is produced the quantity of mechanical energy does not remain constant but decreases. Thus, heat can also be interpreted as the intermediary quantity between mechanics and thermodynamics, the sector of physics to which now we turn.

Thermodynamics. The first quantity which is necessary to consider is temperature. Be given a system C of particles $m_1, m_2,\dots,m_n$ whose speeds are $v_1, v_2,\dots, v_n$ in the reference frame of C. The average kinetic energy of every particle is

$$E_{K,m} = \frac{1}{n}\left(\sum \frac{1}{2} m_i v_i^2\right).$$

If all the particles have the same mass, this formula is transformed into

$$E_{K,m} = \frac{1}{n}\sum \frac{1}{2} m v_i^2 = \frac{1}{2} m \left(\frac{1}{n}\sum v_i^2\right) = \frac{1}{2} m v_{qm}^2,$$

where v_q^2 is defined as mean-square velocity. Its formula is

$$v_{qm}^2 = \frac{1}{n}(v_1^2 + v_2^2 + \cdots v_n^2).$$

Temperature T of a system of particles is an intensive quantity correlated to the kinetic energy of the system calculated in the reference frame of the system itself. Basically, the higher the average kinetic energy of particles composing the system, the higher its temperature. Temperature is not a measure of the amount of heat in a system simply because there is no point in asking how much heat a body possesses. Heat, as we have seen, indicates the passage of energy between two systems, it is not a property of a single system, it is a quantity which correlates two systems. However, temperature has a relation to heat. For, with notable exceptions, if heat is supplied to a system, its temperature increases, whereas if heat is removed from it, its temperature decreases; in other words, an increase in the temperature of the system corresponds to an absorption of heat by the system, whereas a decrease in the temperature of the system corresponds to a release of heat by the system.

After this premise on the notion of temperature, it is appropriate to define the notion of a thermodynamic system: A system is a portion of space delimited by a surface which separates the interior of the system from the exterior.

The complementary of a thermodynamic system is the environment, defined as the set of things that do not belong to the system. A thermodynamic system is *isolated* if it can exchange neither energy nor matter with the environment; is *closed* if it can exchange energy but not matter with the outside world; is *open* if it can exchange both energy and matter. The first principle of thermodynamics is the general law of conservation of energy. It states that

https://doi.org/10.33225/BalticSTE/2023.38

The Internal Energy of an Isolated System is Constant

Let us now connect heat, internal energy, and work of a system. When one supplies a body or system of bodies with an amount of heat dQ, it will partly increase its internal energy by an amount dU, while it will partly produce work dW, so that the relation

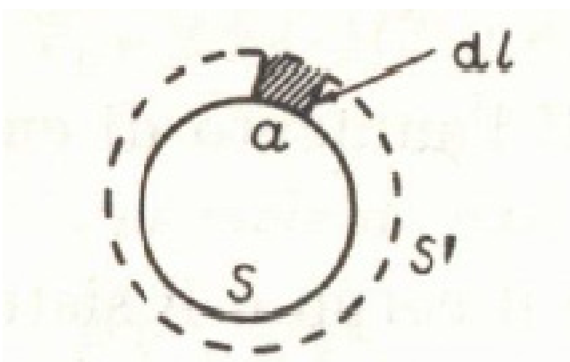
$$dQ=dU+dL \quad 2)$$

holds. If the body performs a transformation or a cycle of transformations at the end of which the state of the system is the same as the initial one, one speaks of a *closed cycle*. At the end of a closed cycle, the internal energy is the same as the initial one. This means that $dU=0$, so that, indicating by Q the sum of all the dQ and by L the sum of all the dL, it will be

$$Q=L.$$

This equation indicates a very important fact: *whenever a system completes a closed cycle, the work obtained and the heat expended are equal*. This is the precise statement of the first principle of thermodynamics which, in addition to enshrining the conservation of energy, shows the equivalence between heat and work. If, instead, the cycle is not closed, equation 2) must be used. For the gases, equation 2) can assume a more expressive form: suppose that a gas with pressure P is inside a container whose wall can expand very slowly until reaching a form whose difference from the initial one is infinitesimal (Fig. 4).

Figure 4
The Figure Referred to the Situation Described in the Running Text



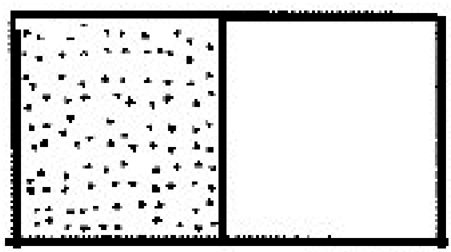
Note. Retrieved from Toraldo di Francia 1976, p. 230.

The gas exerts the pressure P on the walls and therefore performs the work W. If a indicates the element of surface, for the exerted force F the equation $F=P\cdot a$ holds. Being dl the length element, the element of volume will be adl, so that $W=F\cdot ds=P\cdot a\cdot dl=P\cdot dV$. Hence equation 2) gets the form

$$dQ = dU + P \cdot dV.$$

In the previous experience, we have supposed that the walls move very slowly. Suppose the opposite situation: be given a gas in part *A* of the box *AB*, while being part *B* empty (Fig. 5).

Figure 5
Image Representing the Situation Described in the Running Text



Remove suddenly the septum. The gas will expand, but this expansion implies no work. Therefore $dW=0$. It is evident that $dQ=0$ too, so that $dU=0$. In this experience, there is no change in internal energy. Suppose now to make this experience with a perfect gas. It is possible to note that the gas' temperature does not change. Therefore, when internal energy does not vary, the temperature of a perfect gas is not modified while varying its pressure and volume. Ergo, to each value of U a single value of T corresponds and conversely. Thus, one reaches this important conclusion: in a perfect gas internal energy is a *function only of the gas' temperature* (many of the ideas here presented are drawn from Toraldo di Franca 1976, chapter III).

Internal energy is connected to numerous important properties and quantities of a system. The first of them is the *free energy of a system*. It represents the quantity of macroscopic work (change in the kinetic energy) that a system can perform on the environment. It depends on the temperature, pressure, and concentration of the considered chemical species. There are various kinds of free energy. For example, Helmholtz free energy is the internal energy when a transformation with constant volume and temperature is considered. Gibbs free energy represents free energy in transformations performed with constant pressure and temperature. Another important quantity connected with internal and free energies is enthalpy. Given a thermodynamic system, its enthalpy H is defined as the sum of internal energy plus the product of pressure by volume

$$H = U + pV.$$

Enthalpy indicates several significant properties of a thermodynamic system. In particular:

1) In an isobaric transformation (constant pressure) in which only mechanical work is performed, the variation of enthalpy indicates the heat that the system exchanges with the environment.
2) In an isochorobaric transformation (constant volume and pressure) the variation of enthalpy coincides with heat exchange and with the variation of internal energy during the process.
3) In an isobaroentropic transformation (constant pressure and entropy) the variation of enthalpy expresses the variation of free energy.

Enthalpy is subject to a rather complex mathematical treatment which, obviously, cannot be proposed in all its aspects to the pupils of the last three years in high school. However, it is important that these concepts are introduced and explained because the learners should understand that almost all of them have been introduced to clarify the complex relations between energy, work and heat. This is the original problem from which thermodynamics was born in the first half of the 19th century and it is a difficult task. In order to clarify this complex situation, the concepts presented here (and also others) have been created.

Let us move now to the last topic of our itinerary: entropy and the second principle of thermodynamics.

The purely mechanical phenomena are reversible. In principle, nothing within mechanics prevents to reverse the time-harrow and to reverse the phenomenon. On the other hand, according to what we have seen in the previous section on entropy, the thermodynamical phenomena, generally speaking, are not reversible: if we have a box divided by a septum and a gas is contained in a part of the box, when we remove the septum, gas will be distributed in the entire box. For the statistical reasons described above, the opposite process, in which the whole gas comes back in a part of the box, will not take place. The harrow time is irreversible.

An investigation that analyses a physical phenomenon in its entirety will, however, shows that there are no purely mechanical phenomena. Example: the Moon and the Earth rotate around the barycentre of their system. The principles of conservation of mechanical energy and of angular momentum should guarantee that the situation does not change over time. In fact, things are not so simple: the Moon rotating around the Earth causes tides, which cause the parts subject to them to heat up and thus dissipate mechanical energy. The Earth-Moon system thus loses mechanical energy. The Moon continuously moves away from the Earth, which slows down its rotation period. The opposite process does not take place because the whole phenomenon is not purely mechanical, but is thermodynamical and heat is involved. The only reversible phenomena in thermodynamics are those which occur near equilibrium: if two bodies A and B are in contact, heat passes from the hotter A to the colder B. However, if their difference of temperature is negligible, an infinitesimal variation of the initial conditions is sufficient in order to make B hotter and A colder, so that heat can pass in the opposite direction. However, in the physical reality, no properly reversible phenomenon exists. This situation is stated by the *second principle of thermodynamics* which can be expressed by two formulations:

https://doi.org/10.33225/BalticSTE/2023.38

A) It is impossible for the only result of a transformation to be the passage of heat from a body at a given temperature to one at a higher temperature. This formulation is due to Clausius.
B) It is impossible for the only result of a transformation to be the production of work at the expense of heat supplied by a single source at a fixed temperature. This formulation is due to William Thomson, Lord Kelvin (1824-1907).

The two postulates are equivalent. For example, let us suppose B) does not hold. Then, it is possible to obtain work by cooling seawater. Through friction, we could transform this work into heat and supplying heat to a higher temperature source, so violating A).

The second principle of thermodynamics offers this picture of the physical world: a source of heat is more valuable the higher its temperature because the greater the amount of heat that can be converted into work. Suppose some of the heat falls from a higher to a lower temperature. No real transformation is reversible. Therefore, a part of the heat will remain trapped at the lower energy and will be irrecoverable for the purpose of producing work. The energy that descends to a lower temperature degrades and becomes less and less usable. Mechanical energy can be fully converted into work, but not the reverse. When the universe had reached the same temperature in all its parts there would be thermal death. No discernible phenomenon could occur. Clausius clarified this situation through the concept of entropy: suppose that a system performs a reversible transformation, during which a machine supplies the heat Q at the temperature T to the system. We will say that its *entropy* S in increased of the quantity Q/T. Thus, when a system is at the temperature T and receives the quantity of heat dQ, its entropy increases of the quantity

$$dS = \frac{dQ}{T}.$$

Thence, passing from state A to state B entropy increases of the quantity

$$\int_A^B \frac{dQ}{T}.$$

Consider a Carnot machine, namely a thermodynamical cycle on a gas given by four transformations: an isothermal expansion, an adiabatic expansion (that is a transformation in which no exchange of heat between the system and the external environment takes place), an isothermal compression and an adiabatic compression, which return the gas to its initial condition. If a Carnot machine subtracts the heat Q_1 from a source whose temperature is T_1 and pours the quantity of heat Q_2 to a source whose temperature is T_2, the relation $T_1/ T_2= Q_1/ Q_2$ holds. In this case, the increment of entropy is null because the system acquires the entropy Q_1/ T_1 and loses the entropy Q_2/ T_2, which are equal. However, we know this is only an ideal situation. In the universe, the phenomena are irreversible and, in this case, the relation $T_1/ T_2> Q_1/ Q_2$ holds, that is $Q_1/ T_1< Q_2/T_2$. Thence, in an irreversible transformation entropy always increases. Ergo, the second principle of thermodynamics can also be formulated as follows:

https://doi.org/10.33225/BalticSTE/2023.38

In an isolated system, entropy is an increasing function of time, namely

since no real transformation is perfectly reversible, it follows that in an isolated system, entropy will always increase. Therefore, energy degrades and, if the universe is an isolated system, it will be destined to thermal death.

I will not deal here with Boltzmann's definition of entropy because what is expounded is sufficient for my aims.

Conclusions

The main purpose of this work has been to give learners a general conceptual overview of the notion of energy. The basic idea here expressed is that, before considering the mathematical details concerning the various forms of energy, it is appropriate to introduce the concept of energy following a historical approach as it is particularly suitable for the pupils to gain the essence of this notion, which is so important in physics. A further idea is that, while speaking of energy, it is difficult to prescind from thermodynamics because this branch of physics is that through which it is possible to clarify all the nuances of energy as well as its connection with another fundamental notion, that of entropy. Therefore, the suggestion here developed is to propose an itinerary in which six hours (or how many the teacher will consider appropriate) are dedicated to introducing conceptually and historically the notion of energy. At this stage, it is advisable to make limited use of mathematics, though it is impossible to completely avoid it. Afterwards, namely after that the learners have acquired a series of general ideas on energy, this concept can be introduced in mechanics developing the mathematical details appropriate for young people aged 17-19. Later on, energy has to be introduced in thermodynamics. Given the importance of this section of physics in relation to the notion of energy, particular care has been dedicated to this topic, which allows us to understand the deeper implications of the physics of the reversible and irreversible. As it is natural, entropy and its relations with energy play here a pivotal role.

It is paramount to stress two aspects of this paper:

1) The idea behind it has been to discuss the basic principles and not the applications of such principles to the single aspects of physics, for example, as to mechanics, the application of the concept of energy to the different kinds of motions, or to collisions, or to the study of gravitation and, as to thermodynamics, the application of energy concept to the different kinds of transformations, to the notion of specific heat, to the kinetic theory of gases and so on.
2) Other branches of physics, such as electricity and electromagnetism might have been included in this discussion. However, the arguments put forward seem to me to be sufficient to clarify the point of view presented here, and adding new material would have overburdened the work.

In this period the terms multidisciplinarity and interdisciplinarity are widely used, but the concrete examples of an interdisciplinary education are not very numerous. Behind this work, there is the idea to offer an interdisciplinary approach to the concept of energy, in which history of physics becomes an important support in an educational context. A consideration which the teachers might propose concerns, e.g., the fact that the problem of work, heat and energy was posed and solved when machines became essential for the economy of the Western countries and while the industrial revolution was developing. It is not a coincidence that words such as work and energy were used to denote physical quantities. In the common language, they are clearly referred to the activity of man. In physics they lose this anthropocentric meaning, but maintain the idea of an activity exerted on a system, though not necessarily by man. This is an example which shows that theoretical physics is not extraneous to the economic structure of society, although it would be a big mistake to think of an automatic link between the two. However, there is undoubtedly a link. It would be interesting for the teacher of physics to discuss these topics jointly with the teacher of history, thus proposing an attempt of an interdisciplinary education.

It is not important to offer a complete or a completely precise history of the way in which the concept of energy has been developed. This is the task of a historian of science not of a teacher or an expert in science education. What is important, is to appropriately select sections of the history of science, or part of the works of an author, which can be used in science education. Such an operation has been developed in this work as to the notion of energy.

References

Arons, A. B. (1999). Development of energy concepts in introductory physics courses. *American Journal of Physics, 67, 12*, 1063-1067.

Bächtold, M. (2017). How should energy be defined through schooling? *Research in Science Education, 48, 2*, 345-367.

Bächtold, M., & Munier, V. (2019). Teaching energy in high school by making use of history and philosophy of science. *Journal of Research in Science Teaching, 56*(6), 765-796.

Balbi, A. (2023). Lesson on Youtube entitled “Cos’è l’entropia?” [What is entropy?]. YouTube. https://www.youtube.com/watch?v=C40Yjb6Xodc

Bécu-Robinault, K., & Tiberghien, A. (1998). Integrating experiments into the teaching of energy. *International Journal of Science Education, 20*(1), 99-114.

Caneva, K.L. (1998). Colding, Ørsted, and the meaning of force. *Historical Studies in the Physical and Biological Sciences, 28*(1), 1-138.

Coriolis, G.-G. (1829). *Du Calcul de l'effet des machines* [Calculation of the machines’ effect]. Carilian-Gouery.

De Berg, K. (1997). The development of the concept of work: A case where history can inform pedagogy. *Science & Education, 6*, 511-527.

Demkanin, P. (2020). The ways the theory of physics can evolve. *Journal of Baltic Science Education*, *19*(6), 860-863. http://dx.doi.org/10.33225/jbse/20.19.860

Duit, R. (1981). Understanding energy as a conserved quantity-remarks on the article by R.U. Sexl. *European Journal of Science Education, 3*(3), 291-301.

Duit, R. (1987). Should energy be illustrated as something quasi-material? *International Journal of Science Education, 9*(2), 139-145.

Einstein, A., & Infeld, L. (1938). *The evolution of physics*. *The growth of ideas from early concepts to relativity and quanta*. Cambridge University Press.

Entry “Energy” in the English Wikipedia. https://en.wikipedia.org/wiki/Energy

Feynman, R., Leighton, R. B., & Sands, M. (1963). *The Feynman lectures on physics, Volume I: Mainly mechanics, radiation, and heat*. Addison-Wesley Publishing.

Goldring, H., & Osborne, J. (1994). Students' difficulties with energy and related concepts. *Physics Education, 29*, 26-32.

Helmholtz, H. (1847). *Über die Erhaltung der Kraft*. Reimer, Berlin 1847. [Helmholtz, H. (2003). The conservation of Force. In Brush, S. G. (Ed.), *History of modern physical sciences. The Kinetic Theory of Gases Volume 1. (An anthology of classic papers with historical commentary)*. (pp. 89–110). Imperial College Press.

Helmholtz, H. (1854). *Über die Wechselwirkung der Naturkräfte und die darauf bezüglichen neuesten Ermittelungen der Physik. Ein populär-wissenschaftlicher Vortrag, gehalten am 7. Februar 1854, Königsberg*. Königsberg: Gräfe & Unzer. [Helmholtz, H. (1995). On the interaction of natural forces. Lecture delivered February 7, 1854, at Königsberg. In *science and culture: Popular and philosophical essays*, (Ed.), D. Cahan. (pp. 18-45)]. The University of Chicago Press.

Helmholtz, H. (1967). *Opere* [*Works*]. Italian translation. In V. Cappelletti (Ed.). UTET.

Joule, J. P. (1845a). On the existence of an equivalent relation between heat and the ordinary forms of mechanical power. *The London, Edinburgh, and Dublin Philosophical Magazine and Journal of Science, 27*, 205-207.

Joule, J. P. (1847). On matter, living force, and heat. *The Manchester Courier, 5 and 12 May, 1847*. (Reprinted in Joule, J.P. (1884). *The Scientific Papers of James Prescott Joule* (pp. 265-276). The Physical Society.

Joule, J. P. (1850). On the mechanical equivalent of heat. *Philosophical Transactions of the Royal Society of London, 140(0)*, 61–82.

Kaper, W. H., & Goedhart, M. J. (2002). 'Forms of Energy', an intermediary language on the road to thermodynamics? Part I. *International Journal of Science Education*, *24,* (1), 81-95.

Koliopoulos, D., & Ravanis, K. (2001). Didactic implications resulting from students' ideas about energy: An approach to mechanical, thermal and electrical phenomena. *Themes in Education, 2*(2-3), 161-173.

Kubsch, M., Optiz, S., Nordine, J., Neumann, K., Fortus, D., & Krajcik, J. (2021). Exploring a pathway towards energy conservation through emphasizing the connection between energy, systems, and the fields. *Disciplinary and Interdisciplinary Science Education Research, 3*(2), 1-18.

Kuhn, T. (1977). Energy conservation as an example of simultaneous discovery. In *The Essential Tension* (pp. 66-104). University of Chicago Press.

Lehrman, R. L. (1973). Energy is not the ability to do work. *The Physics Teacher, 11, 15*, 15-18.

Mai, Y., Qian, Y., Lan, H., & Li, L. (2021). Students' concept organization regarding chemical equilibrium in upper-secondary education: Based on reaction time technique. *Journal of Baltic Science Education*, *20*(3), 443-455. http://dx.doi.org/10.33225/jbse/21.20.443

Mayer, R. (1842). Bemerkungen über die Kräfte der unbelebten Natur. *Annalen der Chemie und Pharmacie*, *42*, 233–240. [Mayer, R. (1862). Remarks on the forces of inorganic nature. *Philosophical Magazine*, *4*, *24*, 371-377].

Mayer, R. (1845). *Die organische Bewegung in ihrem Zusammenhange mit dem Stoffwechsel. Ein Beitrag zur Naturkunde* [*Organic movement in its relationship to metabolism. A contribution to natural history*]. Verlag der Drechslerschen Buchhandlung.

Sexl, R. U. (1981). Some observations concerning the teaching of the energy concept. *European Journal of Science Education, 3*(3), 285-289.

Solomon, J. (1985). Teaching the conservation of energy. *Physics Education, 20*, 165-170.

Toraldo di Francia, G. (1976). *L'indagine del mondo fisico* [The inquiry of physical world]. Einaudi.

Van Heuvelen, A., & Zou, X. (2001). Multiple representations of work-energy processes. *American Journal of Physics, 69*(2), 184-194.

Van Roon, P. H., Van Sprang, H. F., & Verdonk, A. H. (1994). 'Work' and 'Heat': On a road towards thermodynamics. *International Journal of Science Education, 16*(2), 131-144.

Warren, J. W. (1982). The nature of energy. *European Journal of Science Education, 4*(3), 295-297.

Received: *April 12, 2023* Accepted: *May 18, 2023*

Cite as: Bussotti, P. (2023). Introducing the concept of energy: Educational and conceptual considerations based on the history of physics. In V. Lamanauskas (Ed.), *Science and technology education: New developments and Innovations. Proceedings of the 5th International Baltic Symposium on Science and Technology Education (BalticSTE2023)* (pp. 38-57). Scientia Socialis Press. https://doi.org/10.33225/BalticSTE/2023.38

IMPLEMENTING A NATIONAL DATABASE ON YOUNG CHILDREN'S LEARNING: A PRELIMINARY ANALYSIS OF A LONGITUDINAL STUDY TO EVALUATE THE QUALITY OF PRESCHOOLS

Ching-Ching Cheng , **Shan-Shan Cheng**
National Chiayi University, Taiwan
E-mail: chingching_cheng@mail.ncyu.edu.tw, medusa33tw@hotmail.com

Abstract

In recent years, many policies have been formulated and strongly promoted to improve the quality of early childhood education. In 2012, the Taiwanese government enacted a new national curriculum framework for early childhood education to enhance the quality of early childhood education programs. This new framework is key competence-oriented, meaning preschool educators must focus on children's learning and inquiry processes when designing the curriculum. A series of projects collecting information on the quality of the learning environment and learning outcomes of children aged 2 to 9, called the Early Childhood Learning Database, was built to understand the effectiveness of the curriculum reform. As a longitudinal study, young children's learning is long-term tracked and analyzed to understand the authentic situation and relevant factors to form a policy for optimizing education quality. The preliminary analysis confirmed the positive influence of the new curriculum.
Keywords: *early childhood education, curriculum reform, learning database, quality of preschools*

Introduction

There is a consensus that early childhood education is an essential cornerstone for talent cultivation because early development is the foundation of individual development. In recent years, empirical research has found that the quality of early childhood education will not only affect the learning outcomes in the early childhood education stage, but the influence will continue to follow-up stages: primary school, middle school, and even university (Amadon et al., 2022; Ulferts et al., 2019). To cultivate young people's talents, effective investment of resources in early childhood education is being implemented and undergoing by the government now. Nevertheless, how resources should be allocated requires accurate information as a basis for decision-making, especially the complexity and specificity of early childhood education sites need to be carefully considered (Chen & Li, 2022; Eckhardt & Egert, 2018; Mitchell et al., 2015; Mitchell et al., 2016).

https://doi.org/10.33225/BalticSTE/2023.58

Research Focus

Education has always been highly valued in Taiwan's culture. In recent years, due to the increased understanding of the importance of early childhood education, many policies have been formulated and strongly promoted to improve the quality of early childhood education.

In 2012, the Taiwanese government enacted a new national curriculum framework for early childhood education to enhance the quality of early childhood education programs. This new framework was called Early Childhood Education & Care Curriculum Framework (ECECCF), which is key competence-oriented (Chang et al., 2012). It means preschool educators must focus on children's learning and inquiry processes when designing the curriculum (Shing et al., 2017). This key competence-oriented curriculum helps children develop the knowledge, attitudes, and skills to adapt to life and future challenges. ECECCF aims to develop children's six key competencies: Awareness & Identification, Expression & Communication, Concern for Others & Collaboration with Others, Reasoning & Appreciation, Imagination & Creativity, and Self-Regulation.

Moreover, for a better implementation of ECECCF, the Ministry of Education (MOE) has run the on-site consulting program since 2013. The preschool invites a consultant; a consulting project usually lasts for a year; the consultant meets with the preschool educators monthly. Mentoring, observing in the classroom, and discussing curriculum development with the educators in the preschool were used by consultants to help educators better understand and implement ECECCF. Therefore, researchers and the government need to understand the quality of early childhood education and the effectiveness of the on-site consulting program under this new curriculum framework.

Faas and Dahlbheimer (2021) indicated that quality and its definition were the main issues before a government could monitor quality. Therefore, the meaning of quality in early childhood education should be discussed. OECD (2018) defined that the early childhood education and care (ECEC) quality can be distinguished between structural characteristics and process quality. Different methods should be implemented for measuring the level of these two parts of ECEC quality. Zukani and Ganqa (2022) also argued that quality could be viewed from various perspectives, including input of process (curriculum process implementation and reform) and results (development status and learning of children). All these aspects of ECEC quality need to be considered besides the contents of ECEC quality, how to evaluate it, and from whose perspectives should be considered. Because the concepts and perceptions of quality management are time-changing and culture-dependent, researchers should consider the views of all key groups (Heikka, et al., 2021). There is no nationwide database of early childhood education in Taiwan. Therefore, the main issue of this study was to build a database collecting system for tracking down different aspects of ECEC quality in Taiwan under the new curriculum framework.

Research Questions

1. What are the problems and solutions while implementing the database?
2. What are the preliminary results of analyzing children’s learning and development using this database?

https://doi.org/10.33225/BalticSTE/2023.58

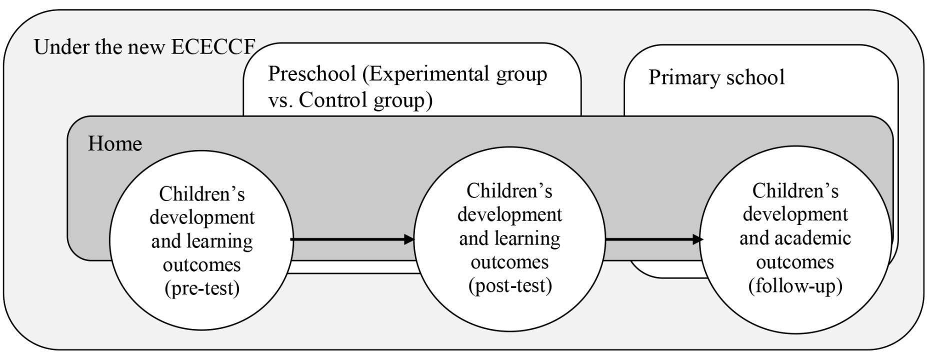
Research Methodology

General Background and Database Design

Since 2014, the MOE in Taiwan has launched a series of projects to build a preschool learning database. An essential task in the early stages of the database is to identify the purpose of this database, such as understanding the current state of education, policy effectiveness analysis, or improvement of the teaching environment. Furthermore, based on the purpose, researchers could decide which specific data should be included in the database for further investigation.

The first step of this study was to call for meetings. MOE officials, preschool and primary educators, and researchers in early childhood education and primary education were invited to determine the database's sample selection and data content. The final decision was to collect data on the quality of the learning environment and the development and learning achievement of children aged 2 to 6 with multiple evaluation tools. Then, to follow the children until the third grade. As a longitudinal study, young children's learning is long-term tracked and analyzed to understand the authentic situation and relevant factors to form a policy for optimizing education quality. The structure of the database design is presented in Figure 1.

Figure 1
The Structure of Database Design



Data Collection

A total of 2,335 children aged 2 to 6 in 178 classrooms were recruited during 2017-2018. For future comparative studies, several preschool features were marked to investigate the relationship between these features and children's learning progress. These features included participation in the ECECCF consulting program, school area, a public or private institution, and children's enrolling ages.

For the reliability of the data, the training programs for examiners were held before the data-collecting period each semester. The training programs consisted of research ethics, instrument operation, and on-site practice, and the person who passed the final test could participate in data collection.

Instruments

Several evaluation tools were chosen to collect data from three main aspects: children's development and learning outcomes, school and home environment, and the level of ECECCF implementation.

Children's development and learning outcomes. Data was initially collected during preschool to understand children's development and learning outcomes. Cognitive development, language development, and learning outcomes (six key competencies) were evaluated. Children's development and learning outcomes were measured in the first semester(pre-test) and followed up every year(post-test). After enrolling in primary school, children's cognitive development, language development, school behaviors, and subject content of mathematics and language were tested yearly for tracking. Children's learning outcomes and school behaviors were evaluated by children's teachers. Researchers or well-trained testers held developmental tests and academic tests.

School and home environment. The school environment part was evaluated from multiple aspects. Data on the organizational atmosphere, partnerships at preschools, the quality of the learning environment, and several structural characteristics, including child-staff ratio, group size, and staff education, were collected. Data were collected through preschool and elementary teachers and well-trained observers' questionnaires. Home environment, parent-teacher cooperation, and other characteristics, like parents' education level, home language, and the number of children, were collected by questionnaires.

The level of ECECCF implementation. In response to the curriculum reform in Taiwan, a research instrument was developed to measure the effectiveness of the preschool teachers' ECECCF implementation (Chang, et al., 2021) during the second semester of each school year. The ECECCF Implementation Scale obtained four subscales with 19 items: Awareness and Adjustment, Learning Centers Arrangement, Teaching Guidance and Curriculum Development. Well-trained researchers observed each classroom from 7:30 to 14:00 and then interviewed the principal teacher of the classroom to rate the level of ECECCF implementation.

All data were coded after collecting and double-checked by different people. Statistical procedures were used to examine the validity and reliability of each characteristic. Furthermore, in this study, T-test, ANOVA, and correlations were used to examine the effectiveness of different levels of ECECCF implementation and children's learning outcomes between the preschool stage and primary school stage.

Results and Discussion

As a national database of early childhood education, the sample size is large and widely distributed throughout the country. Moreover, as a longitudinal study, this database was designed to collect consecutive six-year data. Data was collected from different keyholders, including children, educators of preschools and primary schools, and results from different tools and methods used. These designs aimed to obtain reliable and valuable data for further analysis but made the task more difficult.

https://doi.org/10.33225/BalticSTE/2023.58

Problems and Solutions

Many problems were encountered during the recruiting stage. Because of the high standards of research ethics regulation and people's awareness of personal data protection, the data collection process initially encountered difficulties in sample invitation. To maximize the sample numbers and reduce the dropping rate during the longitude survey, the research team adopted various strategies at the beginning and continuing periods. To increase the participation rate of the invited samples, the project team adopted multiple methods to reduce parents' and teachers' concerns, including preschool visits to hold information sessions and assisting promotion by local government, project websites, and network societies. To decrease the dropping of research participants, the research team made efforts to meet participants' needs from their feedback. For example, after confirming the willingness to participate, the project team would directly contact parents by providing child test results, parenting advice, and gifts for children entering a school and establishing a mutual trust preventing them from dropping out.

Another unexpected issue during the process of data collection was the pandemic. During the year 2020 to 2022, the pandemic impacted children's learning and data collecting process of this study. Since January 2020, Taiwan has limited outsiders' access to campuses and has conducted several periods of online teaching. The data collection schedule has been adjusted accordingly. For example, reschedule all testing staff to enter schools for testing during the short face-to-face teaching periods and continue to contact parents and teachers through mailing questionnaires during the online teaching period. However, these strategies demanding flexible human resources management and extra funds, require more resources.

Preliminary Research Results

The research findings were just from rough analyses, but the results were enlightening. The purpose of enacting the new curriculum framework was to improve the quality of early childhood education, and children's learning outcomes were one of the quality indicators. The data of this study presented positive results on the effectiveness of the new curriculum framework. Children in the higher level of ECECCF implementation classroom performed better in the six key competencies. Moreover, these abilities of six key competencies were correlated to their academic learning outcomes and further development. ECECCF provided a clear guideline for educators to create an appropriate learning environment, observe and understand children and interact with children better (Chang et al., 2012). This study showed that all of these efforts improve children's learning outcomes.

Conclusions and Implications

Establishing a database of early childhood learning is conducive to academic research and can be an essential basis for government decision-making. Databases for different purposes can provide multiple aspects for improving the quality of early childhood education. The number of databases for early childhood education needs to be increased. However, the resources for establishing a database are enormous. From the design to the implementation, a meaningful database is time, human resource, and money-consuming.

https://doi.org/10.33225/BalticSTE/2023.58

Moreover, a recent study noticed that the concepts and perceptions of quality management are time-changing (Heikka, et al., 2021). A database's purpose and contents need to be adjusted from time to time. Our experience building a database shows that a long-term tracking database is more challenging to build and maintain. In addition to providing support and resources, the government can encourage researchers across borders to share and cooperate, making the process and results of building a national database more fruitful. The government could make better decisions and policies based on the results and reach the goal of enhancing the quality of early childhood education.

Acknowledgments

This project is financially supported by the Ministry of Education, Taiwan.

Declaration of Interest

The authors declare no competing interest.

References

Amadon, S., Gormley, W. T., Claessens, A., Magnuson, K., Hummel-Price, D., & Romm, K. (2022). Does early childhood education help to improve high school outcomes? Results from Tulsa. *Child Development, 93*(4), 379-395. https://doi.org/10.1111/cdev.13752

Chang, C. W., Cheng, S. S., Chang, I. W., Liaw, F. R., & Cheng, C. C. (2021). The development of the "Early Childhood Education and Care Curriculum Framework Implementation Scale" in Taiwan. *Hungarian Educational Research Journal, 11*(4), 377-395.

Chen.J. J., & Li, H. (2022). Tian shi (timing) di li (context) ren he (human capital): A new theoretical framework for analyzing the implement ability of imported early childhood practices and making a case for a hybrid model. *Journal of Research in Childhood Education*. https://doi.org/10.1080/02568543.2022.2107588

Eckhardt, A. G., & Egert, F. (2018). Process quality for children under three years in early childcare and family childcare in Germany. *Early Years, 40*(3), 287-305. https://doi.org/10.1080/09575146.2018.1438373

Faas, S., & Dahlheimer, S. (2021). Quality monitoring in day care centers and preschools: Discourses, concepts and experiences from German early childhood education and care. In S. Garris & H. L. Taguchi (Eds.), *Quality Improvement in Early Childhood Education: International Perspectives on Enhancing Learning Outcomes* (pp. 163-180). Palgrave Macmillan.

Heikka, J., Fonsen, E., Mantyjarvi, M., Kiuru, L., Suhonen, K., & Keikonen, L. (2021). Evaluating quality in Finnish early childhood education. In S. Garris & H. L. Taguchi (Eds.), *Quality Improvement in Early Childhood Education: International Perspectives on Enhancing Learning Outcomes* (pp. 21-44). Palgrave Macmillan.

Mitchell, L., Cowie, B., Clarkin-Phillips, J., Davis, K., Glasgow, A., Hatherly, A., Rameka, L., Taylor, L., & Taylor, M. (2015). *Continuity of early learning: Learning progress and outcomes in the early years overview report on data findings*. Report to the Ministry of Education of New Zealand. https://www.educationcounts.govt.nz/__data/assets/pdf_file/0005/163589/Continuity-of-Early-Learning-Learning-Progress-and-Outcomes-Overview-Report.pdf

OECD. (2018). *Starting Strong: Engaging Young Children: Lessons from Research about Quality in Early Childhood Education and Care*. https://www.oecd.org/education/engaging-young-children-9789264085145-en.htm

Shing. M. L., Chou, Y. P., Wang, S. F, & Hsu, S. L. (2017). The key competence-oriented curriculum design and practices in preschools. *The Elementary Education Journal, 64*(4), 4–29.
Ulferts, H., Wolf, K. M. & Anders, Y. (2019). Impact of process quality in early childhood education and care on academic outcomes: Longitudinal meta-analysis. *Child Development, 90*(5), 1474-1489. https://doi.org/10.1111/cdev.13296

Received: *April 14, 2023* Accepted: *May 16, 2023*

Cite as: Cheng, C.-C., & Cheng, S.-S. (2023). Implementing a national database on young children's learning: A preliminary analysis of a longitudinal study to evaluate the quality of preschools. In V. Lamanauskas (Ed.), *Science and technology education: New developments and Innovations. Proceedings of the 5th International Baltic Symposium on Science and Technology Education (BalticSTE2023)* (pp. 58-64). Scientia Socialis Press. https://doi.org/10.33225/BalticSTE/2023.58

THE USE OF INTERNET OF THINGS TECHNOLOGY IN THE PEDAGOGICAL PROCESS

Jan Francisti
Constantine the Philosopher University in Nitra, Slovakia
E-mail: jfrancisti@ukf.sk

Zoltán Balogh
Constantine the Philosopher University in Nitra, Slovakia
Óbuda University, Hungary
E-mail: zbalogh@ukf.sk

Milan Turčáni
Constantine the Philosopher University in Nitra, Slovakia
E-mail: mturcani@ukf.sk

Abstract

Today's trend is the use of information technology in all areas of our lives. Emotions are a basic human characteristic, although they are difficult to define, recognise and classify. Proper assessment and recognition of human emotions can lead to a better understanding of user behaviour. The aforementioned technologies can also be used as a suitable teaching aid, which forms the core of the research and is able to guarantee an increase in the success rate of the teaching process itself in terms of students' understanding of the learning materials. The aim of the research was the use of sensor networks as an element of information and communication technologies in the educational process. Using the possibility of measuring physiological functions through smart wristbands in order to identify changes in students' emotional states. The overall proposed system was able to identify changes in students' emotional state, specifically levels of arousal. Based on the results from the proposed system, teachers should be able to adjust their teaching style in specific situations to suit the students and provide a basis for better teaching and learning.
Keywords: *emotional states, internet of things, physiological functions, teaching process, smart wristbands, sensory networks*

Introduction

In teaching computer science, information and communication technology can be used as a suitable tool to achieve higher-category objectives. Nowadays, ICT is becoming an integral part of the teaching process. Through ICT, even younger generations of students can master the curriculum more easily and effectively, as the teaching of theoretical matters can be directly linked to practical ones (Horváthová, 2005). With the advent of new technologies in the field of computer science come new trends in teaching using information and communication technologies. For example, interactive

https://doi.org/10.33225/BalticSTE/2023.65

tests for students, on which the author has worked. Students can test themselves in an interactive way and have the opportunity for direct feedback to compare success rates. Author (Bílek & Machková, 2016) described the inquiry-oriented way of teaching the subject and also the possibility of discussing a certain topic via videoconferencing with other students from different parts of the world.

The learning environment is an important outcome of the educational process, not just a stage for the actual teaching. The term Virtual Learning Environment (VLE) is broadly understood as the creation of conditions for learning with limited personal participation of the teacher and with the use of information and communication technologies. LMS (Learning Management System) is an information management system for e-learning. The purpose of LMS role is to collect information on how individual students have been assigned to lessons and courses, how and when they have completed them, to which groups the student is assigned, and to manage communication within the learning system (Horváthová, 2005).

While E-learning and the use of various LMS systems for learning management is a relatively common phenomenon, especially in universities and secondary schools, mobile learning is coming to Slovak schools gradually. In doing so, many of the portable devices are increasingly found in children's hands. With these devices, access to the information that is needed is made possible. The essence of mobile learning is that it creates opportunities for learning in context, in the context of where the learner is at the moment (Wei et al., 2021).

Sensor networks can also be used in education and teaching. The effort to incorporate sensory networks into the classroom is to make the teaching process itself more efficient for the educator. The goal of sensory networks in teaching is to provide information to the educator about the feelings of the students. The endeavour in the research represents the use of a sensory network to provide the educator with information and emotional states of the learners. IoT elements can be incorporated into sensor networks for the purpose of aiding teaching in the teaching process. These include IOT-enabled devices such as smart devices in the form of wristbands and other items that can be worn by students (Kummerfeld & Kay, 2017).

In the teaching process, IoT technology can be envisioned as the interconnection of multiple devices that communicate with each other in lecture rooms. These are devices that would monitor the activities of students, such as cameras that would have the role of a motion sensor, also smart wristbands that would monitor the change in physiological functions of students. By combining these devices, the educator would have a visualization of the processed information about the change in the emotional states of the students and based on that, he would be able to adjust the teaching in a different direction.

The educational process gradually begins to focus on the learner's personality, and the teacher acts as a tutor. Mass education in the classroom or through classical e-learning is not capable of responding to the individual needs of the learner. Personalized education represents the way in which students learn with respect to their prior knowledge, skills, and learning styles. Viewing teaching from an emotional perspective means that a distinction needs to be made between two aspects of teaching and student learning: cognitive processes of information processing—the actual mechanisms of learning that produce changes in the memory system—and emotional-motivational processes that

https://doi.org/10.33225/BalticSTE/2023.65

are indirectly involved in the learning process and influence the cognitive aspects of learning, such as its dynamics (Krapp, 2005).

Emotions are fundamental to the human experience, even though they can be difficult to define, recognize, and classify. Feelings and emotions play an important role in human life because they are part of the motivational structure. The extent to which a person is focused, determined, and consistent often depends on their emotions. Emotions are also significant and important in a student's learning, and they significantly affect the results of their learning activities. Positive emotions can facilitate or enhance the procedural aspect of learning, while negative emotions can also have a good impact on the learning outcome. However, the difference between positive and negative emotions is that negative emotions only affect the outcome of learning, such as forgetting material, difficulties in transferring knowledge, etc., and not the process of learning itself (Petlák, 2018).

The aim of current research was to use data obtained from individual sensory features, such as sight, smell, touch, hearing, and taste, to determine the overall emotional state of the user and to understand their actions and mindset. The research focused on the monitoring and evaluation of students' emotional states during the teaching process. One of the basic problems of the teaching process is a lack of focus among students. It is assumed that the emotional state of students also influences this lack of focus. To detect these states as objectively as possible, physiological data such as heart rate can be used. These data can be measured using sensor networks. Based on the research conducted by the aforementioned researchers, it is possible to confirm that sensory networks are a suitable tool for recording and analysing changes in students' emotional state during teaching.

Research Methodology

The research methodology focuses on evaluating human emotions through physiological functions, particularly heart rate, in the context of optimizing the teaching process. The methodology consists of the following steps.

General Background

The research was conducted during the teaching period of the Operating Systems course, which is a compulsory subject consisting of two parts: lectures and exercises. The course concludes with an examination test, and the research was carried out throughout the semester, culminating in the final exam. The primary objective of the Operating Systems (OS) course is to provide students with a foundational understanding of operating system construction and the theoretical underpinnings of computer science. To facilitate the research, an e-learning course was developed in the LMS Moodle environment.

Sample Selection

The students who took the course were divided into two groups. At the beginning of the semester, students who agreed to participate in the research were provided with a smart wristband that could measure heart rate. They were instructed to wear the wristband throughout the entire class, including lectures and Operating Systems exercises.

Instrument and Procedures

Heart rate was used as a physiological indicator to assess the level of arousal in students. This was accomplished using wristbands that contained sensors capable of measuring heart rate, with measurements taken throughout the entire semester. Special attention was given to students' physiological responses during the self-test phase, which involved revisiting lecture material. The wristbands sent heart rate data to a mobile app for processing at regular intervals, with Xiaomi devices set to record data every second.

The data for the experiment was obtained from smart bracelets that students wore during class. The wristbands recorded heart rate data over time, which was then exported and analysed for each student. In addition to heart rate data, time stamps were recorded for various class activities, including exercises and lectures throughout the semester. Information on the timing of self-tests was also obtained from the virtual learning portal Moodle, which was exported in order to identify the time intervals at which students took the tests.

Data Analysis

During the pre-processing of the input files, it was necessary to perform data cleaning in order to remove unnecessary records, such as data from wristbands that were measured prior to the teaching process. Next, the data was merged into a single data matrix, which involved creating a new variable to represent the unique identifier of each student assigned to a specific wristband. Using this identifier, the data from the wristbands was merged with the data from Moodle, and new artificial variables were created to represent information about the type of activity, whether it was an exercise, a lecture, or a self-test. The data was transformed by creating additional variables that explored various factors in combination with heart rate data from the wristbands. These variables included information about the minute of exercise/lecture, the specific activity being performed at a given time, average heart rate, and the difference in heart rate at a given time compared to the average heart rate, among others.

Research Results

According to research (Francisti et al., 2020; Francisti & Balogh, 2020) networks, including smart wristbands, have been found to be effective tools for identifying changes in emotional states. In the research, students wore smart bracelets during the teaching process without any restrictions. The devices were equipped with sensors that measured the physiological function of the heart rate, to identify emotional states. Based on the tests, it was assured that these devices were effective in measuring changes in emotional states during the teaching process.

https://doi.org/10.33225/BalticSTE/2023.65

Data Normalization

Since the heart rate values of different students were in different ranges, it was necessary to create a standardization, or standard variable, to be able to compare the data of students with each other. Through standardization, the research did not work directly with heart rate values, but with the deviation from the average heart rate value that was measured for a given student. The adjusted value was given as a percentage of how much the heart rate in each situation deviated from the mean heart rate of that student. In the first step, normalization had to be implemented since the data obtained did not have the form of normalized data. Subsequently, after normalization, it was also possible to compare the students with each other. As part of the data normalization, the average heart rate of a given student was calculated from all the records that were obtained during the conduct of the research. The obtained average heartbeats of *Rate_Means* were considered as a reference for a given student. Subsequently, new variables were created in the protocol file that were calculated as the differences of the actual heart rate from the *RateAVG* average heart rate. This created variables *rateDiff* (calculated as *rateAVG* - rate, i.e., the deviation of actual heart rate from average heart rate in units of beats per minute). The normalization of the heart rate data represented an intermediate step that allowed us to proceed with further comparisons of the students.

Comparison of Normalized Heart Rate Data According to the Activities of the Pedagogical Process

The students' activities during the semester were diverse and included exercises, self-tests, lectures, presentations, and exams. In order to analyse the data collected from the smart bracelets more accurately and to track changes in heart rate values during these activities, the activities were divided into groups. The categorization was done in such a way that the different activities could be compared with each other.

Creating categories for each activity was also an important step for using the Kruskal Wallis ANOVA statistical method. Through the statistical method used, the changes in heart rate values for each activity were found, as shown in Table 1.

Table 1
Kruskal-Wallis ANOVA Results Comparing Categories of Pedagogical Process Activities

	Valid N	Sum of Ranks	Mean Rank	Means	Std.Dev.
Activity	19	404	21.263	0.308	2.208
Test	11	419	38.091	3.543	2.129
Other	1	17	17	-0.388	-
Lecture	6	33	5.5	-3.793	2.654
Presentation	10	273	27.3	1.478	2.54
Exam	4	180	45	5.045	2.263

https://doi.org/10.33225/BalticSTE/2023.65

The activity in the form of an exam test represented the final grade for the entire semester and had the greatest weight on the final course grade. Therefore, the importance of the activity in terms of student motivation and excitement is also significant.

The self-test activity was designed to serve as a summary of the material covered in the lecture and was conducted at the beginning of each exercise. During the self-test, students were required to answer several questions within a defined time interval. The self-test was administered sequentially, and students were not allowed to return to previous questions. The high heart rate readings during the self-test demonstrated the level of excitement and engagement of the students with the material covered.

The presentation as part of the exercise was ranked third according to the statistical method. During the presentation, the students were familiarized with the objective of the exercise, the issues on the topic were discussed and a discussion took place as the students answered the questions posed. The assumption was that students were quiet during the presentation until they were asked to answer a specific question. In case they were not actively following the lesson, the question might have surprised them and aroused a change in the heart rate value, as demonstrated by the statistical method used.

The activity labelled "Activity" represented the students' independent activity during the exercise. Based on the instructions from the presentation, students worked independently on practical tasks. Subsequently, the results from the task had to be uploaded to the course. The students had sufficient time to complete and submit the practical tasks, which was confirmed by the statistical method.

According to the statistical method conducted, students were most relaxed during lectures when they were going over the theoretical part of the course in the form of a presentation. In addition to the Kruskal_Wallis ANOVA statistical method, the parametric ANOVA method was performed for comparison and confirmed the same order of results.

Comparison of Normalized Heart Rate Data by Self-Test Activity

The self-test was a quiz activity. The main objective was to test the knowledge of students acquired in lectures. Each self-test contained only questions that belonged to the last topic covered.

In the first step of analysing the aforementioned activity, differentials were created for each self-test separately (Table 2).

Table 2
Differences in Heart Rate Values Distributed by Self-Tests

Self-test number	rateDiff Means	rateDiff N	rateDiff Std. Dev.
7	1.45714	5146	8.13073
8	4.35060	6068	7.57225
9	1.94337	4111	7.82053
10	-1.90831	5094	7.06820
11	-1.33549	62249	14.17801

From the calculated differences, students were the calmest on self-tests 10 and 11. Self-test 10 was created on the topic of computer networks. Students also showed interest in this topic in the exercise where practical matters of communication of devices in computer networks were implemented.

The results obtained suggest that students were familiar with the questions on self-test 11 and did not experience significant arousal during the test. This was confirmed by the evaluation of the test results. Self-test 11 was a review of the learning materials and contained the same questions as self-test 7. The aim of repeating the self-test was to observe how students would physiologically respond to the same questions after a time interval of 5 weeks. Based on the calculated heart rate values, it can be inferred that there was no significant physiological response, suggesting that the students were familiar with the material and did not experience any significant cognitive load during the test.

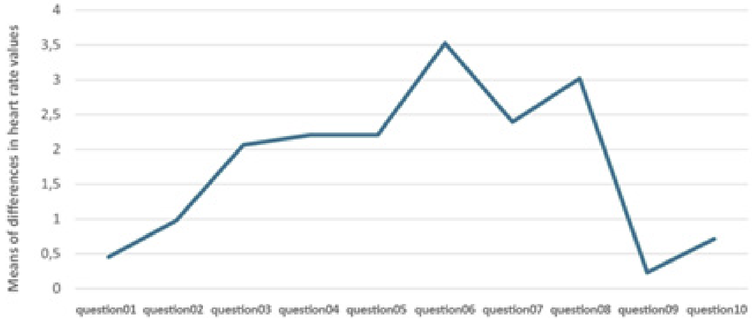
According to the analysis of the physiological function of the heartbeat, students were most excited during self-test 8, which consisted of questions related to computerized mechanical disks. This topic was one of the most content-dense, with detailed descriptions of the methods and principles of mechanical disk function. Based on the highest difference in mean heart rate, it was shown that self-test 8 was more challenging than the others, as evidenced by the physiological function of the heart rhythm, which may have influenced the test results.

Continuing to analyse the data collected, individual questions in the self-tests were identified in more detail, as well as significant changes in the students' heart rate values. Students were most excited when asked to mark one correct answer and least excited when asked to complete the answer. This observation indicates that students might have experienced more difficulty in choosing the correct answer when given multiple options, compared to when they had to recall the information and write down the answer.

In addition to inter-question comparisons within the self-tests, inter-question rankings were also analysed with physiological values of heart rate function. The investigated self-tests were created sequentially. It was investigated whether the heart rate (*rate_Diff*) of students would tend to increase or decrease with higher-order questions in the self-test.

Figure 1

Averages of Heart Rate Values Distributed According to the Order of the Questions



It is also possible that the content of the questions in the later part of the test was less challenging, leading to a decrease in arousal and a subsequent decrease in heart rate. The decrease in heart rate for question 10 may be attributed to the fact that it was the last question of the self-test and the students knew that they had completed the test, resulting in a sense of relief and relaxation. Overall, the results suggest that the order of the questions in the self-test can influence the physiological response of the students.

Since the self-tests included in the analysis were sequential, the optimal number of clicks for successful completion was calculated. The optimal number of clicks included pressing the button for the next question and pressing the button at the end to exit the test (the type of clicks was filtered out in the course log file). The analysis of the self-tests also found that for each self-test, there was an average of 6% of students who had more records in their record set than the optimal number of clicks to pass the self-test. Students whose number of clicks was different from the optimal number of clicks scored lower overall compared to other students who took the self-test according to the calculated optimal number of clicks.

The results obtained in research directly helped us to confirm the claim that based on the physiological function of the heart rate, it is possible to identify the change in the emotional state of students. In research, it has been found and proven that heart rate has an impact on students' behaviour in particular activities and on their performance.

Discussion

The utilization of physiological data, such as heart rate, has been demonstrated in prior research to be an efficacious approach to expose implicit emotions (Kreibig, 2010). Consistent with prior investigations, our study employed bracelets equipped with sensors to monitor heart rate as an indicator of physiological function and gauge fluctuations in the emotional state during self-tests and other educational activities.

The veracity of using heart rate as a reliable indicator of emotional arousal has been established by prior literature. For instance, research published in the Journal of Personality and Social Psychology found that heart rate could be used as a dependable measure of emotional arousal across various contexts (Lang et al., 1993). Furthermore, a study published in PLOS ONE found that heart rate could predict changes in emotional valence with moderate accuracy (Sørensen et al., 2018).

Furthermore, the findings align with previous legal precedent recognizing heart rate as a valid form of evidence in certain contexts, including in litigation in the Slovak Republic where heart rate was utilized to indicate changes in emotional state, specifically arousal (Lacko, 2017). This underscores the potential of physiological data to elicit valuable insights into the emotional states of individuals and enhance our comprehension of human behaviour.

The research centred on utilizing sensor networks and physiological data to refine teaching methodologies and augment student engagement. By leveraging this technology to collect data on students' emotional responses, we were able to create a more personalized and effective educational environment. This is in line with prior research that has recognized the potential of using physiological data to discern emotional states in educational settings (Leppink et al., 2017).

https://doi.org/10.33225/BalticSTE/2023.65

It is imperative that we contextualize, confirm, and elucidate our findings by comparing and contrasting our results with those of others. The findings are consistent with previous research that has established the effectiveness of physiological data in assessing emotional responses. However, the research specifically focuses on utilizing physiological data to enhance teaching methodologies and student engagement.

Conclusions and Implications

The data collected makes it possible to conduct research similar to research that has been conducted in the past. The end result of the research was the creation of a tool designed to optimize the teaching process.

During the research, the students wore wristbands during each teaching process, allowing us to compare the values obtained with the activities. The assumption was made that students would be excited during the writing of the self-tests and the final test. It was also set that students would be calm during lectures and activities in which they worked independently. These assumptions were confirmed during the research. In addition, it was found that the change in the students' emotional state affected their grades in the course.

The results from the wristbands confirmed that the physiological function of the heart rate was able to identify changes in the emotional state of the students. The result of the research demonstrated the possibility and the way in which to distinguish differences in student behaviour during different classroom activities and to determine which activities made students more excited and which made them calmer. Research showed that this approach can be used to optimize the learning process and improve learning outcomes.

In the future, the aim is to create a system that can identify changes in the emotional state of students based on the physiological functions obtained in real time and would serve as an aid for the teacher because it would be able to predict in real time how students behave in a particular activity and whether the activity needs to be modified.

The proposed system should serve as an indirect method of suggesting recommendations for educators. Based on the research in this thesis, educators will be able to implement such an alternative into the teaching process. The research conducted indicates that this approach will be helpful in improving and enhancing the teaching process.

Acknowledgements

This work was supported by the Scientific Grant Agency of the Ministry of Education of the Slovak Republic (ME SR) and of Slovak Academy of Sciences (SAS) under the contract No. VEGA 1/0385/23 and also this work is financially supported by OZ DIVAI - Dištančné vzdelávanie v aplikovanej informatike.

Declaration of Interest

The authors declare no competing interest.

References

Bílek, M., & Machková, V. (2016). Projekt Mascil aneb výzvy pro badatelsky orientovanou výuku chemie [Project Mascil or challenges for research-oriented chemistry teaching]. In M, Prokša & A. Drozdíková (Eds.), ScienEdu (pp. 12-16). Prírodovedecká fakulta UK. https://docplayer.net/25112083-Inovacie-a-trendy-v-prirodovednom-vzdelavani-zbornik-prispevkov-bratislava.html

Francisti, J., & Balogh, Z. (2020). Comparison and evaluation functionality of smart bracelets for obtaining physiological states. In M. Turčáni, Z. Balogh, M. Munk, M. Magdin, & Ľ. Benko (Eds.), *13th International scientific conference on distance learning in applied informatics* (pp. 521–533). Wolters Kluwer. https://www.divai.sk/assets/divai2020.pdf

Francisti, J., Balogh, Z., Reichel, J., Magdin, M., Koprda, Š., & Molnár, G. (2020). Application experiences using IoT devices in education. *Applied Sciences*, *10*(20), Article 7286. https://doi.org/10.3390/APP10207286

Horváthová, Z. (2005). Využitie informačno-komunikačných technológií vo vzdelávaní [The use of information and communication technologies in education]. In R. Jandová (Ed.), *Příprava učitelu a akuální proměny v základním vzdělávání: zborník referátov z medzinárodnej konferencie* [Teacher preparation and academic transformations in primary education: Proceedings of an international conference] (pp. 84-86). Jihočeskáuniverzita v Českých Budějovicích.

Krapp, A. (2005). Emotion und Lernen – Beiträge der Pädagogischen Psychologie [Emotion and learning - Contributions of educational psychology]. *Zeitschrift Für Pädagogik [Journal for Pedagogy]*, *51*(5), 603-610. https://doi.org/10.25656/01:4770

Kreibig, S. D. (2010). Autonomic nervous system activity in emotion: A review. *Biological Psychology*, *84*(3), 394-421. https://doi.org/10.1016/j.biopsycho.2010.03.010

Kummerfeld, B., & Kay, J. (2017). User modeling for the Internet of Things. In M. Bielikova (Ed.), *UMAP '17: Proceedings of the 25th Conference on User Modeling, Adaptation and Personalization* (pp. 367-368). Association for Computing Machinery. https://doi.org/10.1145/3079628.3079658

Lacko, D. (2017). Changes in physiological measures as an indicator of emotional state. In *41st International Conference on Telecommunications and Signal Processing (TSP)* (pp. 700-703). IEEE. https://doi.org/10.1109/TSP.2017.8075985

Lang, P. J., Greenwald, M. K., Bradley, M. M., & Hamm, A. O. (1993). Looking at pictures: Affective, facial, visceral, and behavioral reactions. *Psychophysiology*, *30*(3), 261-273. https://doi.org/10.1111/j.1469-8986.1993.tb03352.x

Leppink, J., Pérez-Fuster, P., Segers, M., & Van Gog, T. (2017). The learning effects of computer simulations in science education. *Computers & Education*, *113*, 1-22. https://doi.org/10.1016/j.compedu.2017.05.006

Petlák, E. (2018). Vplyv emócií na edukáciu [The impact of emotions on education]. In E. Rabel (Ed.), *Manažment* školy *v praxi* [School management in practice]. 12(2018), (pp. 2-7). Wolters Kluwer. https://www.direktor.sk/sk/casopis/manazment-skoly-v-praxi/vplyv-emocii-na-edukaciu.m-548.html

Sørensen, J., Andersen, A. B., Yadav, H., & Pedersen, M. B. (2018). Emotion detection from wrist photoplethysmography signal. *PloS One*, *13*(9), Article e0203002. https://doi.org/10.1371/journal.pone.0203002

Wei, W., Mejia, C., & Qi, R. (2021). A personal learning environment (PLE) approach to mobile teaching and learning on a short-term study abroad. *Journal of Hospitality, Leisure, Sport & Tourism Education*, *29*, Article 100296. https://doi.org/10.1016/J.JHLSTE.2020.100296

Received: *April 10, 2023* Accepted: *May 16, 2023*

Cite as: Francisti, J., Balogh, Z., & Turčáni, M. (2023). The use of internet of things technology in the pedagogical process. In V. Lamanauskas (Ed.), *Science and technology education: New developments and Innovations. Proceedings of the 5th International Baltic Symposium on Science and Technology Education (BalticSTE2023)* (pp. 65-75). Scientia Socialis Press. https://doi.org/10.33225/BalticSTE/2023.65

STUDENTS' PERCEPTIONS AND ATTITUDES REGARDING SCIENCE FOLLOWING THE IMPLEMENTATION OF THE "REWILDING" SCIENCE ACTION

Gabriel Gorghiu , **Mihai Bîzoi** , **Laura Monica Gorghiu** ,
Claudia Lavinia Buruleanu
Valahia University of Targoviste, Romania
E-mail: ggorghiu@gmail.com, mihaibizoi@yahoo.com, lgorghiu@gmail.com,
laviniaburuleanu@yahoo.com

Abstract

The performance of any economy is based on scientific knowledge and technological innovation. Consequently, a highly motivated workforce with skills in science and engineering is key to any prosperous economy. Science education has a critical role in providing scientific literacy to students, as well as in training young people to choose careers linked to STEM education. Understanding the science concepts and their application is nowadays challenging for students, due to lack of interest and motivation. "Science is not for me" is, unfortunately, a frequent phrase heard when discussing with young people. It is clear that the way science is taught must be adapted to the student's profile and needs. In this respect, in Romania, the CONNECT project comes to meet this gap by designing and implementing four structured scenarios, embracing the format of Science actions. In order to evaluate the impact of each Science action in terms of students' perceptions and attitudes concerning science, an instrument based on a 5-point Likert scale was developed in the frame of the project partnership. The feedback of 83 students who participated in the Rewilding Science action was collected, being emphasized that students are feeling more confident to solve problems in science and consider that learning science is enjoyable, even learning science is not easy. Although the majority of the respondents would like to do projects with others using science to improve the world, they - in the same ratio - would not like to be seen as experts in science.
Keywords: *science education, Rewilding Science Action, students' perceptions and attitudes, CONNECT project*

Introduction

Nowadays science education needs to adapt and accommodate a variety of changes (Höttecke & Allchin, 2020), developing a real culture for scientific literacy which should be its main objective (Cofré et al., 2015). However, finding ways to improve and optimize learning can be challenging (Moro et al., 2021).

In that sense, a lot of attention was paid in recent years to STEM education (Takeuchi et al., 2020), mainly due to the lack of interest manifested by primary and secondary school students (van Griethuijsen et al., 2015). More, measuring the students' interest in

https://doi.org/10.33225/BalticSTE/2023.76

science became compulsory, through adopting existing instruments or developing new ones (Taber, 2018). For example, by integrating a new approach into the core curriculum, the CONNECT project tries to gather students and scientists together for solving real problems. In this respect, the CONNECT project's goal is to create an inclusive and sustainable model that may facilitate the adoption of open schooling by a large number of secondary schools, through implementing science-action gamification projects in the core curriculum (CONNECT, 2022). The teaching/learning materials developed in the frame of the project are based on the *Care-Know-Do* model, an innovative one, adapted for each topic proposed by each project partner. In this respect, two types of scientific actions are available for teachers/schools: structured scenarios and open scenarios. Starting from the idea that nature is our source of life, being essential for a good quality of life, among the project resources, the *Rewilding* Science action is proposed as one of the fourth structured scenarios. To sustain that, it was stated that troubling nature has profound implications for education (Sitka-Sage et al., 2017). The outdoor learning movement is rapidly growing, with parents and schools having the mission to reconnect a generation of children with nature (Bates, 2020).

From its initial emphasis on protecting large, connected areas for carnivore conservation, rewilding is nowadays met into a diversity of concepts, and specific actions assisting the restoration of self-sustaining, resilient ecosystems. In Europe, rewilding actions are focused on reaching the EU's environmental ambitions, with the EU Biodiversity Strategy for 2030 and the EU Green Deal being the most recent.

The current rewilding success is linked to public enthusiasm (Genes et al., 2019) and to the understanding of the context of rewilding projects (Carver et al., 2021). Support from the general public and also the involvement of private landowners are considered, in the context of constructing a sustainable, balanced landscape, crucial for the long-term maintenance of benefits (García-Ruiz et al., 2020).

The UN Decade on Ecosystem Restoration aiming to prevent, stop and reverse the degradation of ecosystems is a suitable context in which the rewilding topics can be brought, by policy- and decision-makers, to the forefront of discussions about how to reach post-2020 biodiversity goals. By implementing rewilding activities, the UN Sustainable Development Goals Life on land and Partnerships for the goals are accomplished.

Research Problem

In the face of economic, environmental, and social challenges, education is more critical today (National Research Council, 2012). Recent studies underline that in Western European countries the primary and secondary school students' interest in science and technology is low and seems to be decreasing (van Griethuijsen et al., 2015; Nugent et al., 2015). A trained workforce is compulsory for the economic growth and development of any country. STEM education has an overwhelming contribution in training skilled professionals able to contribute to society's welfare, so making science education more appealing for students of this new generation is more and more important.

This research was necessary to understand the Romanian students' perceptions and attitudes regarding science education. From this starting point, the teachers and various stakeholders will be able to punctually fill the needs of young people in order to learn STEM content, to acquire skills and knowledge for careers based on science education.

https://doi.org/10.33225/BalticSTE/2023.76

The *Rewilding* Science action was designed considering that whether the teacher/learning activities take the format of the *Care-Know-Do* model, the students' engagement and participation in all the steps of the proposed activities will increase. Thus, the science action was structured according to the four steps scenario: (a) *Care* (getting involved in the issue); (b) *Know 1* (applying the scientific ideas); (c) *Know 2* (learning how to conduct an investigation); (d) *Do* (creating an output for public/community). The context of the *Rewilding* Science action was chosen in the way of being linked with real life, by including a problem to solve, fitting also parts of the science curriculum, and providing interest for students aged 7-14.

The learning objectives, following the above-mentioned steps are:

- understanding the scientific context (*Care*);
- applying feeding relationships in a new context (*Know 1*);
- learning the skills to "analyse evidence to support a claim" (*Know 2*);
- coordinating scientific knowledge and skills in a performance assessment (*Do*).

Research Focus

The research was focused on the students' perceptions and attitudes acquired at the end of the *Rewilding* Science action implementation. In this respect, it was analysed mainly in what measure the students' statement "science is not for me" remained alive after they participated in the activities proposed in the frame of the *Rewilding* module.

Research Aim and Research Questions

This research aimed to evaluate the students' perceptions and attitudes related to the implementation of the *Rewilding* Science Action - an original model to sustain and promote science education.

Today's world needs young people who can think in scientific terms in their everyday lives, but also aspire to a career in science. However, according to recent research results, the students consider that the study of science is difficult and not necessary/suitable for them.

The research premise started from the idea that students lacked the so-called "science capital", which refers to their scientific knowledge, attitudes, skills, and experiences. Some key factors which influence the students' aspirations to see themselves in the position of future scientists were identified, such as lower familiarity with the science area, lack of the models to be followed, and also restricted employment opportunities having a scientific background.

At the end of the implementation process of the *Rewilding* Science Action, the research questions were oriented on: (a) how confident are the students with science?; (b) how do the students feel about science? In this respect, it was interesting to measure the students' perceptions and attitudes concerning science, considering how science is taught and learned in the Romanian school today.

https://doi.org/10.33225/BalticSTE/2023.76

Research Methodology

General Background

A solution to the issues referring to the development of the scientific capital is to change the way students learn Science and make Science Education more accessible and attractive to students, exploiting a range of opportunities and starting from the curriculum, by motivation, engagement, and impact. Motivation means learning Science through scientific methods. The engagement refers to the student's interaction with scientists, to involve students' families in a participatory process that promotes the Sciences and also to stimulate a common interest in the Sciences within families, but also for future careers in Sciences. The impact of the Science actions of the CONNECT project refers to students' contribution to solving the community challenges and being aware of the impact of Science in the world. Moreover, the promotion of the concept of "open schooling" contributes overwhelmingly to the promotion of the Sciences.

The Science actions are learning activities that make Science more relevant to students, showing them how scientific research and innovation can change their lives and how they can use Science to make a positive impact as young researchers. The Science actions offered by the CONNECT project are intended to complement the existing units, in line with a range of topics from the school curriculum, being easy for teachers to use them.

In the frame of the CONNECT project, the Science Action *Rewilding* prepares students to plan a campaign in order to convince the local community to reintroduce an animal to its former habitat. The Science Action *Rewilding* is designed to integrate different activities, which can be adapted to existing science lessons.

Rewilding Romania aroused the students from middle school interest, benefiting from the support of students' teachers and families, respectively STEM specialists.

Sample

During the second semester of the 2021-2022 school year, 1182 secondary school students from 7 Romanian counties participated in the implementation process of the CONNECT project science actions, and most of them answered a specific questionnaire concerning their perception related to science. From all the filled questionnaires, 83 accurate feedbacks referred to the implementation of the *Rewilding* Science action. The number is relatively small considering that other Science actions (oriented on *Plastic Biodegradation*, *Carbon Footprint* and *Green Energy*) were selected as appropriate by science teachers, being adopted in conjunction with the Romanian secondary school curricula, but also with the planning of the school-year activities in the second semester. The gender distribution of the sample was almost equal: 43 female students and 40 male students.

Instrument and Procedures

The CONNECT Project evaluation team created an instrument for collecting the students' feedback, introducing most of the questions with possible answers based on a

5-point Likert scale (*Totally disagree - Disagree - Neither disagree nor agree - Agree - Totally Agree*).

Data Analysis

Data analysis was made by exploiting the Microsoft Excel facilities, by examining the students' answers distribution related to each category of questions. For the present research, the considered sets of data were focused on the students' perceptions and attitudes regarding their feeling and trustful in science.

Research Results

The analysis of the students' feedback concerning the implementation of the *Rewilding* Science Action takes into account this CONNECT project resource as used by teachers within the topic of the interdependence between species, taught mainly during Biology lessons. It includes 4 different steps that can be used in the frame of the existing science lessons, presented in brief in Table 1.

Table 1
Description of the Implementation Steps of the Rewilding Science Action - Rewild Romania

Activity	Learning objective	Student's activities	Involvement
CARE: The challenge Rewild Romania	Care about the issue Understand the scientific context	Learn about each animal. They vote for one.	Teacher STEM professional Family
KNOW 1: Bisons	Apply feeding relationships to a new context	Explore a case study about bisons' rewilding in the Făgăraș mountains. Complete a similar problem independently.	Teacher
KNOW 2: Beavers	Learn the skill "weight evidence to support a claim"	Consider the claim that rewilded beavers are good for the environment. Persuade others that beavers should return to the Danube Delta.	Teacher STEM professional
DO: Campaign	Coordinate scientific knowledge and skill in a performance assessment	Plan and deliver a campaign to persuade an audience that an animal should be rewilded.	Teacher Specialist STEM Family

The general picture of the data obtained based on the students' responses to the questionnaire is provided in Table 2.

Table 2
Students' Feedback on the Perception and Attitudes Concerning Science Collected After the Implementation of the Rewilding Science Action - Rewild Romania (n=83)

Items	Totally disagree	Disagree	Neither disagree nor agree	Agree	Totally Agree
Feeling confident talking about science	1	6	20	35	21
Feeling confident doing science projects with other people (with other colleagues)	1	2	15	27	38
Using science to come up with questions and ideas	1	3	16	43	20
Feeling confident to solve problems in science	2	4	11	33	33
Feeling confident about personal knowledge in science to learn new topics	1	2	10	50	20
Knowing how to justify personal views using arguments and evidence	1	1	4	40	37
Learning science is enjoyable	0	1	9	41	32
Learning science is easy	4	11	39	19	10
Considering that science activities are fun	0	0	11	53	19
Willing to do projects with others using science to improve the world	0	1	5	42	35
Willing to be seen as an expert in science	2	5	32	23	21
Willing to have a job involving science	0	12	46	12	13

The first research question was how confident the Romanian students were with science, a general picture of answers to this question is provided by the first six items mentioned in Table 1.

According to the students' feedback, being asked how confident they were talking about science and doing science projects, a significant number of students (20, respectively 15, corresponding to 28% and 18% respectively from the total of respondents) kept a neutral position (neither disagree nor agree) in relationship with the above-mentioned topics assessed. 56 students out of a total of 83 *totally agree* and *agree* feeling confident talking about science. Although only 25% of students are feeling confident talking about science, almost 46% are feeling confident doing science projects with other people (with other colleagues).

It is important to notice that more than half of the respondents, students who participated in the *Rewilding* Science action, agreed that they used science to come up with questions and ideas and an equal number of students (33, representing almost 40% of the total of the respondents) *agreed* and *totally agreed* to feel confident to solve problems in science.

https://doi.org/10.33225/BalticSTE/2023.76

Personal knowledge in science - which makes students able to learn new topics - represented another topic in discussion. 50 students out of the total of 83 respondents answered that they were feeling confident with this issue, while a per cent by 24% *totally agreed* with this statement. Relatively surprising - having in view the complexity and the challenge of the topic -, except for 6 students, the others *agreed* and *totally agreed* regarding how to justify personal views using arguments and evidence.

The second research item was oriented on how the students felt about science.

Learning science seems to be enjoyable for a large majority of the students (88%) participating in this research, suggesting that their teachers have the facilities needed to make the activities attractive. However, learning science seems to not be ready to hand, almost half of the respondents *neither disagreed nor agreed* with the statement "learning science is easy". On the other hand, science activities are considered "fun" by 87% of students, and 93% of the respondents would like to do projects with others using science "to improve the world".

If the next two items are analysed in the context of the aim of the research, a consistent number of students (32 from a total of 83) remained neutral (*neither disagreed nor agreed*) within the perspective to be seen as experts in science. Only 25 respondents stated that they would like a job that involved science.

Discussion

As the *Rewilding* Science Action can easily be adapted for nowadays students, their feedback following its implementation was probably correlated with the teachers' involvement in the scenario, an aspect that remains to be analysed in future research, especially taking into account the need to know the teachers' understanding of the integration of science practices with science content (Bismack et al., 2022).

The students from the target group are feeling confident doing science projects with other people - the DO stage (create a *Rewilding* campaign) means that a group of students collect evidence for claims, plan the presentation and present it. Thus, the students collect evidence for the claims (the animal can survive in Romania; people want it to be rewilded; the animal has a positive effect on the food network, and it has other benefits), and in this way, students become confident talking about science.

Epistemic beliefs play a role in forming the students' interest in science (Jaber & Hammer, 2016). The students participating in Rewilding activities are feeling generally confident talking about science, although there are a significant number of respondents without a clear perception of that. Because the third part of the interviewed students is not feeling confident talking about science, it is obvious that teachers and stakeholders should create opportunities for students to formulate questions and ideas, to encourage them to discuss and explain natural phenomena. The teachers should cultivate the students' confidence in oral communication, and they should understand what students say and do, and also contribute actively to deepening the students' reasoning. In the frame of the CONNECT project activities, *Rewilding* is configured by science and traditional ecological knowledge (TEK), the last one providing a complementary body of knowledge to science. It should be noticed that the secondary school students were actively involved in discussions about endangered animals in Romania, they argued about the food chain and the importance of the return of a particular animal in terms of ecosystem restoration. Thus, Rewilding - as transformative change - proved to offer a motivation for students' engagement in science education, using science to come up with questions and ideas. Learning about each animal (during the CARE stage), in order to understand the scientific context that sustains the enlargement of the students' basis of ideas, different algorithms of thinking are consolidated with possibilities to be extrapolated in other areas of science. The home task is fun, with structured discussions where the family is involved by talking about the different animals who are candidates for rewilding, and finally, voting for their favourite.

Inquiry and investigation, production of ideas and solutions, and application of knowledge to new problems support scholars in learning sciences (National Research Council, 2012; Darling-Hammond et al., 2020). Students answered that they were feeling confident to solve problems in science**,** and the KNOW 2 stage sustains their responses. Thus, the students learn the skill of "weight evidence to support a claim". In this stage, the teacher clarifies the need for the new skill and where it fits, models the thinking process, offering coaching/support for students, but finally, the students make their decision. During the assessment, several pieces of relevant evidence plus full reasoning that connects the evidence to the claim are highly noted.

The productive instructional strategies constitute one of the four areas of science of learning and development (SoLD) (Darling-Hammond et al., 2020). Meaningful work that builds on students' prior knowledge and engages them in rich, engaging tasks was identified as a part of the productive instructional strategies. The students enrolled in the CONNECT project and were feeling generally confident about personal knowledge in science to learn new topics, and only 3 respondents out of 83 *totally disagreed* or *disagreed* with this statement. This feature contributes to the KNOW 1 stage, the learning objective being oriented on applying feeding relationships to a new context. After exploring a case study about bison rewilding in Făgăraș mountains, the students completed a similar problem independently.

The science includes not only concepts and facts but also scientific ways of thinking and reasoning (McNeill, 2011). Well-designed collaborative learning opportunities were identified as another part of the productive instructional strategies. Those encourage students to explain and elaborate their thoughts and co-construct solutions (Darling-Hammond et al., 2020). In the frame of the CONNECT project, out of 83 respondents, 77 students considered that they knew how to justify personal views using arguments and evidence**.** The *Open Schooling* pillar enables schools to create a flexible learning environment, inspiring students to explore the world through science. More than that, during the KNOW stages the students acquire knowledge and skills specific to Science. The students materialize their knowledge and skills in participatory scientific actions, including the evaluation process (DO stage).

Looking toward the future of education in the 21st century, a robust STEM curriculum is unquestionably required (Bidarra & Rusman, 2017). This is achievable by fostering students' curiosity, developing hands-on activities, and making activities more enjoyable. Strong positive correlations between STEM dimensions and STEM knowledge and science enjoyment respectively were established (Falk et al., 2016). For learning science, it was attributed the term "enjoyable" by a consistent majority of students (Table 2)**.** This can be explained through the design of the *Rewilding* activities in a non-formal framework. Some distinct periods of the Romanian school year, such as

https://doi.org/10.33225/BalticSTE/2023.76

"School in a different way" and "The green week" were considered suitable by teachers to unfold the specific activities of the CONNECT project. The interaction with scientists at their working places, visiting the bisonniere, and specific activities in virgin forests, such as the study of fauna and flora are certainly enjoyable. Fostering children's curiosity and enjoyment is facilitated by innovative and imaginative approaches to learning in natural environments (Prince, 2022). This one is possible by following a nature-led, human-enabled approach, the role of the teacher being determinant.

Generally, ''authentic'' science opportunities are valued by teachers who successfully taught outside. The teachers who were less successful in teaching outside valued the outdoors for the potential for fun (Glackin, 2016). However, both science opportunities and fun activities can be achieved in the frame of *Rewilding* Science Action. The fun tasks to apply scientific ideas, the inclusive strategies for students' skill development, and the support from a scientist make learning science easy and Science activities fun (Table 1). In the above-mentioned context, there are more opportunities for students to undertake extra research. In the frame of the CONNECT project activities, there are opportunities for students to consider the viewpoints of various stakeholders, such as researchers, farmers, and businesses.

Improving the world by doing projects with others using science seems to be a concern of the students. Why can the *Rewilding* Science Action lead to this approach? According to Loynes (2022), "wild" experiences can contribute to a change in human-nature relations and can promote pro-environmental values and behaviours. The students understand better the role of wild animals within the food webs, the contributions of ecosystems to human well-being, and the potential of rewilding to diminish the undesirable effects of extreme climate on biodiversity (Thakur et al., 2020).

Increasing the diversity of individuals who choose science careers is supported, in recent years, by a growing interest in improving science education (Stockwell et al., 2015). The professional models of the scientists encourage and sustain the students' statement "I would like to be seen as an expert in science" (Table 2). However, a significant number of respondents are not fully convinced that working in science is attractive. This indecisiveness could be due to the relatively limited time spent by students in the frame of *Rewilding* activities to incline the balance towards an agreement with the statement of the question in the discussion.

Middle school years are considered a critical developmental stage in terms of students' interests in STEM, respectively their likelihood of entering into STEM careers can be increased (Jiang et al., 2021). As it was mentioned previously, nowadays working areas require young people intending to get a career in science. According to recent research, too many students believe that "science is not for me", and that situation is hard to change. According to data from Table 2**,** only 25 out of 83 students agreed with the statement "I would like a job that uses science", although *Rewilding* provides an easy-to-use and effective approach for involving a scientist that gives students insight into STEM careers and makes this issue more real. Consequently, a lot of efforts should be continuously made, by all the parties involved in school education, in order to determine a desirable change in this approach by students, starting from the early education stage.

https://doi.org/10.33225/BalticSTE/2023.76

Conclusions and Implications

This study has surveyed how the *Rewilding* Science action - proposed in the frame of the CONNECT project - brought students closer to the sciences. The action - developed as an open schooling approach - tries to encourage and support the cooperation between schools with scientists and local communities, in order to help young people to acquire skills to solve real problems. In this sense, monitoring the students' feedback immediately after the action implementation becomes essential to provide evidence of the results and also to determine whether improvements should be considered in terms of bringing more students near science and its actual challenges.

This research provides empirical evidence referring to students' perceptions and attitudes after the implementation of STEM-related experiences in the format of meaningful and enjoyable activities, integrated within the curriculum in a great measure.

Nature and the way we take care of it represent the foundation on which we can build a better life in Romanian ecosystems. By understanding how rewilding activities affect nature, students make important steps to be aware that science learning could offer solid scientific knowledge, but also premises for successful STEM careers.

Acknowledgements

This work was funded through the Project "*CONNECT - Inclusive open schooling through engaging and future-oriented science*", in the frame of the HORIZON 2020 - EU.5.d. Programme - "Encourage citizens to engage in science through formal and informal science education, and promote the diffusion of science-based activities, namely in science centres and through other appropriate channels", Topic: "SwafS-01-2018-2019-2020 - Open schooling and collaboration on science education", Grant agreement ID: 872814.

Declaration of Interest

The authors declare no competing interest.

References

Bates, C. (2020). Rewilding education? Exploring an imagined and experienced outdoor learning space. *Children's Geographies*, *18*(3), 364-374. https://doi.org/10.1080/14733285.2019.1673880

Bidarra, J., & Rusman, E. (2017) Towards a pedagogical model for science education: Bridging educational contexts through a blended learning approach. *Open Learning: The Journal of Open, Distance and e-Learning*, *32*(1), 6-20. https://doi.org/10.1080/02680513.2016.1265442

Bismack, A., Davis, E. A., & Palincsar, A. S. (2022). Science practice-readiness: Novice elementary teachers' developing knowledge of science practices. *Science Education*, *106*(2), 364-384. https://doi.org/10.1002/sce.21698

Carver, S., Convery, I., Hawkins, S., Beyers, R., Eagle, A., Kun, Z., Van Maanen, E., Cao, Y., Fisher, M., Edwards, S.R., Nelson, C., Gann, G.D., Shurter, S., Aguilar, K., Andrade, A., Ripple, W.J., Davis, J., Sinclair, A., Bekoff, M., Noss, R., Foreman, D., Pettersson, H., Root-Bernstein, M., Svenning, J.C., Taylor, P., Wynne-Jones, S., Featherstone, A.W., Fløjgaard, C., Stanley-Price, M., Navarro, L.M., Aykroyd, T., Parfitt, A., & Soulé, M. (2021). Guiding principles for rewilding. *Conservation Biology*, *35*, 1882-1893. https://doi.org/10.1111/cobi.13730

Cofré, H., González-Weil, C., Vergara, C., Santibanez, D., Ahumada, G., Furman, M., Podesta, M. E., Camacho, J., Gallego, R., & Perez, R. (2015). Science teacher education in South America: The case of Argentina, Colombia and Chile. *Journal of Science Teacher Education*, *26*, 45-63 https://doi.org/10.1007/s10972-015-9420-9

CONNECT (2023). *Inclusive open schooling through engaging and future-oriented science*. https://www.connect-science.net/about-the-project/

Darling-Hammond, L., Flook, L., Cook-Harvey, C., Barron, B., & Osher, D. (2020). Implications for educational practice of the science of learning and development. *Applied Developmental Science, 24*(2), 97-140. https://doi.org/10.1080/10888691.2018.1537791

Falk, J. H., Staus, N. L., Dierking, L. D., Penuel, W. R., Wyld, J., & Bailey, D. (2016). Understanding youth STEM interest pathways within a single community: the Synergies project. *International Journal of Science Education*, *Part B*, *6*, 369-384. https://doi.org/10.1080/21548455.2015.1093670

García-Ruiz, J. M., Lasanta, T., Nadal-Romero, E., Lana-Renault, N., & Álvarez-Farizo, B. (2020). Rewilding and restoring cultural landscapes in Mediterranean mountains: Opportunities and challenges, *Land Use Policy*, *99*, 104850, https://doi.org/10.1016/j.landusepol.2020.104850

Genes, L., Svenning, J. -C., Pires, A. S., & Fernandez, F. A. S. (2019). Why we should let rewilding be wild and biodiverse. *Biodiversity and Conservation*, *28*, 1285-1289. https://doi.org/10.1007/s10531-019-01707-w

Glackin, M. (2016). 'Risky fun' or 'Authentic science'? How teachers' beliefs influence their practice during a professional development programme on outdoor learning. *International Journal of Science Education*, *38*(3), 409-433. https://doi.org/10.1080/09500693.2016.1145368

Höttecke, D., & Allchin, D. (2020). Reconceptualizing nature-of-science education in the age of social media. *Science Education*, *104*, 641-666. https://doi.org/10.1002/sce.21575

Jaber, L. & Hammer, D. (2016). Engaging in science: A feeling for the discipline. *Journal of the Learning Sciences*, *25*(2), 156-202. https://doi.org/10.1080/10508406.2015.1088441

Jiang, Y., Popov, V., Li, Y., Myers, P. L., Dalrymple, O., & Spencer, J. A. (2021). "It's like i'm really there": Using VR experiences for STEM career development. *Journal of Science Education and Technology*, *30*(6), 877-888. https://doi.org/10.1007/s10956-021-09926-z

Loynes, C. (2022). Wild adventure. A restorying. In S. Hawkins, I. Convery, S. Carver, & R. Beyers (Eds.), *Routledge handbook of rewilding* (1st ed.). Routledge. https://doi.org/10.4324/9781003097822

McNeill, K. L. (2011). Elementary students' views of explanation, argumentation, and evidence, and their abilities to construct arguments over the school year. *Journal of Research in Science Teaching*, *48*(7), 793-823. https://doi.org/10.1002/tea.20430

Moro, C., Phelps, C., Redmond, P., & Stromberga, Z. (2021). HoloLens and mobile augmented reality in medical and health science education: A randomised controlled trial. *British Journal of Educational Technology*, *52*(2), 680-694. https://doi.org/10.1111/bjet.13049

National Research Council. (2012). Education for life and work: Developing transferable knowledge and skills in the 21st century. Committee on defining deeper learning and 21st century skills. J. W. Pellegrino & M. L. Hilton (Eds.), *Board on testing and assessment and board on science education, division of behavioral and social sciences and education*. The National Academies Press.

Nugent, G., Barker, B., Welch, G., Grandgenett, N., Wu, C. R., & Nelson, C. (2015). A model of factors contributing to STEM learning and career orientation. *International Journal of Science Education*, *37*(7), 1067-1088. https://doi.org/10.1080/09500693.2015.1017863

Prince, H. (2022). Rewilding children and young people. The role of education and schools. In S. Hawkins, I. Convery, S. Carver, & R. Beyers (Eds.), *Routledge handbook of rewilding* (1st ed.). Routledge. https://doi.org/10.4324/9781003097822

Sitka-Sage, M. D., Kopnina, H., Blenkinsop, S., & Piersol, L. (2017). Rewilding Education in Troubling Times; or, Getting Back to the Wrong Post-Nature. *Visions for Sustainability*, *8*, 20-37. https://doi.org/10.13135/2384-8677/2334

Stockwell, B. R., Stockwell, M. S., Cennamo, M., & Jiang, E. (2015). Blended learning improves science education. *Cell*, *162*(5), 933-936. https://doi.org/10.1016/j.cell.2015.08.009

Taber, K. S. (2018). The use of Cronbach's Alpha when developing and reporting research instruments in Science Education. *Research in Science Education*, *48*, 1273-1296. https://doi.org/10.1007/s11165-016-9602-2

Takeuchi, M. A., Sengupta, P., Shanahan, M. -C., Adams, J. D., & Hachem, M. (2020). Transdisciplinarity in STEM education: A critical review. *Studies in Science Education*, *56*(2), 213-253. https://doi.org/10.1080/03057267.2020.1755802

Thakur, M. P., Bakker, E. S., (Ciska) Veen, G. F., & Harvey, J. A. (2020). Climate extremes, rewilding, and the role of microhabitats. *One Earth*, *2*(6), 506-509. https://doi.org/10.1016/j.oneear.2020.05.010

van Griethuijsen, R. A. L. F., van Eijck, M. W., Haste, H., den Brok, P. J., Skinner, N. C., Mansour, N., Gencer, A. S., & BouJaoude, S. (2015). Global patterns in students' views of science and interest in science. *Research in Science Education*, *45*, 581-603. https://doi.org/10.1007/s11165-014-9438-6

Received: *April 12, 2023* Accepted: *May 14, 2023*

Cite as: Gorghiu, G., Bizoi, M., Gorghiu, L. M., & Buruleanu, C. L. (2023). Students' perceptions and attitudes regarding science following the implementation of the "Rewilding" science action. In V. Lamanauskas (Ed.), *Science and technology education: New developments and Innovations. Proceedings of the 5th International Baltic Symposium on Science and Technology Education (BalticSTE2023)* (pp. 76-87). Scientia Socialis Press. https://doi.org/10.33225/BalticSTE/2023.76

DIFFERENCES IN GRAPHIC ILLUSTRATIONS IN THE CONTENTS OF NATURAL SCIENCES IN REGULAR TEXTBOOKS AND TEXTBOOKS FOR STUDENTS WITH SPECIAL EDUCATIONAL NEEDS IN THE REPUBLIC OF SERBIA

Saša A. Horvat , Tamara N. Rončević ,
Ivana Z. Bogdanović, Dušica D. Rodić
University of Novi Sad, Republic of Serbia
E-mail: sasa.horvat@dh.uns.ac.rs, tamara.hrin@dh.uns.ac.rs, ivana.bogdanovic@df.uns.ac.rs, dusica.milenkovic@dh.uns.ac.rs

Abstract

The most important source of knowledge in primary school teaching is the textbook. This research aimed to determine the differences in graphic illustrations in the contents of natural sciences in a regular textbook and a textbook for children with special educational needs in the Republic of Serbia. As the number of subjects that deal with the contents of natural sciences for children with special educational needs is small, as well as the number of schools that implement this type of teaching, physics is taken as a subject, because the number of common topics is quite similar. The research aim was to analyze illustrations in selected physics textbooks for the 6th grade of primary education, by the criteria for dividing illustrations by types, for determining abstractness and relative representation of illustrations. In addition, a supplementary classification of illustrations was applied. The obtained results indicate that the number of illustrations concerning the number of words is higher in textbooks for children with special educational needs, as well as that the most represented are illustrations from everyday life and greater abstraction compared to regular textbooks. Since the physics textbook for children with disabilities is quite old, these results can be examined in practice among teachers and help future textbook authors to write the best quality textbook taking into account the needs of teachers and children with special educational needs.
Keywords: *image analysis, teaching physics, type of illustrations, special educational needs*

Introduction

Working with children with special needs is challenging. These children require more attention, and a special approach to each child individually. Modern teaching began slowly with the inclusion of children with special needs in the regular school system in the hope that this will bring benefits to these children to be better accepted in modern society. The process of acquiring knowledge, building skills and habits,

https://doi.org/10.33225/BalticSTE/2023.88

developing abilities, and adopting value systems and behaviors describe the concept of education (Gvozdenović, 2011). In 1994, in The Declaration of the Rights of the Child, the United Nations emphasized the importance of including children with disabilities in regular education to reduce discrimination and emphasize the equality of all children regardless of socioeconomic status, intellectual disability or other forms of disability. In 2009, inclusive education was introduced in Serbia for the first time with the adoption of the law on the basics of the education system, without discrimination and separation of those from marginalized and vulnerable social groups, as well as those with disabilities (Karić et al., 2014). A set of 54 textbooks for inclusive education was introduced at all levels of study, on which 360 experts worked for four years. The set also includes manuals for teachers, which consist of special education and work. Teachers can change and duplicate assignments, and assignments are also available on CD.

To facilitate and support a child's learning and progress, it is necessary to adjust the strategy used by the teacher. This also helps the other children in the group, who do not have learning difficulties, to master the material faster and easier. An individual educational plan (IEP) is a written document that plans to support the education and upbringing of a child with developmental disabilities. However, if the specificity of students is not known and respected and different ways, forms, and means of learning are not applied, then the IEP will not bring success either. Even the IEP as a document will become something that everyone is afraid of, and that is that everything will be reduced to filling out additional documentation and will require special individual work with the child, which again represents a burden in addition to working with other children in the class. The IEP should be used for planning and monitoring the progress of children, to support their individuality and diversity. Instead of lectures and teaching units, the focus becomes learning and progress. The goal of education is not only the adoption of materials but also preparation for life and work (Janjić et al., 2012).

Research Problem

The most important source of knowledge for students, in addition to teachers' lectures, is the textbook. During school, students are offered several textbooks that help them acquire important competencies, such as how to solve problems more easily or how to learn more efficiently. We can say that students are the most competent when choosing appropriate textbooks. Today, students learn and acquire knowledge with the help of various media and with different teaching strategies. Different didactic theories and pedagogical concepts are applied in practice. In some of them, the role of the textbook is glorified, and it represents the main source of knowledge, while in others the use in teaching is neglected or completely avoided. As information technology advances more and more, progress is visible in the graphic and visual preparation of textual teaching media, so that with their attractiveness and functionality they can attract the attention of new generations of students, which we call the Z-generation (Matijević et al., 2013).

Students' interest is far greater in learning by using illustrated material. It reduces fatigue, trains the imagination and simplifies the learning process. It is also very important to note that the use of visual teaching methods is closely related to verbal and practical techniques. Dimopoulos et al. (2003) classified the illustrations in the textbooks according to the type as realistic illustrations; conventional illustrations and hybrid illustrations.

https://doi.org/10.33225/BalticSTE/2023.88

Representation of reality using photographs and drawings as it is natural to human optical perception is called realistic illustrations. It is much easier for students to understand certain concepts when they are presented in forms from everyday life. Visual representations such as graphs, diagrams, symbols and molecular structures represent reality in a transferred symbolic meaning. All these visual representations fall under the notion of conventional illustrations. They are very important for scientific writing and are constructed according to scientific and technological conventions. They contain and connect scientific concepts and large amounts of abstract data in a very efficient way. Visual representations that contain elements of both realistic and conventional illustrations are hybrid illustrations. Most often, these are conventional schematic representations enriched with realistic elements. In this way, it is easier for students to interpret conventional illustrations, which are also the most difficult to understand, supplementing them with natural real elements (Dimopolous et al., 2003).

The illustration emphasizes a certain property of the content of the material and in that way makes the knowledge more complete, more lasting, more interesting, stimulating and more efficient. If after reading a text we do not look at the illustration on the next page, it is very possible that the text will not be very clear to us. When we have a scheme in front of us, we can arrange the details and meaning of the read text. Those who have a scheme or illustration in advance remember and understand the content of the text better because the scheme provides a general expectation of possible scenarios and reduces the number of potential meanings of words and sentences in the text. A scheme or illustration is an understandable representation of a material (Chatman & Sparrow, 2011). Souza and Porto (2012) classified illustrations in textbooks into nine subcategories. This classification is based on the contents shown in the illustrations:

- laboratory equipment and experiments,
- industrial plants and production,
- graphs and diagrams,
- models,
- analogies,
- illustrations from everyday life,
- illustrations of mineral, plant and animal samples,
- illustrations relating to the history of science and,
- concepts of natural sciences.

It is very important to prepare good illustrations that present the topic, in order to make it easier to understand some of the examples related to that topic. The student then actively learns how to observe phenomena and recognize the conditions that determine whether the desired change or result will occur.

Research Focus

The correct didactic design of natural science textbooks is of great importance for the education of students and their complete development. The contents of the classes should enable students, according to their intellectual capabilities, to acquire a certain body of knowledge necessary for further learning and improvement. The research problem is to what extent the selected textbooks meet the standards. The textbook must have as many examples as possible, with the help of which general phenomena are explained, to meet the quality standards related to the didactic design of textbooks (Gajtanović & Vait, 2015).

Research Aim and Research Questions

The main aim of this research was the qualification of illustrations according to the content as well as the differences in graphic illustrations in the context of natural sciences in the selected Physics textbook for the 6th grade of elementary school and the Physics textbook for children with developmental disabilities. Differences in graphic illustrations in selected physics textbooks were analyzed using the method of Dimopoulos et al. (2003), and the classification of types of illustrations based on image content, according to Souza and Porto (2012).

The specific objectives of the research are as follows:

1) Analysis of the relative representation of illustrations in selected textbooks,
2) Classification of illustrations according to the type of illustrations and according to the content of the image,
3) Determining the degree of abstractness of illustrations in selected textbooks using different markers

Research Methodology

General Background

Two Physics textbooks that are used in primary education in the Republic of Serbia were selected for the analysis of the illustrations. The selected textbook used by children without developmental disabilities is Čaluković, N. (2013): Physics for the 6th grade of primary school, Krug, Belgrade (*Regular textbook* in future text) and the textbook for children with developmental disabilities by Pejnović, B. (1995): Physics for the 6th Grade of primary school, Institute for textbooks and teaching aids, Belgrade (in future text *Special textbook*). The research was conducted during the summer semester of the academic year 2021-2022.

Instrument and Procedures

The analysis of the illustrations was performed using the method developed by Dimopoulos et al. (2003) and by Souza and Porto (2012). Physics is the only textbook with natural science content that is adapted for children with developmental disabilities. The degree of abstractness of the illustrations in the selected textbooks was determined using different markers that include maximum (high), moderate and minimal (low) abstractness (Dimopoulos et al., 2003). Illustrations with low abstractness are characterized by a numerical value of the index of abstraction from 0 to 1, with moderate from 1 to 2 and with high abstractness from 2 to 3 (Dimopoulos et al., 2003).

https://doi.org/10.33225/BalticSTE/2023.88

Data Analysis

First, the relative representation of illustrations in selected Physics textbooks was analyzed, which is seen as the number of illustrations per 1000 words. Then the illustrations were analyzed according to the type of illustrations (realistic, conventional and hybrid) and according to the content of the image. To determine the degree of abstraction of each image, the following formula was used: the average value of the marker, whether there is a numerical symbol or a geometric shape in the image; color palette, which refers to the appearance of color in the illustration, and contextualization, which shows what the background of the image is. The collected data were analyzed using Microsoft Office Excel software programs.

Research Results

Analysis of the Relative Representation of Illustrations

The relative representation of illustrations of the content of natural sciences was observed in selected *Physics textbooks for the sixth grade* and was viewed as the number of illustrations per 1000 words. A comparison was made on the following topics covered in textbooks that are common in both textbooks:

1. Introduction to Physics
2. Physical quantities
3. Force
4. Motion

In addition to these common topics, topics that differ in these two textbooks, namely *Mass, density and pressure* represented in the Regular textbook as well as the topic of *Substance structure* represented in the Special textbook.

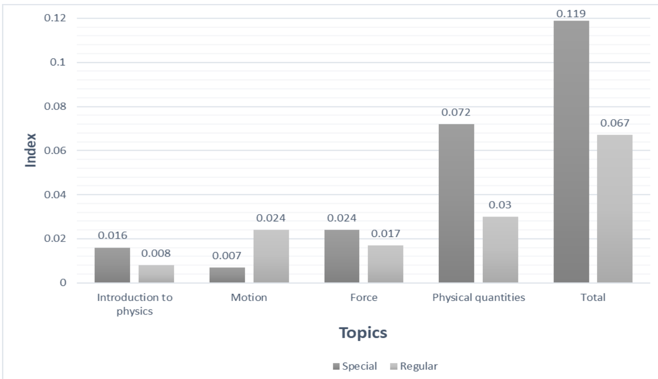
Topics that do not contain a sufficient number of words (1000) are usually not considered. However, although *textbooks* for children with disabilities do not have extensive topics, these topics (less than 1000 words) were averaged per 1000 words that the topic would have. Before presenting the tables of results of the analysis on the above-mentioned topics, Table 1 shows the average representation of illustrations of both textbooks that are being analyzed - *Special* and *Regular* to more easily explain the further obtained results as well as the previously mentioned results (relative representation index).

Table 1
Average Representation of Illustrations in Physics Textbooks

Topics	Special textbook			Regular textbook		
	Number of words	Number of illustrations	Number of illustrations per 1000 words	Number of words	Number of illustrations	Number of illustrations per 1000 words
Introduction to Physics	301	5	16	1189	10	8
Motion	404	3	7	1395	25	24
Force	533	13	24	1132	34	17
Physical quantities	375	27	72	962	10	30

The results in *Table 1* show that the number of words in each topic is significantly lower in a special textbook than the number of words in a regular textbook. However, the results also show that the total number of illustrations per 1000 words is higher in a special textbook than in a regular textbook. *Figure 1* shows the results of the index of relative representation of illustrations in textbooks. Based on the results obtained, it is concluded that the index of relative representation of illustrations in the regular textbook is significantly lower in all topics, except for the topic of movement.

Figure 1
Index of the Relative Representation of Illustrations in Selected Physics Textbooks



Analysis of Types of Illustrations in Textbooks

As previously noted, there are three types of illustrations: realistic, conventional and hybrid. Further in the research, the representation of all types of illustrations in selected physics textbooks will be explored, followed by the classification of illustrations according to the type of illustrations and the degree of abstractness of all three types of illustrations. In Figure 2, the results are presented that show the representation of types of illustrations in selected textbooks.

Figure 2
Percentage of Illustrations by Type

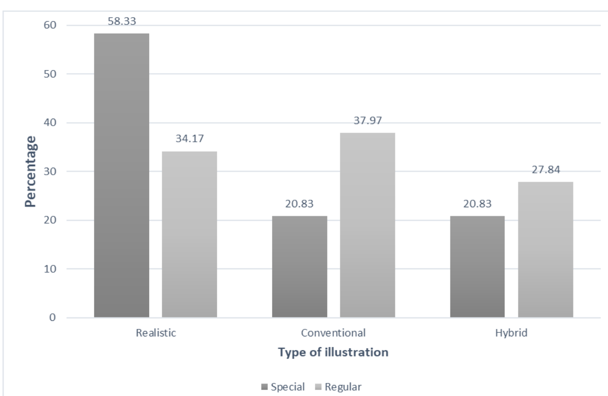


Figure 2 clearly shows that the number of realistic illustrations is the largest, while the number of conventional and hybrid illustrations is equal in a special textbook, while in a regular textbook, the most common are conventional illustrations, then realistic and hybrid illustrations.

Further analysis results showed that in the Regular textbook, the most represented were realistic illustrations belonging to illustrations from everyday life (40.74%), then those belonging to laboratory equipment and experiments (22.22%) and then those belonging to the history of physics (18.51%). On the other hand, the results of the analysis of realistic situations from the special textbook also showed that most illustrations belonged to laboratory equipment and experiments (39.28%), while realistic illustrations with graphics and diagrams and illustrations of industrial production and plants had the same percentage (21.43%), while illustrations from the history of physics were not presented.

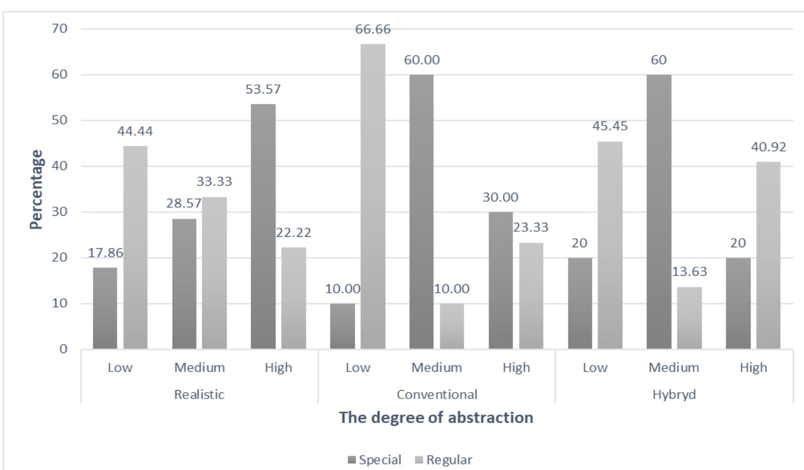
Based on the analysis of conventional illustrations, it was obtained that the Special textbook had the most illustrations that belonged to illustrations from everyday life (40%), followed by graphics and diagrams (20%), and then laboratory equipment and experiments (13.33%), and analogies (13.33%). In the regular textbook, illustrations were represented in the same order, only differing in percentage amount.

Further analysis of hybrid illustrations, showed that the most represented hybrid illustrations in the Regular Textbook are illustrations belonging to graphics and diagrams (36.36%), followed by laboratory equipment and experiments (31.81%) and illustrations from everyday life (13.63%). The analysis of the special textbook showed that the most common illustrations from everyday life (40%) are illustrations belonging to graphics and diagrams (30%) and then those belonging to laboratory equipment (20%).

Analysis of the Degree of Abstractness of Illustrations in Textbooks

Figure 3 shows the results of the analysis of the degree of abstraction of illustrations.

Figure 3
The Degree of Abstraction of Illustrations



The results show that in the textbook for students with special educational needs, realistic illustrations are dominated by highly abstract illustrations, while conventional and hybrid illustrations are predominantly illustrations of moderate abstractness. In regular textbooks, illustrations of low-level abstractness are the most represented in all three types of illustrations.

Discussion

Based on the total number of illustrations, it is noticed that a greater number of illustrations in the textbook for children with special educational needs is understandable because children with special educational needs can more easily adopt concepts through graphic representations. Textbooks play a crucial role in shaping the image using its textual and visual representation (Gulya & Fehervari, 2023).

Considering the differences between textbooks, some trends and differences in illustrations in physics textbooks can be observed (Souza & Porto, 2012). A physics textbook for children with disabilities contains a much larger number of images compared to the number of words compared to a regular textbook. This is understandable because the image is much more valuable than the text (Hibbing & Ranckin-Erikson, 2003). As for the abstractness of illustrations, they are more complex in textbooks for children with special educational needs. This suggests that some children with special educational needs may have difficulty reading, and visual displays can be easier to understand than the text itself (Levin et al., 1987).

Science textbooks tend to rely on visuals rather than text (Dimopoulos et al., 2003). Due to the limitations of children with special visualization needs, this textbook relies more on everyday life than on models or historical facts. Abstract knowledge is more represented as the educational level rises (Dimopoulos et al., 2003). In the initial classes, there are concepts of high abstractness, and such concepts can be clarified and brought closer to students by applying illustrative-graphic methods by selecting and applying high-quality and appropriate illustrations (Hrin et al., 2016).

Some children had difficulties gathering information presented in the textbooks because textbooks are organized so that the task of reading them is difficult for some children (Ciborowski, 1992). Further, the Ministry and institutions used to offer little help and a small number of textbooks for teachers who teach children with special education needs. Appropriate instruction in classrooms with diverse learners requires at first a variety of instructional methods to address individual needs (Mercer et al., 1996) and also a variety of textbooks. The key role of this research is to enable better development of textbooks both in physics and for students with special needs. Research that had to focus on the comparison of illustrations of regular textbooks and textbooks for children with special needs has not been done so far. The differences of the visual images in the two types of textbooks can possibly lead to the development of different teaching strategies and more effective use of visual material in physics teaching for both groups of students (Dimopoulos et al., 2003).

What is crucial is that these results can be momentum in further research. Some form of survey or questionnaire that could be solved by children with special needs, and which would rely on these results could be the wind at the back to develop instructional aids specifically addressed to learners' special needs.

https://doi.org/10.33225/BalticSTE/2023.88

This study had some limitations. First of all, this was a small study that examined only two physics textbooks by one researcher. There was no measured interreliability in categorizing the images in the textbooks and the findings should not be considered applicable to all physics textbooks. The big limit of this study is the textbooks themselves. It is also necessary to refresh the field of textbooks for children with special educational needs because the analyzed textbook is almost thirty years old. More and more children with minor developmental disabilities are also being included in schools with regular education so this should be taken into account.

Conclusions and Implications

In this research, the contents of two selected Physics textbooks from different publishers were analyzed. It should be noted that the first edition is used in regular physics classes (regular textbook) for the sixth grade of elementary school (out of eight), while the second publisher's textbook is used in teaching children with special educational needs (Special textbook). The entire contents of these textbooks were analyzed: the number of illustrations, the index of relative representation of illustrations and the degree of abstractness analysis of illustrations. A comparison was made on common topics covered in both textbooks: Introduction to Physics, Physical Quantities, Force and Motion.

The results showed that the total number of illustrations on the number of words in the regular textbook was much lower than in the textbook for children with special educational needs. The number of words in the regular textbook is significantly higher than in the special textbook, while the number of illustrations is higher in the textbook for children with special educational needs, which is understandable because the textbook for children with special educational needs should present as many illustrations as possible, to make their content more accessible and comprehensible. The type of illustrations on the same topic in the regular textbook is more complex and usually with the text, while the type of illustrations in the textbook for children with special educational needs is simpler and clearer.

The results of the analysis of the degree of abstraction show that in the regular textbook, all types of illustrations are of low abstractness, while in the textbook children with special educational needs are variable. Realistic illustrations are mostly high, while conventional and hybrid illustrations are mostly of medium abstractness.

The results of the analysis of the types of illustrations according to the content have shown that the special textbook illustrations belong to only a few types of illustrations: everyday life, laboratory equipment and graphics and diagrams, while the results in the regular textbook showed that all types of illustrations are represented, but the most are the illustrations from everyday life and graphic and diagrams. It can be concluded that the content in books for children aged in the sixth grade of elementary school has a wide variety of illustrations, while the textbook for children aged sixth grade of elementary school with special educational needs has a greater number of illustrations but is as unique as possible and those from every day and real life.

For the physics textbook to give inspiration to students for independent and research work, it should contain as many laboratory exercises as possible, and tasks explained by pictures, drawings, and diagrams. The laws of physics need to be explained through realistic examples for students to understand the purpose of this very important natural science and apply it in everyday life. A picture is worth a thousand words. Therefore, the graphic allocation of concepts makes it easier to understand.

Future directions of research can be a potential survey among teachers who teach in schools about the quality of graphic illustrations as well as textbooks themselves.

Acknowledgements

The authors gratefully acknowledge the financial support of the Ministry of Science, Technological Development and Innovation of the Republic of Serbia (Grant No. 451-03-47/2023-01/200125) and the Provincial Secretariat for Higher Education and Scientific Research.

Declaration of Interest

The authors declare no competing interest.

References

Chatman, L., & Sparrow, B. (2011). The feeling of doing across levels of analysis - The effect of perceived control on learning. *Horizons of Psychology*, *20*(3), 73-91.

Ciborowski, J. (1992). *Textbooks and the students who can't read them: A guide for the teaching of content*. Brookline.

Čaluković, N. (2013). *Fizika, udžbenik za 6. Razred osnovne škole* [*Physics, textbook for 6. Elementary school class*]. Krug.

Dimopoulos, L., Koulaidis, V., & Sklaveniti, S. (2003). Towards an analysis of visual images in school science textbooks and press articles about science and technology. *Research in Science Education, 33*(2), 189–216. https://doi.org/10.1023/A:1025006310503

Gajtanović, Z., & Vait, D. I. (2015). Analiza udžbenika matematike za treći razred osnovne škole prema standardima D-grupe. [Analysis of mathematics textbooks for the third grade of elementary school according to d-group standards]. *Zbornik radova Učiteljskog fakulteta, 9*, 263-288. https://doi.org/10.5937/zrufpl1509263G

Gulya, N., & Fehervari, A. (2023). Addressing disability representation in EFL textbooks used in Hungarian public education. *International Journal of Educational Research Open, 4,* Article 100226. https://doi.org/10.1016/j.ijedro.2023.100226

Gvozedenović, S. (2011). Obrazovanje i drugi srodni pojmovi [Education and other related concepts]. *Sociološka luča, V*(2), 82-93.

Hibbing, A. N., & Rankin-Erickson, J. L. (2003). A picture is worth a thousand words: Using visual images to improve comprehension for middle school struggling readers. *The Reading Teacher, 56*(8), 758–770. http://www.jstor.org/stable/20205292

Hrin T., Segedinac, M., Milenković, D., Popović, M., & Bogdanović, I. (2016). Analiza ilustrativnosti u osnovnoškolskim udžbenicima hemije [Illustrations analysis in primary school chemistry textbooks], *Vaspitanje i obrazovanje, 41*(1), 71-84.

Janjić, B., Milojević, N., & Lazarević, S. (2012). *Primena i unapređenje inkluzivnog obrazovanja u Srbiji, Priručnik za zaposlene u vrtićima i školama* [Implementation and improvement of inclusive education in Serbia, Handbook for employees in kindergartens and schools]. Udruženje studenata sa hendikepom.

Karić, T., Mihić, V., & Korda, M. (2014). Stavovi profesora razredne nastave o inkluzivnom obrazovanju dece sa smetnjama u razvoju [Attitudes of classroom teachers on inclusive education of children with disabilities]. *Primenjenja psihologija, 7*(4), 531-548.

Levin, J. R., Anglin, G. J., & Carney, R. N. (1987). On empirically validating functions of pictures in prose. In D. M. Willows & H.A. Houghton (Eds.), *The psychology of illustration*: Vol.1 (pp. 51-78). Springer-Verlag.

Matijević, M., Rajić, V., & Topolovčan, T. (2013). Učenička percepcija srednjoškolskih udžbenika [Student perception of high school textbooks]. *Život i škola, 29*(1), 64-78.

Mercer, C. D., Lane, H. B., Jordan, L., Allsopp, D. H., & Eisele, M. R. (1996). Empowering teachers and students with instructional choices in inclusive settings. *Remedial and Special Education*, *17*(4), 226–236 https://doi.org/10.1177/074193259601700405

Pejnović, B. (1995): *Fizika za 7. razred osnovne škole* [Physics for the 7th grade of elementary school]. Zavod za udžbenike i nastavna sredstva, Beograd.

Souza, F. D., & Porto, P. A. (2012). Chemistry and chemical education through text and image: Analysis of twentieth century textbooks used in Brazilian context. *Science & Education, 21*(5), 705–727. https://doi.org/10.1007/s11191-012-9442-z

Received: *April 10, 2023* Accepted: *May 09, 2023*

Cite as: Horvat, S. A., Rončević, T. N., Bogdanović, I. Z., & Rodic, D. D. (2023). Differences in graphic illustrations in the contents of natural sciences in regular textbooks and textbooks for students with special educational needs in the Republic of Serbia. In V. Lamanauskas (Ed.), *Science and technology education: New developments and Innovations. Proceedings of the 5th International Baltic Symposium on Science and Technology Education (BalticSTE2023)* (pp. 88-98). Scientia Socialis Press. https://doi.org/10.33225/BalticSTE/2023.88

FUNDAMENTAL AND BASIC COGNITIVE SKILLS REQUIRED FOR TEACHERS TO EFFECTIVELY USE CHATBOTS IN EDUCATION

Maja Kerneža
University of Maribor, Slovenia
E-mail: maja.kerneza1@um.si

Abstract

With the rapid advancement of technology, education is undergoing a transformational change. Chatbots have become increasingly popular in recent years and are being utilized as teaching assistants to support teachers and students in various ways. However, little research has been done on the skills required by teachers to prepare curriculum content using chatbots. The research aims to identify the skills teachers need to prepare curriculum content with chatbots. It examines the fundamental and cognitive skills individuals need to interpret content generated by chatbots and explores the difference between self-assessment and evaluator-based assessment. Fifty-eight third-year students, pre-service teachers, in the Elementary education program attempted to write a lesson plan using ChatGPT and completed a questionnaire to assess the skills required. Their communication with the chatbot as well as their prepared lesson plans were reviewed by an evaluator who rated the skills of the participating pre-service teachers. Results indicate that pre-service teachers tend to overestimate their skills required to interpret chatbot-generated content compared to the evaluator's ratings. Such discrepancies could lead to inaccurate or incomplete assessments of their skills, which could hinder their potential for growth and development.
Keywords: *artificial intelligence, chatbots in education, cognitive skills, fundamental skills, lessons plan*

Introduction

In December 2022, the field of artificial intelligence, particularly the area of chatbot development and utilization, experienced a surge in growth with the launch of the ChatGPT chatbot. However, chatbots are not a new concept, as they have been in existence for almost six decades. The first chatbot, called ELIZA, developed by Weizenbaum in 1966, utilized pattern matching to simulate psychotherapist conversation with human patients. While ELIZA may be unfamiliar to the general public, many individuals are familiar with more modern virtual chatbot assistants, such as Amazon's Alexa and Apple's Siri, which operate on logical and virtual chatbot systems. The fundamental goal and premise of so-called chat-bots is that a computer converses with human clients in natural language in a manner that is as human-like as feasible (Bradeško & Mladenić, 2012). They are computer programs that mimic and process human communication, allowing people to interact with digital devices as if they were speaking with another person (Ciechanowski

https://doi.org/10.33225/BalticSTE/2023.99

et al., 2019). The dialogues thereafter typically serve some specific purpose, such as conducting web searches, organizing computer files, scheduling appointments, etc., depending on the work the bot was designed for (Bradeško & Mladenić, 2012).

Chatbots are increasingly being used in education. Clarizia et al. (2018) introduced it as a useful technology for supporting education, as they enable one of the most important ways to promote and enable personalized learning, not only increasing support and inclusion of students but also significantly reducing the administrative workload of teachers and enabling them to focus more on curriculum development and research (Cunningham-Nelson et al., 2019). Their advantage is that they are an interactive mechanism compared to traditional e-learning systems (Kowalski et at., 2011), and their users are only limited by the creativity and imagination of the user (Roos, 2018). In 2021, Okonkwo and Ade-Ibijola presented a study in which they analyzed 53 articles from reputable digital databases, with the aim of understanding the use of chatbots in education, including basic information, benefits, challenges, and suggestions for future research on the use of chatbots in education. Their study found that chatbot technology is used in various areas of education, including teaching and learning (66 %), administration (5 %), assessment (6 %), advisory (4 %), and research and development (19 %). They highlight that the introduction of chatbot systems in education can bring personalized online learning and greater accessibility to learning materials, which students can access from anywhere and at any time. Lin and Chang (2020) and Murad et al. (2019) added that chatbots are good technological innovations that improve students' interest in learning, cognitive skills acquisition, and academic achievements. They also have a successful impact on students' motivation (Bii et al., 2018), improve their learning experience (Sandu & Gide, 2018) and much more. Georgescu (2018) stated that the effects that chatbots can have on education are changing humanity forever with new methods and principles. As a complement to existing methods and learning approaches, chatbots can play an important role in presenting pedagogical content and assessment. They can create new ways of evaluating and providing real-time feedback, among other things. In addition to the benefits of using chatbots in education, it is important to mention the teacher's skills in their use. Teachers must be skilled in the use of chatbots, which means they must have basic skills for working with technology, such as knowledge of computer use and internet applications, as well as basic knowledge of programming and artificial intelligence. Additionally, it is important for teachers to develop their cognitive skills, such as the ability to think critically, adapt their teaching to different learners and their needs, and the ability to lead interactions using chatbots, which can become key in personalized learning. Teachers must be prepared for changes and adjustments in the use of chatbot technology in education and be ready for learning and developing new skills that will be required for the effective use of this technology in the classroom.

Although there are some studies that deal with the area of teacher's use of chatbots in teaching (e.g., Bii et al., 2018; Chocarro, 2023), there is a lack of research that examines the fundamental and basic cognitive skills that teacher needs for successful and productive communication with a chatbot, with the aim of curriculum content planning and lesson planning.

https://doi.org/10.33225/BalticSTE/2023.99

Research Problem

The use of chatbots in educational environments requires special skills from teachers. Most existing research on the use of chatbots focuses on the opportunities they offer teachers and other educators to assess curriculum goals. However, it is difficult to find research that explores the skills that teachers need for preparing curriculum content with the use of chatbots. They need to understand the concept they want to present to their students, they need to be able to design instructional material suitable for use with a chatbot, they need to use the correct technologies, and be able to analyze data collected from chatbot usage to improve their teaching. To create an effective and interactive learning environment with the help of chatbots, teachers need to have certain skills that must be defined and monitored to ensure a quality curriculum preparation process with the use of chatbots. According to Atlas (2023), chatbots for teachers provide a unique opportunity to improve the educational process and connect with students in new ways by providing individual feedback and assistance, allowing teachers to focus on other tasks.

Research Focus

The aim of this study was to explore the fundamental and basic cognitive skills that teachers require for preparing curriculum content with the use of chatbots. The research focus was based on fundamental research questions:

RQ1: What are *fundamental skills* that teachers require for interpreting content generated by chatbots?
RQ2: What are *basic cognitive skills* that teachers require for interpreting content generated by chatbots?
RQ3: How do pre-service teachers assess their *fundamental skills* required for interpreting content generated by chatbots?
RQ4: How do pre-service teachers assess their own *basic cognitive skills* required for interpreting content generated by chatbots?
RQ5: What is the difference between self-assessment and evaluator-based assessment regarding the *fundamental* and *basic cognitive skills* that teachers require for interpreting content generated by chatbots?

Research Methodology

General Background

In the academic year 2022/2023, the use of chatbots in the work of students of the academic undergraduate program Elementary education, has expanded with the launch of the ChatGPT chatbot. They use it as an aid in learning, as a tool for writing essays and assignments, and as a means of planning lessons and other curriculum content. However, it often becomes apparent that students are not fully proficient in the use of chatbots, frequently merely copying generated content without critically evaluating it, neither linguistically nor substantively. Additionally, during discussions about their use of chatbots, students often overestimate their skills.

https://doi.org/10.33225/BalticSTE/2023.99

In order to study the abilities that teachers need to plan the curricular content in their teaching, third-year students of the Elementary education undergraduate program attempted to write a high-quality and didactically justified lessons plan for teaching literature, and engineering and technology in March 2023, using the chatbot ChatGPT (5 students who were unable to log into ChatGPT worked with ChatJBT instead). The topics varied, but in all cases, they were related to the exact topic that the students had recently written a lesson plan, delivered a presentation on, and tested it in the classroom. They then led the communication with the chatbot themselves until they were satisfied with the plan. Because they had already prepared the plan for the presentation in the "traditional way", they were familiar with the theoretical background of the prepared curricular content, while also being informed about the appropriate didactic approaches to teaching the prepared content. Then they shared the plan with the researcher through the 1ka web application, which allows for anonymous submission, and also compared a two-part questionnaire to assess the fundamental skills and cognitive abilities necessary for the successful use of chatbots for preparing educational content.

The uniqueness of this study lies in its focus on the skills required by teachers to prepare curriculum content using chatbots, a topic that has received little attention in previous research. The study explores both fundamental and cognitive skills required for interpreting chatbot-generated content, which helps teachers develop the necessary competencies to effectively utilize chatbots as teaching aids in their classrooms.

Sample

The present study utilized a purposive non-random sampling method consisting of 58 third-year students enrolled in the Elementary Education program at the Faculty of Education in Slovenia, during the academic year 2022/2023. Of the participants, 12.06 % were male and 87.94 % were female, and all were aged between 20–22 years. The selected participants had previous experience in using the chatbot ChatGPT for academic purposes, including writing lesson plans for educational work as part of practical training. The sampling procedure aimed to include individuals who were similar to the population with respect to the research questions posed. The formation of the sample adhered to ethical guidelines, ensuring that participants' rights were not violated, and the treatment of results was anonymous.

Instrument and Procedures

Prior to conducting the proposed study, a pilot study was carried out. Nine individuals (3 students, 3 teachers, 3 university professors) attempted to write a lesson plan for teaching literature, and science and technology, using the ChatGPT chatbot. Based on their work, the skills required for working with the chatbot were evaluated, and fundamental and basic cognitive abilities needed for interpreting the chatbot's outputs were identified. Fundamental skills are specific to communicating with a chatbot, while basic cognitive skills are more general skills that are useful in interpreting any type of text. These abilities were also monitored in the main study.

The curriculum preparations generated with the chatbots were reviewed by a researcher who identified *fundamental skills* that teachers need to successfully communicate with a chatbot, based on the communication between pre-service teachers and the chatbot. The main nine identified skills include:

1. Ability to recognize and troubleshoot issues: Awareness that the chatbot sometimes does not understand the posed question, resulting in an incorrect answer. In this case, the individual must identify this problem and find appropriate solutions.
2. Abstract thinking: The ability to think abstractly, recognize different concepts related to content, connect ideas, identify patterns, and perform the analytical process of thinking.
3. Awareness that chatbots are capable of learning: Understanding that chatbots are programmed to learn and improve their abilities over time, which means that the chatbot also learns from its queries, behaviors, and actions, contributing to the improvement (or not) of the chatbot's performance.
4. Creativity: Awareness that chatbots do not necessarily provide appropriate solutions or answers to users' questions. In this case, the individual must be able to find new ways of communicating with the chatbot.
5. Incorporating knowledge from diverse fields: The ability to discern and recognize the content generated by the chatbot, as it may deal with content from different thematic areas, which may result in inadequate answers for the particular field.
6. Language skills of the individual: The ability to express questions and requests in a language format that the chatbot understands, usually in the form of clear and understandable thoughts. Additionally, the individual must be able to understand the chatbot output.
7. Recognition and understanding of language limitations of the chatbot: The ability to recognize and understand the language limitations of chatbots, which are programmed to understand only a limited range of linguistic structures and expressions.
8. Understanding concepts: awareness of the context of the generated content, understanding it, and understanding the content that the chatbot conveys, while also recognizing the purpose of the chatbot and distinguishing between different response options.
9. Understanding the logic and programming of chatbots: Knowledge that chatbots are based on certain logic and programming and understanding this logic to better understand how the chatbot works and what is expected of it.

The main seven identified *basic cognitive skills* for interpreting the text generated by a chatbot are:

1. Attention to detail: An individual must carefully monitor the chatbot's responses to ensure that important information is not overlooked.
2. Comprehension: An individual must be able to understand the language used by the chatbot and explain its meaning.
3. Critical thinking: An individual must be able to evaluate the chatbot's responses based on accuracy, relevance, and completeness.
4. Cultural competence: An individual must be attentive and sensitive to cultural differences that may affect or arise in conversations with a chatbot.

https://doi.org/10.33225/BalticSTE/2023.99

5. Emotional intelligence: An individual must be able to recognize and understand the emotions conveyed by some chatbots (e.g., Replika, Woebot, Mitsuku, Xiaoixe, Cleverbot), and respond appropriately to them. Additionally, individuals need emotional intelligence when using a chatbot if questions or situations arise that trigger emotional responses.
6. Logical reasoning: An individual must be able to use logical reasoning skills to understand the chatbot's responses and draw conclusions from them.
7. Memory: An individual must remember the information provided by the chatbot in previous conversations.
8. Problem-solving: At times, an individual must use their problem-solving skills to determine how to formulate questions to obtain the necessary information from the chatbot.

Based on the identified fundamental (9) and cognitive (7) skills necessary for successful communication with a chatbot, two assessment scales were designed. Within the first scale, which focused on *fundamental skills*, students rated their abilities in abstract thinking, language skills, creativity, recognition and understanding of language limitations of the chatbot, understanding concepts, understanding the logic and programming of chatbots, ability to recognize and troubleshoot issues, incorporating knowledge from diverse fields, and awareness that chatbots are capable of learning. The reliability of the questionnaire was checked with Cronbach's Alpha coefficient, which is .901 and shows excellent internal consistency. Within the second scale, which focused on *basic cognitive skills*, students rated their basic cognitive skills when communicating with a chatbot: comprehension, memory, attention to detail, critical thinking, problem-solving, logical-reasoning, emotional intelligence, and cultural competence. They assessed the abilities on both scales on the basis of a 5-point Likert scale (1 – not capable at all, 2 – not capable, 3 – neither capable nor incapable, 4 – capable, 5 – very capable). The reliability of the questionnaire was again checked with Cronbach's Alpha coefficient, which is .922 and also shows excellent internal consistency. Similarly, the researcher reviewed and assessed the fundamental and basic cognitive skills of participating students based on their submitted reports, re-evaluating the students on a 5-point Likert scale (1 – not capable at all, 2 – not capable, 3 – neither capable nor incapable, 4 – capable, 5 – very capable).

Data Analysis

The internal reliability of the questionnaire was assessed using Cronbach's alpha, which confirmed the appropriateness of the questionnaire design. Data from online questionnaires were analyzed in terms of descriptive statistics, including the number of participants, minimum and maximum response values, mean, and standard deviation. The same procedure was used to calculate data related to evaluator ratings. Self-evaluation and evaluator-evaluation data were compared to determine the characteristics of the relationship between the data.

Research Results

The results were systematically presented according to the addressed skills, which were divided into fundamental skills and basic cognitive skills. Table 1 displays the outcomes and comparison between self-evaluation and evaluator-evaluation of fundamental skills for successful communication with a chatbot that pre-service teachers had.

Table 1
Self-Evaluation and Evaluator-Evaluation of Fundamental Skills for Successful Communication with a Chatbot That Pre-Service Teachers Have

Grade	*N*	Min.	Max.	*M*	*SD*	Min.	Max.	*M*	*SD*	χ^2	*df*	*p*
		Student self-evaluation				Evaluator-evaluation						
Troubleshoot	57	2	5	3.82	.759	1	5	3.37	.919	88.985	12	.001
Abstract thinking	58	2	5	3.78	.773	1	5	3.48	1.112	91.814	12	.001
Chatbot learning	58	2	5	3.53	.922	1	5	3.19	.963	90.160	12	.001
Creativity	58	3	5	3.93	.697	2	5	3.53	.799	53.650	6	.001
Diverse fields	57	2	5	3.91	.714	1	5	3.40	.904	60.488	12	.001
Language skills	58	2	5	4.05	.711	2	5	3.50	.884	56.801	9	.001
Chatbot language	57	2	5	3.77	.708	1	5	3.51	1.020	95.951	12	.001
Understanding concepts	57	2	5	3.88	.781	1	5	3.44	.945	108.284	12	.001
Understanding logic	57	1	5	3.55	1.018	1	5	3.09	1.074	95.453	16	.001

Note. Troubleshoot = Ability to recognize and troubleshoot issues; Abstract thinking = Abstract thinking; Chatbot learning = Awareness that chatbots are capable of learning; Creativity = Creativity; Diverse fields = Incorporating knowledge from diverse fields; Language skills = Language skills of the individual; Chatbot language = Recognition and understanding of language limitations of the chatbot; Understanding concepts = Understanding concepts; Understanding logic = Understanding the logic and programming of chatbots.

As shown in Table 1, it is evident that pre-service teachers received the highest ratings for language skills (*M* = 4.05), creativity (*M* = 3.92) and incorporating knowledge from diverse fields (*M* = 3.91), while they identified the weakest fundamental skills as the ability to recognize and troubleshoot issues, awareness that chatbots are capable of learning and understanding the logic and programming of chatbots, recognition and understanding of language limitations of the chatbot (*M* = 3.77), understanding the logic and programming of chatbots (*M* = 3.55), awareness that chatbots are capable of learning (*M* = 3.53). The evaluator rated the students highest in creativity (*M* = 3.53), language skills (*M* = 3.50) and abstract thinking, and lowest in the ability to recognize and troubleshoot issues (*M* = 3.37), awareness that chatbots are capable of learning (*M* = 3.19) in understanding the logic and programming of chatbots (*M* = 3.09). In all cases, a statistically significant difference between the ratings of participating pre-service

https://doi.org/10.33225/BalticSTE/2023.99

teachers and evaluators was also evident, indicating a statistically significant difference in the assessment of students' fundamental skills. The results indicate that students rated their fundamental skills for working with a chatbot higher than the evaluator who reviewed their products, and the evaluator's response dispersion is higher as well. This may suggest that the evaluator had different expectations or criteria for evaluating the students' work, or that the students may have overestimated their own abilities.

In addition, the self-evaluation and evaluator-evaluation of basic cognitive skills necessary for successful communication with a chatbot, which are possessed by pre-service teachers, were also examined.

Table 2
Self-Evaluation and Evaluator-Evaluation of Basic Cognitive Skills for Successful Communication with a Chatbot that Pre-Service Teachers Have

Grade	*N*	Min.	Max.	*M*	*SD*	Min.	Max.	*M*	*SD*	χ^2	*df*	*p*
		Student self-evaluation				Evaluator-evaluation						
Attention to details	58	1	5	3.74	.890	1	5	3.34	.928	132.288	16	.001
Comprehension	58	1	5	3.91	.844	1	5	3.57	.920	141.546	16	.001
Critical thinking	58	2	5	3.84	.834	1	5	3.41	.992	74.105	12	.001
Cultural competence	57	1	5	3.49	1.002	1	5	3.09	1.128	-89.617	16	.001
Emotional intelligence	58	1	5	3.43	1.126	1	5	3.28	1.089	86.795	16	.001
Logical reasoning	58	2	5	3.76	.802	1	5	3.12	1.010	69.727	12	.001
Memory	58	1	5	3.74	.785	1	5	3.33	.962	102.889	16	.001
Problem-solving	58	1	5	3.74	.874	1	5	3.31	1.030	89.452	16	.001

The results presented in Table 2 indicate that pre-service teachers rated their basic cognitive skills for communicating with chatbots fairly high. They considered their strong areas to be comprehension ($M = 3.91$), critical thinking ($M = 3.84$) and logical reasoning ($M = 3.76$), while they evaluated their cultural competence ($M = 3.49$) and emotional intelligence ($M = 3.43$) slightly lower. Similarly, the evaluator identified comprehension ($M = 3.57$) and critical thinking ($M = 3.41$) as strong areas of the participants, while the abilities of logical reasoning ($M = 3.12$) and cultural competence ($M = 3.09$) were rated lower. As with fundamental skills, there was also a greater dispersion of evaluator responses for basic cognitive skills, but the emotional intelligence of the participants was identified as more consistent. Similar to fundamental skills, there was also a statistically significant difference between self-evaluation and evaluator rating in basic cognitive skills, where again, evaluator ratings were significantly lower than student self-ratings.

Discussion

The number of studies exploring the use of chatbots in education is increasing (e.g., Kuhail et al., 2023; Yildiz Durak, 2023; Hew et al., 2023). Within the presented study, fundamental and basic cognitive skills required by teachers for interpreting content generated by chatbots were identified. The study investigated and presented how pre-service teachers assess those skills for interpreting content generated by chatbots. The results provide an answer to the question of what the difference is between self-assessment and evaluator-based assessment regarding the fundamental and basic cognitive skills that teachers require for interpreting content generated by chatbots. When interpreting the results, it is necessary to be aware of the challenges, controversies, and opportunities that the introduction of chatbots into education brings (Hwang & Chang, 2021; Kooli, 2023).

The study's results are considered in the context of the research questions. The response to the first two research questions defines the fundamental and basic cognitive skills that teachers require to interpret content generated by chatbots. The most basic fundamental skills that an individual needs for successful communication with chatbots include the ability to recognize and troubleshoot issues, abstract thinking, awareness that chatbots are capable of learning, creativity, incorporating knowledge from diverse fields, language skills of the individual, recognition and understanding of language limitations of the chatbot, understanding concepts, and understanding the logic and programming of chatbots. On the other hand, basic cognitive skills are more general skills that individuals also require for communication with chatbots, including: Attention to detail, comprehension, critical thinking, cultural competence, emotional intelligence, logical reasoning, memory, and problem solving.

The main finding of the study is that pre-service teachers assess their fundamental skills required for interpreting content generated by chatbots at a higher level than the evaluator of their communication skills with the chatbot. Differences emerge that are important for the work of pre-service and in-service teachers with chatbots, while also considering other factors and variables related to self-evaluation (Mabe & West, 1982). Such discrepancies could lead to inaccurate or incomplete assessments of their skills, which could have negative consequences in terms of their learning and development. Moreover, the statistically significant difference between self-evaluation and evaluator rating suggests that the students may not be fully aware of their strengths and weaknesses, which could hinder their ability to improve and develop their skills in a meaningful way. This is particularly relevant in the context of education, where self-assessment and reflection are critical components of the learning process. Inaccurate or inflated self-evaluations could prevent students from identifying areas of improvement and taking appropriate action to address them, which could limit their potential for growth and development. Taking into account all that has been mentioned, we can draw parallels with Wollny et al. (2021) – chatbots have the potential to develop into powerful teaching tools that can provide insightful feedback to students, but we are not there yet. There is still more work to be done in the area of chatbots in education.

Other aspects and challenges in the research on chatbots in education are also significant, as they can greatly influence users' distorted perceptions of chatbots and limit their use in education. For instance, Okonkwo in Ade-Ibijola (2021) highlighted ethical issues, user relationships, control and maintenance, and recommended well-defined rules for chatbot usage that are consistent with user ethics. They also advised conducting more research on the functionality of chatbot systems, as it would significantly contribute to a positive impact on education.

https://doi.org/10.33225/BalticSTE/2023.99

Conclusions and Implications

The use of chatbots in education is on the rise, with the majority of applications focused on teaching and learning, administration, assessment, advisory, and research and development. This study discusses the potential of chatbots to revolutionize education by making it more accessible, engaging, and personalized. The advantages of using chatbots in education include integration of content, quick access, motivation, engagement, personalization, and immediate feedback. Nonetheless, there are also challenges to be addressed, such as ethical considerations, security issues, and the need for training and support for pre-service (and in-service) teachers. Overall, chatbots have great potential for improving education and should be further explored and developed in the future. This study has implications for the design of educational programs aimed at preparing pre-service teachers to work with chatbots. There is a need for more focused training on the fundamental skills that pre-service and in-service teachers struggle with. While pre-service teachers may have strengths in communicating with chatbots, there are areas for improvement, particularly in cultural and emotional intelligence. Overall, the study's findings and implications have relevance for teacher training and development programs in various countries around the world, as they navigate the potential of chatbots to revolutionize education and the challenges that come with their use.

Acknowledgements

Thanks go to the research program P5-0433; Digital Restructuring of Deficit Occupations for Society 5.0 (Industry 4.0). The research program is financed by the Slovenian Research Agency (ARRS).

References

Atlas, S. (2023). *Chatbot prompting: A guide for students, educators, and AI-augmented workforce*. University of Rhode Island.

Bill, P. K., Too, J. K., & Mukwa, C. W. (2018). Teacher attitude towards the use of chatbots in routine teaching. Universal *Journal of Educational Research*, *6*(7), 1586–1597. http://dx.doi.org/10.13189/ujer.2018.060719

Bradeško, L., & Mladenić, D. (2012). A survey of chatbot systems through a Loebner Prize competition. In *Proceedings of Slovenian language technologies society eighth conference of language technologies, 2,* (pp. 34–37). Institut Jožef Stefan.

Chocarro, R., Cortiñas, M., & Marcos-Matás, G. (2023). Teachers' attitudes towards chatbots in education: A technology acceptance model approach considering the effect of social language, bot proactiveness, and users' characteristics. *Educational studies*, *49*(2), 295–313. https://doi.org/10.1080/03055698.2020.1850426

Ciechanowski, L., Przegalinska, A., Magnuski, M., & Gloor, P. (2019). In the shades of the uncanny valley: An experimental study on human-chatbot interaction. *Future Generation Computer Systems*, *92*, 539–548. https://doi.org/10.1016/j.future.2018.01.055

Clarizia, F., Colace, F., Lombardi, M., Pascale, F., & Santaniello, D. (2018). Chatbot: An education support system for student. In: Castiglione, A., Pop, F., Ficco, M., Palmieri, F. (Eds.), *Cyberspace Safety and Security* (pp. 291–302). Springer. https://doi.org/10.1007/978-3-030-01689-0_23

Cunningham, N., Boles, W., Trouton, L., & Margerison, E. (2019). A review of chatbots in education: Practical steps forward. In *30th annual conference for the Australasian Association for engineering education (AAEE 2019): Educators becoming agents of change: Innovate, integrate, motivate* (pp. 299–306). Engineers Australia. https://eprints.qut.edu.au/134323/

Georgescu, A. A. (2018). Chatbots for education – trends, benefits and challenges. In *Conference proceedings of "eLearning and software for education" (eLSE)*, *14*(2), 195–200.

Hew, K. F., Huang, W., Du, J., & Jia, C. (2023). Using chatbots to support student goal setting and social presence in fully online activities: Learner engagement and perceptions. *Journal of Computing in Higher Education*, *35*(1), 40–68. http://dx.doi.org/10.1007/s12528-022-09338-x

Hwang, G. J., & Chang, C. J. (2021). A review of opportunities and challenges of chatbots in education. *Interactive Learning Environments*. https://doi.org/10.1080/10494820.2021.1952615

Kooli, C. (2023). Chatbots in education and research: A critical examination of ethical implications and solutions. *Sustainability*, *15*(7), Article 5614. https://doi.org/10.3390/su15075614https://doi.org/10.3390/su15075614

Kowalski, D., Hoffman, R., Jain, R., & Mumtaz, M. (2011). E_universities services in the new social eco-systems: Using conversational agents to help teach information security risk analysis. In: *SOTICS 2011: The first international conference on social eco-informatics* (pp. 91–94). IARIA.

Kuhail, M. A., Alturki, N., Alramlawi, S., & Alhejori, K. (2023). Interacting with educational chatbots: A systematic review. *Education and Information Technologies*, *28*(1), 973–1018. http://dx.doi.org/10.1007/s10639-022-11177-3

Lin, M. P. C., & Chang, D. (2020). Enhancing post-secondary writers' writing skills with a chatbot. *Journal of Educational Technology and Society*, *23*(1), 78–92. https://www.jstor.org/stable/26915408

Mabe, P. A., & West, S. G. (1982). Validity of self-evaluation of ability: A review and meta-analysis. *Journal of Applied Psychology, 67*(3), 280–296. https://doi.org/10.1037/0021-9010.67.3.280

Murad, D. F., Irsan, M., Akhirianto, P. M., Fernando, E., & Murad, S. A. (2019). Learning support system using chatbot in "Kejar C Package" homeschooling program. In *2019 international conference on in-formation and communications technology (ICOIACT)* (pp. 32–37). IEEE.

Roos, S. (2018). *Chatbots in education: A passing trend or a valuable pedagogical tool*? Dissertation. Uppsala University.

Sandu, N., & Gide, E. (2019). Adoption of AI-chatbots to enhance student learning experience in higher education in India. In *18th International Conference on Information Technology Based Higher Education and Training (ITHET), Magdeburg, Germany* (pp. 1–5). https://doi.org/10.1109/ITHET46829.2019.8937382

Wollny, S., Schneider, J., Di Mitri, D, Weidlich, J, Rittberger, M., & Drachsler, H. (2021). Are we there yet? - A systematic literature review on Chatbots in education. *Frontiers in Artificial Intelligence,* 4. https://doi.org/10.3389/frai.2021.654924

Yildiz Durak, H. (2023). Conversational agent-based guidance: Examining the effect of chatbot usage frequency and satisfaction on visual design self-efficacy, engagement, satisfaction, and learner autonomy. *Education and Information Technologies*, *28*(1), 471–488. http://dx.doi.org/10.1007/s10639-022-11149-7

https://doi.org/10.33225/BalticSTE/2023.99

Received: *April 11, 2023* Accepted: *May 10, 2023*

Cite as: Kerneža, M. (2023). Fundamental and basic cognitive skills required for teachers to effectively use Chatbots in education. In V. Lamanauskas (Ed.), *Science and technology education: New developments and Innovations. Proceedings of the 5th International Baltic Symposium on Science and Technology Education (BalticSTE2023)* (pp. 99-110). Scientia Socialis Press. https://doi.org/10.33225/BalticSTE/2023.99

EXPLORING INTERACTIVE H5P VIDEO AS AN ALTERNATIVE TO TRADITIONAL LECTURING AT THE PHYSICS PRACTICUM

Jelena Kosmaca , Ilva Cinite , Girts Barinovs
University of Latvia, Latvia
E-mail: jelena.kosmaca@lu.lv, ilva.cinite@lu.lv, girts.barinovs@lu.lv

Abstract

Interactive learning materials can be a more efficient and engaging way of studying physics than lecturing. This research aims to explore the use of interactive H5P video as an alternative to traditional teacher-led class presentations at the university physics practicum. The quasi-experimental research design was implemented with 60 undergraduate students at the University of Latvia, during two introductory-level practical laboratory classes on the topics of mechanical bending and fluid viscosity. Knowledge tests were used to assess the learning outcomes, classroom observations provided an insight into students' group work with the video, a survey revealed student attitudes to the H5P video, as well as their preferences in preparation for the physics classes. Results show that both presentation formats contributed to reasonably high scores in the Exit ticket test at the end of the class. No statistically significant differences were found between the groups working in different conditions, implying that video was successfully used for a group activity to substitute lecturing in preparation for laboratory work. Potential applications of H5P video for individual and group work are discussed in line with the student preferences.
Keywords: *H5P, educational technology, interactive video, mixed methods, physics laboratory*

Introduction

Interactive methods and active learning through discussion with peers have been long recognized to be a more efficient way of learning physics than traditional methods, such as lecturing with a teacher standing in front of students and presenting information (Hake, 1998). Interactive methods flourished with the development of educational technology; multimedia tools, such as computer-based *PhET* simulations, *YouTube* videos, various quiz apps etc., have a positive effect on learning outcomes and attitudes. For example, compared to traditional lecturing, multimedia visualization can make students enjoy learning quantum physics (Nyirahabimana et al., 2023).

Video is advantageous for meaningful learning because dynamic visualization and narration output load both visual and verbal channels in the learner's information system (Mayer, 2009). On the downside, one risk associated with video in the educational process is passive watching (Richtberg & Girwidz, 2019). Higher engagement and knowledge acquisition have been reported for videos segmented in shorter clips (Guo et al., 2014), as well as videos with questions and visuals (Kestin & Miller, 2022). Some

https://doi.org/10.33225/BalticSTE/2023.111

general principles for effective educational videos (Brame, 2016) have been summarized on account of educational research, in particular, cognitive learning theories (Mayer, 2009). Furthermore, empirical insights have been formulated for specific applications, such as Massively Open Online Course (MOOC) lectures (Guo et al., 2014) or physics laboratory works (Lewandowski et al., 2019).

Appropriate design video can be as efficient for knowledge acquisition as traditional formats of learning materials, such as live lectures (Brockfeld et al., 2018) or printed text (Merkt et al., 2011). Yet the usefulness of video compared to the traditional formats remains debatable among teachers and learners. One reason why many prefer text over video can be that a text document is easier for skimming information and self-regulating their learning (Alexander, 2013). Probably, interactive video with advanced navigation and automated feedback might be able to compete with textual and lecture instructions better than traditional video.

Interactive video or *hypervideo* is a video, enriched with interactive features, such as hyperlinks, navigation controls, pop-up questions etc. Technically it is a traditional video with a layer of interactive content added in the post-production process, for instance, using *H5P* technology (www.h5p.org). *H5P* is licensed under the MIT license; it is free and open-source, easy to use, and has integrations in popular learning management systems, such as *Canvas*, *Blackboard* and *Moodle*. According to preliminary research (Richtberg & Girwidz, 2019), *H5P* video can find applications for physics learning in various contexts. To date, empirical studies on the *H5P* tool for learning physics at university are limited to a few (see e.g., Chong et al., 2019; Desai & Kulkarni, 2022; Kosmaca & Siiman, 2023).

In the current study, interactive *H5P* videos were designed for a group activity with discussion in class to explore how preparing with an *H5P* video in contrast to traditional lecturing may influence learning outcomes, how students interact with the video presentation in a group, and how they perceive learning with *H5P* video in general. Ultimately, the aim of this research was to explore the suitability of interactive *H5P* video as a tool for learning physics at the university. The following research questions (RQ) were formulated:

- RQ1: Can interactive *H5P* video of a pre-recorded presentation be as sufficient as a traditional class lecturing for achieving learning outcomes of practical work in physics?
- RQ2: How do students interact with an *H5P* video presentation during physics class?
- RQ3: What are student perceptions of *H5P* video in context with their learning preferences?

Research Methodology

General Background

The mixed-method quasi-experimental research design was used to assess the use of interactive video with groups of students at the University of Latvia. Pre-recorded interactive *H5P* video presentations were introduced in the physics practicum to prepare students for laboratory work in person, as an alternative to class presentations used in the traditional lecturing approach (further referred to as traditional presentations). Data were collected via pre-and post-tests, classroom observations during regular practical classes in physics and student surveys. The scope of this study was limited to the first-year undergraduate students enrolled in the biology and biotechnology study programs, who participated in the regular practical laboratory classes in physics during the first semester of the academic year 2022/23.

Sample

Convenience sampling was used to select the research sample from the students taking practical laboratory classes as a part of their mandatory introductory-level physics courses. In total, 60 students (39 female, 21 male) took part in the study from September-December 2022. There were 25 biotechnology students in the Biophysics course and 35 biology students in the Physics for Natural Sciences course that participated in this research. They belonged to five study groups, coded as 1A, 2A, 3B, 4B, 5B. Participants were informed about the research at the beginning of the semester, before the class with *H5P* and at the end of the semester; in oral form and via written informed consent. Students were informed that their knowledge test scores would not impact the course results or relationship with teachers and that participation was voluntary. Attitude surveys were anonymous.

Instrument and Procedures

Knowledge tests and self-report questionnaires were the main instruments used to assess the knowledge acquisition and perception of interactive *H5P* video, they were supported by qualitative classroom observations.
First, at the beginning of the semester, students were administered two paper-based pre-tests.

1. The Half Force Concept Inventory (HFCI1) pre-test (Han et al., 2015), which consists of 14 multiple-choice questions, is based on the Force Concept Inventory (FCI) test (Hestenes et al., 1992). It is a recognized instrument for measuring the understanding of fundamental concepts in Newtonian mechanics.
2. In addition to the HFFCI1, students completed a test with 18 multiple-choice questions, which covered specific learning outcomes of the practical laboratory classes in the course (e.g., how to assess measurement uncertainties, how to experimentally determine the viscosity of a liquid using the Stokes method etc.). The questions were reviewed for face validity by four physicists experienced in teaching the course.

Next, during the classes with the *H5P* video, teachers observed the group work and took notes about students' interactions throughout the activity. At the end of the class, participants were asked to complete paper-based Exit ticket tests, which contained 10 True/False statements about the class topic. The Exit ticket items were created and reviewed for face validity by the course teachers. Finally, at the end of the semester, participants were asked to fill in anonymous questionnaires distributed via electronic *MS Forms*.

https://doi.org/10.33225/BalticSTE/2023.111

Interactive H5P Video Presentations

Interactive *H5P* video presentations were designed for two topics corresponding to introductory-level physics laboratory: Bending, where students explore the mechanical properties of a solid material in a three-point bending test, and Viscosity, where they determine the viscosity coefficient of a liquid material by the Stokes' method.

The teachers' created class presentation slides (*MS PowerPoint*) were used for the traditional live talk and as a base for interactive *H5P* video presentations. For each of the presentations (Bending and Viscosity), the teacher recorded the slides with her voiceover. Then the video was edited (*DaVinci Resolve*) and posted on *YouTube*. The total length of the video clips was 11 minutes for Bending and 13 minutes for Viscosity. An interactive layer was added to the *YouTube* video using the *H5P* plugin in *Moodle*. The interactions (multiple-choice questions with automated feedback, forced stops, labels and external hyperlinks) split the timeline of the video into 1-2-minute-long segments. The final presentations were posted on the course page in *Moodle*, where they could be accessed by the course participants.

The presentations were tested with students during regular 90-minute classes. At the beginning of the class with an interactive *H5P* video presentation teacher announced that instead of her conventional talk, there was a pre-recorded presentation. The task for the students would be to watch the presentation together and give their group answers to the questions appearing on the screen during the presentation. The video was accessed from *Moodle* on the class computer and projected on the big screen typically used for the demonstrations and class presentations. One student, who agreed to moderate the activity, had the computer mouse to control the video and interact with the questions appearing on the screen. Others were listeners, who could participate in discussions. The teacher, though she stayed in the class, did not interfere with the group during the activity, and only took the notes. After the video presentation ended, students were asked about any remaining uncertainties and were allowed to conduct their laboratory work in small groups. At the end of the class, they were asked to complete the paper-based Exit ticket.

Data Analysis

Individual scores of the students participating in the pre-tests (the HFCI1 and the laboratory learning outcome test) and post-tests (Exit tickets) were calculated from the response values 0 (Incorrect) or 1 (Correct). The values for the mean score and standard deviation were determined from the individual total scores, which indicate the proportion of correct answers. The group scores were compared using a two-tailed Mann-Whitney U test with the significance level set to .05. The responses to the questionnaire were converted from a 5-point Likert scale to values from 1 (Strongly Disagree) to 5 (Strongly Agree).

https://doi.org/10.33225/BalticSTE/2023.111

Research Results

Effectiveness of Interactive H5P Video for Achieving Learning Outcomes

The scores of the HFCI1 pre-tests were in the interval 29-30% for the two A groups and 18-27% for the three B groups, matching typical results for non-calculus-based groups (18-37%) at the University of Latvia (Cinite & Barinovs, 2021). The results of the laboratory learning outcome pre-test for the two A groups (50%) were slightly higher than for the three B groups (35-42%).

Quantitative analysis of the Exit ticket scores compared the groups of students in terms of their conceptual understanding of the two physics practicum topics (Bending and Viscosity) at the end of the class. Table 1 summarizes the group scores on Bending, which was tested first with the A1 and A2 groups. Both groups achieved relatively high scores (76% and 81% out of 100%); the mean score for Interactive video presentation was slightly higher than for Traditional live presentation. There was no control group; yet two students were absent on the day of the class and performed the bending experiment separately, without any presentation. After just the practical measurements, the Exit tickets scores (proportion of the correct answers) for these two students were only 10% and 30%, much lower than for any of the students working with the class presentation.

Table 1
Exit Ticket Group Scores in the Practical Class on the Topic of Bending

Condition	Group	*M* (*SD*), %
Traditional live presentation	1A (n = 10)	76 (16)
Interactive video presentation	2A (n = 9)	81 (11)

Note: Mean scores (*M*) represent the proportion of the correct answers to True/False statements. *SD* – standard deviation.

For the second practical work (Viscosity), the conditions were swapped: 1A group worked with an interactive *H5P* video but 2A received a traditional class presentation. Here the mean score of the group on the Interactive video condition was again higher compared to the other group (Table 2) as well as to themselves working with the traditional class presentation on Bending (Table 1). Mann-Whitney *U* tests were performed to evaluate whether the group 1A and 2A Exit ticket scores differed. The results indicated that there was no significant difference between the Bending scores (U = 37, p = .56), as well as the Viscosity scores (U = 82, p = .16) of 1A and 2A. The result is not significant at $p < .05$.

https://doi.org/10.33225/BalticSTE/2023.111

Table 2
Exit Ticket Group Scores in the Practical Class on the Topic of Viscosity

Condition	Group	*M* (*SD*), %
Interactive video presentation	1A (n = 11)	83 (18)
Traditional live presentation	2A (n = 11)	71 (18)
Interactive video presentation	3B (n = 11)	73 (7)
Interactive video presentation	4B (n = 11)	73 (20)
Traditional live presentation	5B (n = 9)	69 (15)

Note: Mean scores (*M*) represent the proportion of the correct answers to True/False statements. *SD* – standard deviation.

The interactive video presentation on the topic Viscosity was also tested with the B groups, which worked with another teacher. Like the A groups students, the two B groups working with the interactive video (3B and 4B) showed similar score results as the group 5B working with the traditional live presentation (Table 2). This suggests an interactive video presentation can be as sufficient as a traditional class presentation for achieving learning outcomes of practical work.

Students' Interaction with an H5P Video Presentation During the Class

Teacher notes during the interactive video presentation activity gave an insight into possible scenarios for the student group work with interactive video presentations: 1A, 2A, 3B and 4B. From observations with those groups, the activity was similar to that of a traditional class presentation. Students watched the video with attention and took their notes, as usual. Some took pictures of the screen with their smartphone cameras. Questions appearing on the screen engaged students in a group discussion. Each question took approximately 10 seconds to process it individually first, and then about 1-2 minutes to discuss and select answers as a group. For the discussion students often referred to the theoretical overview in *PDF*, which was a complimentary learning material available in the course page on *Moodle*.

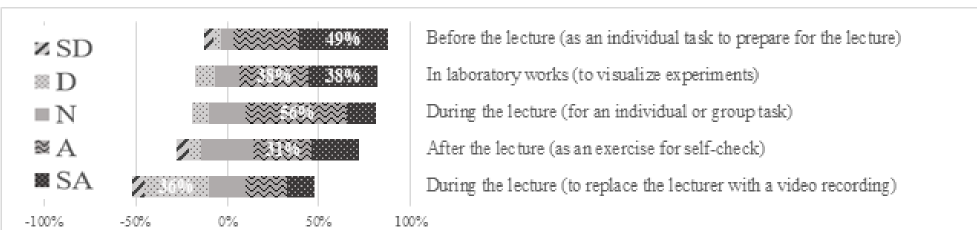
Each group designated moderators to input responses into the interactive video. Although the moderators' conduct differed slightly across groups. The moderator in the 2A group did not urge any correct answer based on their opinion but rather selected answers given by the rest of the group. Before submitting each answer, they checked with the group that everyone agrees. The same was true for groups 3B and 4B. A similar scenario was observed in group 1A, with one difference in that they were somewhat less active in the discussion part. In the beginning, almost everyone tried to contribute to finding correct answers, though such activity gradually decreased towards the end of a 13-minute video. This coincided with the group 1A moderator taking the initiative to come up with their personal opinion on the correct answers for each of the questions. Then the rest of the group would just silently agree with the moderator.

All of the four groups working with the interactive video presentation managed to complete the 11–13-minute video presentations in approximately 20 minutes, which is similar to the amount of time typically spent on a traditional live presentation (15-25 minutes). For all four groups, the task was self-explanatory and clear, students did not require any assistance from the teacher to organize their work. In the final frames of the video, the goal, tasks and procedure for the practical work were described. Students did not express any uncertainties and showed readiness to proceed with the practical work measurements.

Student Perceptions of H5P Video

At the end of the semester, participants of this study were asked to fill out an anonymous survey, to show their attitudes towards the *H5P* video and preferences for the preparation format for the practical classes. Figure 1 shows the distribution of responses (n = 45, response rate 75%) to the question "Where do you think interactive videos can be useful in the learning process?" on the Likert scale for agreement. Students would agree most with the option that the *H5P* video can be useful as an individual task to better prepare for the lecture and to visualize experiments in laboratory works. The option for using the *H5P* video during the lecture, for example, as individual or group assignments showed a reasonably high agreement rate, although, more than 36% of the respondents would disagree that *H5P* could help replace the lecturer with a video recording.

Figure 1
Respondents' Position on the Usefulness of Interactive Video



Note: Responses express agreement with the statements on the Likert scale. The bars represent the proportion of responses in each of the scale categories (Strongly Disagree (SD), Disagree (D), Neutral (N), Agree (A), Strongly Agree (SA)). Mode values for each of the statements are denoted with the percentage of total responses (n = 45).

The preferences among A and B groups regarding the preparation format for laboratory work in the physics practicum were divided. Half of the respondents (50%) would prefer to prepare as a group during the class, another half – individually, either before (41%) or during the class (9%). Theoretical overview in textual *PDF* format was ranked as their first format preference, traditional *MS PowerPoint*– second, and interactive *H5P* video presentation – their third preference. Apparently, the popularity of the *PDF* format could be explained by the proportion of students preferring individual over group work.

Finally, respondents of the survey reflected on their experience with the physics classes and attitude to the used learning materials in general. A few selected feedback responses are quoted below:

- "It was most convenient to use presentations that could then be reviewed again at home. The biggest plus was that they were both discussed in the lectures and available afterwards."

- "I liked that there was quite a lot of material available to prepare for assignments, supplement knowledge before the lesson, and if questions arose after the lesson, you could find questions mainly in all theoretical materials."
- "I liked doing lab work in a free way, that is, going through it at my own pace. The use of video did not cause any technical problems."
- "...I did not like that the theoretical descriptions contained a lot of information that was not necessary for the experiment."
- "I found the reference video/audio material very helpful. You can find out which areas need improvement, and you can revise several times if you don't understand at first."

Such responses show that students value the instant availability of learning material and an opportunity to build personalized learning paths by choosing the format, going through and revising the materials at their own pace. Interactive video can be a suitable tool to fulfil these wishes.

Discussion

The aim of this study was to explore the use of interactive *H5P* video as an alternative to traditional teacher-led class presentations at the university physics practicum. The statistical tests did not indicate significant differences in scores of the Exit ticket tests on the condition of Interactive video presentation compared to the Traditional presentation scores. This could mean that such a design of an interactive *H5P* video presentation (pre-recorded slides with voiceover and embedded questions) can be as efficient as a live presentation for the acquisition of knowledge in practical classes of an introductory-level physics course. The videos were designed following the principles of multimedia learning (Mayer, 2009) and efficient educational videos (Brame, 2016). Enriching the presentations with questions to viewers segmented the video to manage cognitive load and promote active learning in contrast to passive watching. Embedded questions have been demonstrated to support knowledge acquisition and to harness learners' engagement with an educational video in physics (Kestin et al., 2022).

The multiple-choice questions also initiated group discussions during the task of watching the video. The observed scenario of working with the task was approximately similar in each group; however, it was noticed that some groups were more active in discussion than others. Although the *less active* groups managed to achieve similar test scores as the *more active* groups, student involvement in group work activities can be desired in contemporary physics class. Since collaboration is among important 21st century skills that can be acquired in the physics class (Bao & Koenig, 2019), it would be useful to research how collaborative learning scripts can be advanced, for example, with an interactive branching scenario video (Kosmaca & Siiman, 2023). Introducing group tasks can facilitate a student-centered learning environment, which aligns with the directions of the physics education transformation in Latvian universities (Cinite & Barinovs, 2021).

The participants of this study acknowledged the use of interactive video in the study process, similarly to previous studies surveying students about *H5P* for physics learning (Desai & Kulkarni, 2022; Kosmaca & Siiman, 2023; Richtberg & Girwidz, 2019). Though, traditional learning material formats, such as *PDF* text documents, were selected more often as their first choice for laboratory work preparation, presumably because printed instructions are perceived as a more efficient medium in terms of locating information (Alexander, 2013). According to received feedback, students value learning materials that can be used at their own pace. Moreover, they expressed higher agreement that *H5P* video can be used before the lecture than during the lecture. The ability to "go at your own pace" has been previously mentioned among students' perceived advantages of an interactive video pre-lab activity in the introductory physics laboratory course (Lewandowski et al., 2019). Altogether, it can be inferred that tasks with interactive videos suited for individual learning would be appreciated. To further explore the usability of the interactive *H5P* videos created at the University of Latvia, they can be tested for watching individually in comparison with the *PDF* text format.

A major limitation to the generalization of the current study results was a relatively small sample size obtained by convenience method, which could leverage outcomes of statistical analysis. Besides, interactive videos were designed for only two laboratory work topics. These limitations could be addressed in future research by using probability sampling and performing measurements with larger groups of students, as well as using interactive video presentations throughout the semester.

Conclusions and Implications

Interactive *H5P* video presentations were successfully applied for the group work activity at the physics practicum. Similar knowledge test scores suggest an interactive video with embedded questions can be used as an alternative to lecturing in preparation for a laboratory work in physics. Student survey shows that students positively perceived this format of instruction. Interactive *H5P* video is seen as a useful tool for a group task during the lecture; though, participants of this study would not agree that it can substitute the lecturer.

Teachers wishing to integrate *H5P* videos (along with other formats of learning materials) in their classes should consider student preferences. The survey respondent preferences were divided in half between individual and group preparation for the laboratory work. Therefore, it would be beneficial to design educational videos suitable for individual as well as group learning. This research could further develop to investigate possible effects of the interactive video design on various learning outcomes, create new scenarios for the individual or group work supported by interactive video, and measure student satisfaction or collaboration during such activities.

Declaration of Interest

The authors declare no competing interest.

References

Alexander, K. P. (2013). The usability of print and online video instructions. *Technical Communication Quarterly*, *22*(3), 237–259. https://doi.org/10.1080/10572252.2013.775628

Bao, L., & Koenig, K. (2019). Physics education research for 21st century learning. *Disciplinary and Interdisciplinary Science Education Research*, *1*(1), 1–12. https://doi.org/10.1186/s43031-019-0007-8

Brame, C. J. (2016). Effective educational videos: Principles and guidelines for maximizing student learning from video content. *CBE Life Sciences Education*, *15*(4), es6.1-es6.6. https://doi.org/10.1187/cbe.16-03-0125

Brockfeld, T., Müller, B., & de Laffolie, J. (2018). Video versus live lecture courses: A comparative evaluation of lecture types and results. *Medical Education Online*, *23*(1). https://doi.org/10.1080/10872981.2018.1555434

Chong, K. E., Wong, K. L., Leung, C. W., & Ting, F. S. T. (2019). Flipped-classroom with interactive videos in first year undergraduate physics course in Hong Kong. *Optics InfoBase Conference Papers*, *Part F130*-, 1–13. https://doi.org/10.1117/12.2523439

Cinite, I., & Barinovs, G. (2021). Increased student performance on physics concept inventory test after student-centred approach in universities of Latvia. In. V. Lamanauskas (Ed.), *Science and technology education: Developing a global perspective. Proceedings of the 4th International Baltic Symposium on Science and Technology Education (BalticSTE2021)* (pp. 39-48). Scientia Socialis Press. https://doi.org/10.33225/BalticSTE/2021.39

Desai, T. S., & Kulkarni, D. C. (2022). Assessment of interactive video to enhance learning experience: A case study. *Journal of Engineering Education Transformations*, *35*(S1), 74-80. https://doi.org/10.16920/jeet/2022/v35is1/22011

Guo, P. J., Kim, J., & Rubin, R. (2014). How video production affects student engagement. In *Learning at Scale*. https://doi.org/10.1145/2556325.2566239

Hake, R. R. (1998). Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses. *American Journal of Physics*, *66*(1), 64–74. https://doi.org/10.1119/1.18809

Han, J., Bao, L., Chen, L., Cai, T., Pi, Y., Zhou, S., Tu, Y., & Koenig, K. (2015). Dividing the Force Concept Inventory into two equivalent half-length tests. *Physical Review Special Topics - Physics Education Research 11*(1), 010112. https://doi.org/10.1103/physrevstper.11.010112

Hestenes, D., Wells, M., & Swackhamer, G. (1992). Force concept inventory. *The Physics Teacher*, *30*(3), 141–158. https://doi.org/10.1119/1.2343497

Kestin, G., & Miller, K. (2022). Harnessing active engagement in educational videos: Enhanced visuals and embedded questions. *Physical Review Physics Education Research*, *18*(1), 10148. https://doi.org/10.1103/PhysRevPhysEducRes.18.010148

Kosmaca, J., & Siiman, L. A. (2023). Collaboration and feeling of flow with an online interactive H5P video experiment on viscosity. *Physics Education*, *58*(1), 015010. https://doi.org/10.1088/1361-6552/ac9ae0

Lewandowski, H. J., Pollard, B., & West, C. G. (2019). Using custom interactive video prelab activities in a large introductory lab course. *Physics Education Research Conference Proceedings*. 312–317. https://doi.org/10.1119/perc.2019.pr.Lewandowski

Mayer, R. E. (2009). *Multimedia learning* (2nd ed.). Cambridge University Press. https://doi.org/10.1017/CBO9780511811678

Merkt, M., Weigand, S., Heier, A., & Schwan, S. (2011). Learning with videos vs. learning with print: The role of interactive features. *Learning and Instruction*, *21*(6), 687–704. https://doi.org/10.1016/j.learninstruc.2011.03.004

Nyirahabimana, P., Minani, E., Nduwingoma, M., & Kemeza, I. (2023). Students' perceptions of multimedia usage in teaching and learning quantum physics: Post-assessment. *Journal of Baltic Science Education*, *22*(1), 37–56. https://doi.org/10.33225/jbse/23.22.37

Richtberg, S., & Girwidz, R. (2019). Learning physics with interactive videos – Possibilities, perception, and challenges. *Journal of Physics: Conference Series*, *1287*(1), 012057. https://doi.org/10.1088/1742-6596/1287/1/012057

Received: *April 19, 2023* Accepted: *May 12, 2023*

Cite as: Kosmaca, J., Cinite, I., & Barinovs, G. (2023). Exploring interactive H5P video as an alternative to traditional lecturing at the physics practicum. In V. Lamanauskas (Ed.), *Science and technology education: New developments and Innovations. Proceedings of the 5th International Baltic Symposium on Science and Technology Education (BalticSTE2023)* (pp. 111-121). Scientia Socialis Press. https://doi.org/10.33225/BalticSTE/2023.111

ENVIRONMENTAL EDUCATION IN PRIMARY SCHOOL: MEANING, THEMES AND VISION

Vincentas Lamanauskas , **Rita Makarskaitė-Petkevičienė**
Vilnius University, Lithuania
E-mail: vincentas.lamanauskas@sa.vu.lt,
rita.makarskaite-petkeviciene@fsf.vu.lt

Abstract

Environmental problems are faced all over the world. The quality of the environment has a tendency to deteriorate, so environmental education becomes one of the essential conditions for continued existence. In order to improve the situation, it is necessary to raise public awareness and encourage behaviour change. It is obvious that environmental education is needed, which would raise people's level of awareness, and encourage them to change their behaviour, accordingly, changes would take place in the field of production and industry, consumption habits, and the relationship with the environment itself. Environmental education is especially important in primary school. In forming children's environmental awareness, a great responsibility falls on the primary school teacher, therefore his preparation in the field of environmental education must be adequate.

Empirical qualitative research aimed to reveal how future primary school teachers understand the meaning of environmental education, the topic, and what kind of realisation vision they have. 136 students from two Lithuanian universities, future teachers of preschool and primary education participated in the study. Verbal research data were analysed using the quantitative content analysis method.

The research results allow us to state that environmental education is treated as significant, the themes of environmental education cover various areas that can and should be studied in primary school. Future teachers' environmental education implementation vision at school includes both cognitive and practical-behavioural components.

Keywords: *environmental education, qualitative research, primary school, pre-service teachers*

Introduction

In recent years, more and more attention has been paid to environmental education both in European Union and in Lithuania. The position of each of us in the field of environmental education is particularly important. The earlier children are introduced to environmental issues, the stronger they engage in such activities themselves, involve friends, relatives (Collado et al. 2020; Treagust et al., 2016). Attention to environmental protection at school helps to develop conscious citizens. At school, children not only acquire knowledge about environmental protection but also learn various other things important for environmental protection, e.g., to behave responsibly with nature and in nature. No less important is sensitivity to environmental protection and its recognition

https://doi.org/10.33225/BalticSTE/2023.122

as a very important element in life, conscious understanding of environmental problems and arguments, and behaviour in trying to avoid or solve them (McBride, et al. 2013). Children become more interested in what harms the environment and how to preserve it (Yeşilyurt, 2020; Treagust, 2016). A stronger connection with nature is formed, and they start to care more about environmental issues. When speaking about formal education, the role of the teacher is very important. Some research shows that primary school teachers' science literacy is not sufficient (Lamanauskas, 2022a, 2022b). On the other hand, research studies show that environmental education in primary school is extremely important (Barraza, 2001; Plourde, 2002; Shafer, 1996), gradually forming pro-environmental behaviour, which is less harmful to the environment, and favourably affects it (Steg & Vlek, 2009). As environmental requirements grow, there is an increasing need to act sustainably, responsibly, and respectfully, to protect and restore the environment (Buchanan et al., 2019).

It is obvious that it is necessary to strengthen environmental education in primary school as one of the most important components of natural science education (Lamanauskas, 2009). The results of a study conducted in Indonesia showed that most teachers agreed that it was important to integrate environmental education into the learning process of students, especially primary school students. However, this integration still has limitations, e.g., lack of time (Sukma et al., 2020). On the other hand, despite the fact that the relevance of environmental education has been recognised, there are still very few changes in school practices (Stanišić & Maksić, 2014).

The implementation and effectiveness of environmental education depends mainly on the competence of teachers. Spanish researchers analysed the situation of environmental education, teacher competencies and teacher training. The analysis revealed the lack of environmental competencies of future primary school teachers, as well as obvious gaps in teacher training programmes in terms of environmental education (Álvarez-García et al., 2015). A similar situation has been recorded in previous studies, stating that the training of future teachers in the field of environmental education is insufficient (Tilbury, 1992). Various approaches are used for the improvement of environmental literacy. Saribas et al. (2017) analysed the impact of special environmental courses on improving the environmental literacy of university students. The results showed that the participants' attitude towards the environment, awareness of the use of the environment and beliefs about their effectiveness increased significantly, although, at the end of the course, their environmental knowledge and concern for the environment did not change significantly. Turkoglu study (2019) showed that pre-service teachers had more theoretical knowledge than in-service teachers and in-service teachers had more practical knowledge than pre-service teachers. Thus, an important question remains, how to integrate environmental education into the daily learning of students. Researchers claim that there is a need for more specific content of environmental education in teacher training study programmes (Kennelly et al., 2008).

The importance of natural science knowledge in environmental education is emphasized by Kuckienė and Makarskaitė-Petkevičienė (2006), Yeşilyurt et al. (2020). Recent Turkish researchers presented an action study, confirming that environmental knowledge provision improves primary school students' environmental awareness. Fokides and Kefalinou (2020) revealed measures, i.e., the impact of spherical videos on primary school students' environmental education, teaching them about endangered species.

https://doi.org/10.33225/BalticSTE/2023.122

Treagust et al. (2016) study in primary classes showed that girls were more attentive to environmental issues than boys. One-year younger students were less empathetic towards the environment, and they needed reminders that the environment is fragile. In addition, more gifted students are more interested in environmental issues and other issues related to the environment than their less gifted peers.

There is also an interest in school content, and how many and what environmental elements are presented in educational programmes and measures (Kuckiene & Makarskaitė-Petkevičienė, 2006). Collado et al. (2020) examined the benefits of an environmental education programme included in the school curriculum for children's attitudes towards the environment and their behaviour. It has been established that encouraging learning in nature and having as much contact with nature as possible during learning, leads to better environmental achievements.

In 2022 General education programmes have been updated in Lithuania. The development of values, including environmental ones, becomes an important part of education. In the general programme of preschool education (In Lithuania, it is the education of 5-6-year-old children) six areas of education are distinguished, one of them is natural science education, the focus of which is on the child's research, experiments, experiential learning and through this, knowledge about the environment, nature is acquired. While playing and exploring the environment, the child learns what natural recourses are, conserves them (turns off the tap, turns off the light, saves paper, etc.), sorts the waste of used materials. Children are encouraged to reason about responsible and safe behaviour in nature, to notice examples of positive and negative human behaviour in nature.

In the general programme of natural sciences (grades 1-8) students are encouraged to recognize natural science problems and solve them, guided by the principles of sustainable development, healthy lifestyle, responsibly applying the acquired knowledge and skills in various life situations. The emphasis on natural science literacy is evident in the programme, as this would help the student in making personal decisions, the validity of solutions to local and global natural science problems; to understand the changes in nature caused by human activity and to take personal responsibility for preserving the environment, protecting one's own and other people's health. However, when describing achievements, it is more viewed from the perspective of a person but not from the position of nature, emphasizing the benefits provided to a person by nature. For example, *it explains the importance of preservation and care of natural resources for people's quality of life, the usefulness of recycling secondary raw materials. It gives examples of how it contributes and could contribute to the preservation of the environment, and conservation of resources*. And this is confusing because knowledge does not mean understanding and living according to environmental principles.

Thus, the pursuit of one of the most important educational priorities of the 21st century – educational renewal – encourages analysing and evaluating the possibilities of environmental education in primary school, on the other hand, the integration of environmental issues into the content of university study programmes. The aim of the study was to analyse the position of students, future teachers of preschool and primary education, in terms of the significance, problems and vision of practical implementation of environmental education. Three research questions were formulated:

https://doi.org/10.33225/BalticSTE/2023.122

- How do future teachers understand the importance of environmental education?
- What environmental issues (environmental content) should be analysed in primary school?
- What is the future teachers' vision for the implementation of environmental education at school?

Research Methodology

General Characteristics

The research is qualitative, and pilot in nature. It is specifically recognized as "basic or generic qualitative research" (Merriam, 1998). Basic or generic qualitative studies have the essential characteristics of qualitative research (e.g., eliciting meaning, researcher as data collection and analysis instrument, and detailed description). Qualitative research was chosen because it is a descriptive and inductive method that aims to extract the meaning from the research participants' attitudes and forms conditions to collect and present the data in detail from a holistic point of view (Yıldırım & Simsek, 2011). The research was conducted in January - March 2023. The research is based on the premise that studies of students' opinions and evaluations are important because they allow identifying current problems, clarifying already known ones, and predicting opportunities for improving studies.

Sample

136 university students, future teachers of preschool and primary education participated in the study. The research sample consists of two universities – Vilnius (*N* = 121) and Klaipėda (*N* = 15), studying Childhood pedagogy (*N* = 110) and Preschool education pedagogy (*N* = 26). All the respondents were female. The distribution of students by year of study is given in Table 1.

Table 1
The distribution of students by year of study [n (%)]

Course	*n*	%
The first	43	31.6
The second	72	52.9
The third	12	8.8
The fourth	9	6.6
Total	136	100.0

Qualitative sample size may best be determined by the time allotted, resources available, and study objectives (Patton, 1990). Thus, it is fairly assumed that such a sample is fairly representative in a qualitative study and allows for appropriate conclusions to be drawn.

https://doi.org/10.33225/BalticSTE/2023.122

A student survey was carried out in auditoriums, by submitting the prepared questionnaires. All students were informed about the objectives of the study, and their participation was voluntary and anonymous. Verbal consent was obtained from the students to participate in the survey.

Instrument

Open-ended questions were used in the study. The subjects were asked three questions:

- What is the significance/importance of environmental education?
- What environmental issues do you think should be addressed in primary school?
- What is your vision for the implementation of environmental education at school?

The wording of the research questions was discussed with two researchers.

The questions include students' general understanding of the meaning of environmental education, the content of environmental education, and the vision of the implementation of such education in primary school.

Data Analysis

The obtained qualitative (verbal) data of the study were analysed using quantitative content analysis. This allows us objectively and systematically analyse textual/verbal data and draw appropriate conclusions. Content analysis as a method is a scientifically based and effective solution that allows drawing reasonable conclusions from various sources of textual information (Coners & Matthies, 2014). Through multi-reading and analysis, relevant meaningful units are distinguished in the information array, which are then combined into subcategories and categories. The frequency of their use is calculated. Data analysis was performed by two researchers independently. The data and categories have been reviewed several times. In the final step, the researchers sought consensus on the assignment of subcategories to categories. The coordination and adjustment took place in two stages. There was a one-week break between the first and the second coordination stages. The concordance rate was higher than 85 %. Miles and Huberman (1994) stated that it was enough for the reliability of data to find a correspondence percentage higher than .70. The significance and completeness of the findings were continuously checked by the researchers.

Research Results

The students' opinion about the importance of environmental education in primary school was analysed. After the content analysis of the submitted answers, two categories were extracted: *Environmental knowledge and understanding* and *Environmental consciousness development* (Table 2).

Table 2
Environmental Education Meaning / Importance [n (%)]

Categories	Subcategories	Statements	*n* (%)
Environmental knowledge and understanding 47 (52.5)	Environmental knowledge acquisition 24 (26.7)	It is important to educate people about environmental protection	7 (7.8)
		To encourage students to be interested in environmental protection	6 (6.7)
		It is important to have knowledge about how to protect nature	5 (5.6)
		To introduce the growing generation to current problems	2 (2.2)
		To provide knowledge about environmental protection	2 (2.2)
		To improve students' knowledge about environmental protection	2 (2.2)
	Environmental understanding 23 (25.8)	To form an understanding that nature needs to be protected	8 (9.2)
		It is important to understand environmental issues	6 (6.7)
		To instil an understanding of the importance of nature conservation	3 (3.3)
		To form an understanding of the harm of environmental pollution	3 (3.3)
		To help people understand the importance of nature conservation	1 (1.1)
		Understanding of global problems	1 (1.1)
		To help people understand the importance of nature conservation	1 (1.1)
Environmental consciousness education 43 (47.5)	Development of skills/habits 16 (17.7)	To teach children to protect nature	5 (5.6)
		To develop environmental habits	4 (4.4)
		It is important to develop critical thinking	2 (2.2)
		To contribute to environmental protection	2 (2.2)
		To educate emphatic students	1 (1.1)
		Set a good example for children	1 (1.1)
		To teach to take care of nature	1 (1.1)
	Education of a responsible citizen 10 (11.1)	To educate a conscious citizen	5 (5.6)
		To educate environmentally friendly citizens	4 (4.4)
		To encourage society to protect the environment	1 (1.1)
	Education of a responsible consumer 9 (9.9)	To educate a conscious consumer	4 (4.4)
		To educate less consumeristic habits	2 (2.2)
		To educate a habit to sort waste	2 (2.2)
		Drawing attention to the harm of consumerism	1 (1.1)
	Education of responsibility and respect for nature 8 (8.8)	To develop an understanding that environmental protection is the responsibility of every person	2 (2.2)
		To develop a sense of responsibility	2 (2.2)
		To form a responsible attitude towards nature	2 (2.2)
		To form a sense of respect for nature.	1 (1.1)
		It is respect for self and others	1 (1.1)

Note: Totally 90 semantic units were extracted

https://doi.org/10.33225/BalticSTE/2023.122

Table 2 shows that speaking about the importance of environmental education, the statements were evenly distributed therefore it was possible to extract two broad categories *Environmental knowledge and understanding* and *Environmental consciousness education.* The first category consists of two subcategories *Environmental knowledge acquisition* and *Environmental understanding.* The statements in them were also similarly distributed, only the statements assigned to one subcategory were characterised by the keyword knowledge, to the other – by understanding.

The second category consists of 4 subcategories. The biggest of them is – *Development of environmental skills/habits*. Teaching children to protect nature, development of critical thinking, empathy, etc., find a place here. The second subcategory is *Education of a responsible citizen.* Statements assigned to this subcategory mention a citizen who would be able to protect the environment, environmental problems would not be unfamiliar to him, and he would have sufficient awareness to solve them. The third subcategory is *Education of a responsible consumer.* The statements show that future primary school teachers express concern about excessive consumption, and the need to educate a conscious consumer who is able to sort waste and understands that consumption habits need to be improved and changed. The fourth smallest subcategory *Education of responsibility and respect for nature* combines statements about a sense of responsibility, a responsible attitude towards nature, and respect for it.

School is the space, where the child creates his environmental knowledge system and the contexts, various activities, and tools necessary for them. Together with the student, his environmental knowledge goes home to the family. And if an environmentally friendly way of life is implemented in the family, then there are fewer objections when developing the child's environmental awareness, and it can be expected that the student will be a responsible citizen and consumer in the future, able to solve environmental problems as well.

The content of environmental education is an extremely significant component of primary school. Environmental education problems/topics to be studied in primary school are diverse from the students' point of view, covering a wide range of topics. Five categories are extracted, reflecting the theme of environmental education: *Waste problems*, *Environmental pollution*, *Global climate change*, *Environmental solutions,* and *Value crisis*. The results are presented in Table 3.

https://doi.org/10.33225/BalticSTE/2023.122

Table 3

Environmental Issues/Topics to be Studied in Primary School [n (%)]

Categories	Subcategories	Statements	*n* (%)
Waste problems 74 (35.1)	Waste management 58 (27.5)	Waste (garbage) sorting	48 (22.8)
		Waste recycling	10 (4.7)
	Waste damage to nature 16 (7.6)	Garbage damage	12 (5.7)
		Abundant use of plastic	3 (1.4)
		Impact of waste on nature	1 (0.5)
Environmental pollution 45 (21.3)	Environmental pollution 19 (9.0)	Pollution	16 (7.6)
		Harmfulness of pollutants	2 (0.9)
		Risk of environmental pollution	1 (0.5)
	Air pollution 14 (6.6)	Air pollution/pollution	8 (3.8)
		Vehicle pollution	6 (2.8)
	Water pollution 10 (4.7)	Water pollution /	10 (4.7)
	Soil pollution 2 (1.0)	Soil pollution	1 (0.5)
		Land depletion	1 (0.5)
Global climate change 38 (17.8)	Climate change 35 (16.4)	Climate change	14 (6.6)
		Global warming	12 (5.7)
		Climate warming	4 (1.8)
		Greenhouse effect	3 (1.4)
		Thinning of the ozone layer	2 (0.9)
	Anthropogenic impact 3 (1.4)	Climate preservation	2 (0.9)
		Human impact on climate	1 (0.5)
Environmental solutions 31 (14.5)	Conservation of recourses 15 (6.9)	Energy (electricity) saving	6 (2.8)
		Water conservation	4 (1.8)
		Resource conservation	2 (0.9)
		Renewable energy sources	2 (0.9)
		Food saving	1 (0.5)
	Fostering a sustaina-ble lifestyle 16 (7.6)	Nature conservation	5 (2.4)
		Use of secondary raw materials	5 (2.4)
		Sustainable living	2 (0.9)
		Environmental management	2 (0.9)
		Pollution reduction	1 (0.5)
		"Zero waste" lifestyle principles	1 (0.5)
Value crisis 24 (11.3)	Destruction of biodi-versity 17 (8.0)	Deforestation / Destruction	9 (4.2)
		Endangered species	4 (1.8)
		Poaching and killing animals	1 (0.5)
		Animal hunt	1 (0.5)
		Loss of biodiversity	1 (0.5)
		Mistreatment of animals	1 (0.5)
	Consumerism 7 (3.3)	Overconsumption/consumerism	5 (2.4)
		Human consumerism	2 (0.9)

Note: Totally 212 semantic units were extracted

The abundance and diversity of the statements made by future primary school teachers show that they notice many sensitive problems in the environment and would think that they should be discussed with the students. After analysing the statements and grouping them, 5 categories were extracted. The largest among them is the *Waste problem* (it accounts for more than a third of all statements), which consists of two subcategories *Waste management* and *Waste damage to nature.* These subcategories differ in that one combines statements about waste management as a process, and the other – insights about consequences to nature.

The category *Environmental pollution* consists of 4 subcategories: *Environmental pollution* (speaking in general terms, without distinguishing any sphere), *Air pollution, Water pollution, Soil pollution*. Thus, students understand pollution as a global phenomenon, covering all spheres, they discern the causes of pollution (pollution caused by vehicles), and consequences (land depletion, harmfulness of pollutants).

Global climate change is the third category. It consists of two subcategories Climate change (warming, greenhouse effect, thinning of the ozone layer) and *Anthropogenic impact.*

If the first three categories include environmental issues, then the remaining two are more related to a person, how much he is ready to be responsible for what is happening and make the necessary decisions. So, the fourth category is *Environmental solutions.* It consists of two subcategories. One of them is *Fostering a sustainable lifestyle* (nature conservation, use of secondary raw materials, environment management, "zero waste" lifestyle) – when each starts with himself, looking for harmony with the environment. The second subcategory – *Resource conservation*, includes energy, water, food saving, resource conservation, using renewable energy sources.

Slightly more than a tenth of all statements fall into the fifth category – *Value crisis.* The subcategory *Destruction of Biodiversity* combines the statements about deforestation, poaching and animal hunting, etc. Students also pay attention to excessive consumption, which is why the second subcategory is called *Consumerism.*

Environmental education is also an education of spiritual values. Future teachers also notice the value aspect, name it, and feel that environmental problems cannot be solved without a change in human values. These are related things.

An important aspect of environmental education in primary school is future primary school teachers' vision about the implementation of environmental education. After analysing the data, four categories were extracted: *Strengthening of environmental education*, *Strengthening of formal environmental education*, *Development of informal environmental education, Promotion of sorting and use of secondary raw materials.* The results are presented in Table 4.

https://doi.org/10.33225/BalticSTE/2023.122

Table 4

The Vision of Environmental Education Implementation at School [n (%)]

Categories	Subcategories	Statements	*n* (%)
Strengthening of environmental education 61 (48.6)	Development of environmental knowledge and understanding 25 (19.8)	To help students understand the meaning of protecting the environment	8 (6.3)
		To develop students' environmental awareness	6 (4.7)
		To provide students with a wider understanding of the environment	5 (4.0)
		To provide students with knowledge about the environmental protection	5 (4.0)
		To acquaint children with environmental issues	1 (0.8)
	Development of environmental skills 22 (17.6)	To encourage to manage the environment	5 (4.0)
		To encourage students to actively participate in environmental protection activities	4 (3.2)
		To teach to protect nature	3 (2.4)
		To develop educational environmental activities	3 (2.4)
		More practical knowledge	3 (2.4)
		To develop critical thinking	2 (1.6)
		To teach to project consequences	1 (0.8)
		To develop children's habits to take care of nature	1 (0.8)
	Development of environmental value attitude 10 (8.0)	To teach to love nature	4 (3.2)
		To motivate children to be interested in environmental protection	3 (2.4)
		To develop carefulness to ecological problems	2 (1.6)
		To teach children to be responsible for environmental protection	1 (0.8)
	Teacher involvement 4 (3.2)	To contribute personally to environmental sustainability	2 (1.6)
		To show a personal example	2 (1.6)
Strengthening formal environmental education 24 (18.8)	Increasing the effectiveness of lessons 23 (18.0)	To integrate environmental issues into other educational activities	12 (9.3)
		To create videos for children about environmental protection	7 (5.5)
		To develop environmental education during lessons	2 (1.6)
		To discuss environmental issues in more detail in world cognition lessons	2 (1.6)
	Educational environment improvement 1 (0.8)	To set up an ecology classroom at school	1 (0.8)
Development of non-formal environmental education 22 (17.5)	Environmental action organisation 10 (8.0)	To organise lessons-actions	4 (3.2)
		To organise school environment management actions	3 (2.4)
		To initiate environment management actions	3 (2.4)
	Environmental project implementation 10 (7.9)	To prepare environmental projects	6 (4.7)
		To participate in environmental projects	4 (3.2)
	Other environmental activity organisation 2 (1.6)	Organise educational environmental trips	1 (0.8)
		Organise environmental quizzes	1 (0.8)
Promotion of sorting and use of secondary raw materials 19 (15.1)	Increasing awareness of the importance of sorting 16 (12.7)	To talk more about waste sorting	8 (6.3)
		To encourage students to sort garbage	5 (4.0)
		To introduce waste sorting skills to children	3 (2.4)
	Promotion of the use of secondary raw materials 3 (2.4)	To encourage the use of secondary raw materials	3 (2.4)

Note: Totally 126 semantic units were extracted

Table 4 shows that after grouping students' observations about environmental education visions at school, 4 categories were extracted. Almost half of the statements are combined by *Strengthening of environmental education.* This category consists of two bigger and two smaller subcategories. *Development of environmental knowledge and understanding* and *Development of environmental skills* account for ¾ of all statements. Future teachers would think that it is necessary to help children understand many things happening in the environment, to acquaint them with the environment, and its problems, involve them in activities and working together, develop environmental skills as well as critical thinking and problem-solving abilities. The statements of motivation, interest in the environment, and love for nature are combined by the third subcategory *Development of environmental value attitudes*. Students note that environmental education would be strengthened by the involvement of the teacher, his participation and being an example for his students. These aspects are covered by the fourth subcategory *Teacher involvement.*

The other two categories are *Strengthening formal environmental education* and *Development of non-formal environmental education*. The first consists of two subcategories *Increasing the effectiveness of lessons* (integration of environmental issues into various activities, creating environmental videos, more environmental topics in world cognition lessons) and *Educational environment improvement,* for example, by setting up an ecology classroom. *The vision of the development of informal environmental education* is revealed by three subcategories: *Environmental action organisation,* which is usually understood as environmental management; *Environmental project implementation* (their preparation and participation in them); *Other environmental activity organisation* (educational trips, quizzes).

The fourth category *Promotion of sorting and use of secondary raw materials* combines two subcategories: *Increasing awareness of the importance of sorting* (talking about sorting and teaching sorting, and sorting) and *Promotion of the use of secondary raw materials*, which could lead to a more sustainable lifestyle.

Discussion

The aim of the study was the position of preschool and primary education teachers in terms of the meaning, problems, and vision of practical implementation of environmental education. From the point of view of students, the meaning of environmental education is as if twofold. Two almost equal categories reflect the importance of environmental education, i.e., environmental knowledge and understanding and development of environmental awareness. Environmental education in primary school is carried out throughout the entire pedagogical process – in everyday life and in the classroom. At this stage, children's emotional and value attitude towards the environment is intensively formed, environmental knowledge is formed, empathy is developed, etc. Therefore, acquiring environmental knowledge and environmental awareness are significant components of environmental education. Researchers claim that teachers at all levels of education should teach their students that they have to live together with the environment (Yurttaş & Sülün, 2010), environmental awareness development becomes one of the essential aspirations (Sola, 2014).

The conducted study showed that future primary school teachers have a thorough understanding of environmental education problems. Such a concept includes not only practical but also value aspects. This is related to other studies stating that most university students have prior environmental concepts and think that in order to solve environmental problems they face, good environmental education is necessary (Esteban Ibáñez et al., 2020).

The study showed that future teachers emphasize the strengthening of environmental education, which is mainly associated with the development of knowledge and understanding, as well as the formation of environmental skills. However, proper attention is not paid to the development of environmental value attitudes. In the vision of students' environmental education, both formal and informal environmental education development is emphasized. The least emphasis is placed on the promotion of sorting and the use of secondary raw materials. It can be said that students' position basically reflects the prevailing environmental discourse. One must agree with researchers' opinion that it is necessary for teacher educators to redesign and develop new courses and programmes to enhance conceptual environmental knowledge and educational experiences for beginning and experienced teachers (Meier & Sisk-Hilton, 2017). University studies should include curricula that provide environmental education using alternative strategies and do not limit environmental education to any one course (Candan & Erten, 2015). Prospective teachers should be informed about environmental problems and encouraged to participate in environmentally oriented social and cultural activities (Çokçalışkan & Çelik, 2017).

The study has several limitations. Only prospective teachers of preschool and primary education participated in the study. The study data were not analysed in terms of possible gender differences due to the homogeneity of the study population. Despite these limitations, the study reveals the position of future teachers on the issue of environmental education, however, highlights certain guidelines for better preparation of future preschool and primary education teachers. The changing environment brings many different changes. Practically all of us are becoming more digitally literate, and our needs are changing. Environmental awareness and literacy is becoming an equally important topic. Environmental education becomes the core of modern education and is the key to the transformation of modern systems and society as a whole. More detailed research is needed in the field of effective implementation of environmental education at the primary education level.

Conclusions and Implications

It has been established that future teachers have a fairly clear position on the issue of environmental education. Environmental education is treated as a significant part of general education. The importance of environmental education is expressed in two equal components – environmental knowledge and understanding, and environmental awareness (skills/habits, responsibility, respect for nature). Students would tend to use not only formal (environmental knowledge, subject integration, use of methods, various activities) but also informal (talks, actions, projects) opportunities for environmental education of primary school students. They tend to convey environmental knowledge to students in various ways - through experience, active participation of students, practical activities, knowledge obtained and developing understanding.

https://doi.org/10.33225/BalticSTE/2023.122

Students see different areas of environmental education, which should be covered in primary school. Topics include such areas as waste issues, environmental pollution, global climate change, environmental solutions, value crisis. Judging from the point of view of age groups, primary school students (7-11 years old) are usually willing to take responsibility, are empathetic, understand the moral imperative, their thinking is strongly dependent on experience, they learn quickly from authority figures, so, the position of the teacher, his active participation in environmental activities, his environmental values are very important. This aspect was revealed in the study. However, the teacher's cooperation with the students' parents on environmental education issues is equally important, however, this element was not revealed in the study.

Future teachers' vision of implementing environmental education at school includes both a cognitive component (strengthening of environmental education through the development of knowledge and understanding, value attitude formation), and a practical-behavioural component (increasing the awareness of waste sorting and promoting the use of secondary raw materials).

Declaration of Interest

The authors declare no competing interest.

References

Álvarez-García, O., Sureda-Negre, J., & Comas-Forgas, R. (2015). Environmental education in pre-service teacher training: A literature review of existing evidence. *Journal of Teacher Education for Sustainability*, *17*(1), 72-85. https://doi.org/10.1515/jtes-2015-0006

Barraza, L. (2001). Environmental education in Mexican schools: The primary level. *The Journal of Environmental Education*, *32*(3), 31-36. https://doi.org/10.1080/00958960109599143

Buchanan, J., Pressick-Kilborn, K., & Maher, D. (2019). Promoting environmental education for primary school-aged students using digital technologies. *Eurasia Journal of Mathematics, Science and Technology Education, 15*(2), Article em1661. https://doi.org/10.29333/ejmste/100639

Candan, S., & Erten, S. (2015). Pre-service teacher opinions about ecofriendly person activity package developed to raise environmental awareness. *International Electronic Journal of Environmental Education*, *5*(2), 62-85. https://eric.ed.gov/?id=EJ1077728

Çokçalışkan, H., & Çelik, Ö. (2017). Investigation of pre-service classroom teachers' environmental awareness and attitudes. *International Electronic Journal of Environmental Education*, *7*(2), 73-83. https://dergipark.org.tr/en/pub/iejeegreen/issue/75809/1235194

Collado, S., Rosa, C. D., & Corraliza, J. A. (2020). The effect of a nature-based environmental education program on children's environmental attitudes and behaviors: A randomized experiment with primary schools. *Sustainability, 12*(17), Article 6817. https://doi.org/10.3390/su12176817

Coners, A., & Matthies, B. (2014). A content analysis of content analyses in research: Purposes, data sources, and methodological characteristics. *PACIS 2014 Proceedings*, *111*. https://aisel.aisnet.org/pacis2014/111

Esteban Ibáñez, M., Musitu Ferrer, D., Amador Muñoz, L. V., Claros, F. M., & Olmedo Ruiz, F. J. (2020). University as change manager of attitudes towards environment (The importance of environmental education). *Sustainability*, *12*(11), Article 4568. http://dx.doi.org/10.3390/su12114568

Fokides, E., & Kefalinou. M. (2020). Examining the impact of spherical videos in teaching endangered species/environmental education to primary school students. *Journal of Information Technology Education: Research, 19*, 427-450. https://doi.org/10.28945/4612

Gamtos mokslų bendroji programa [General program of natural sciences] (2022). Vilnius. https://www.emokykla.lt/upload/EMOKYKLA/BP/2022-10-10/22_Gamtos%20moksl%C5%B3%20BP_2023-02-28_%C4%AEKELTA%2023-02-28.pdf

Yeşilyurt, M., Balakoğlu, M. O., & Erol, M. (2020). The impact of environmental education activities on primary school students' environmental awareness and visual expressions. *Qualitative Research in Education*, *9*(2), 188–216. https://doi.org/10.17583/qre.2020.5115

Yıldırım, A., & Simsek, H. (2011). *Sosyal Bilimlerde Nitel Ara¸stırma Yöntemleri* [Qualitative research methods in social sciences]. Seçkin.

Yurttaş, G. D., & Sülün, Y. (2010). What are the most important environmental problems according to the second grade primary school students? *Procedia Social and Behavioral Sciences*, *2*(2), 1605–1609**.** https://doi.org/10.1016/j.sbspro.2010.03.244

Kennelly, J., Taylor, N., & Maxwell, T. W. (2008). Addressing the challenge of preparing Australian pre-service primary teachers in environmental education: An evaluation of a dedicated unit. *Journal of Education for Sustainable Development*, *2*(2), 141–156. https://doi.org/10.1177/097340820800200211

Kuckienė, A., & Makarskaitė-Petkevičienė, R. (2006). Aplinkosaugos elementai 1-os klasės ugdymo turinį įgyvendinančiuose vadovėliuose [Elements of environmental protection in textbooks implementing the 1st grade educational content]. *Gamtamokslinis ugdymas / Natural Science Education*, *3*(2), 37-44. https://www.doi.org/10.48127/gu-nse/06.3.37a

Lamanauskas, V. (2009). Gamtamokslinio ugdymo stiprinimo svarba ir būtinumas pradinėje mokykloje [Importance and necessity of strengthening of natural science education in a primary school]. *Gamtamokslinis ugdymas / Natural Science Education*, *6*(1), 4-7. https://doi.org/10.48127/gu-nse/09.6.04

Lamanauskas, V. (2022a). Mokytojų pasirengimas organizuoti ir realizuoti gamtamokslinį ugdymą pradinėje mokykloje [Preparedness of teachers to organize and implement science education in primary school]. *Gamtamokslinis ugdymas bendrojo ugdymo mokykloje / Natural Science Education in a Comprehensive School*, *28*, 15-22. https://doi.org/10.48127/gu/22.28.15

Lamanauskas, V. (2022b). Natural science education in primary school: Some significant points. *Journal of Baltic Science Education*, *21*(6), 908-910. https://doi.org/10.33225/jbse/22.21.908

McBride, B. B., Brewer, C. A., Berkowitz, A. R., & Borrie, W. T. (2013). Environmental literacy, ecological literacy, ecoliteracy: What do we mean and how did we get here? *Ecosphere*, *4*(5), 67-85. http://dx.doi.org/10.1890/ES13-00075.1

Meier, D., & Sisk-Hilton, S. (2017). Nature and environmental education in early childhood. *The New Educator*, *13*(3), 191-194. https://doi.org/10.1080/1547688X.2017.1354646

Merriam, S. B. (1998). *Qualitative research and case study applications in education*. Jossey-Bass Publishers.

Miles, M. B., & Huberman, A. M. (1994). *Qualitative data analysis: An expanded sourcebook.* USA.

Patton, M. (1990). *Qualitative evaluation and research methods* (pp. 169-186). Sage.

Plourde, L. A. (2001). Elementary science education: The influence of student teaching – where it all begins. *Elementary Science Education*, *123*(2), 253-259.

Priešmokyklinio ugdymo bendroji programa [General program of pre-school education] (2022). ŠMS. https://www.emokykla.lt/upload/EMOKYKLA/BP/2022-10-10/02_Priesmokyklinio%2BBP_G_2023-03-16_%C4%AEKELTA%2023-03-22.pdf

Saribas, D., Doganca Kucuk, Z., & Ertepinar, H. (2017). Implementation of an environmental education course to improve pre-service elementary teachers' environmental literacy and self-efficacy beliefs. *International Research in Geographical and Environmental Education*, *26*(4), 311-326. https://doi.org/10.1080/10382046.2016.1262512

Shafer, S. M. (1996). What's so important about science education? *European Education*, *28*(3).

Sola, A. (2014). Environmental education and public awareness. *Journal of Educational and Social Research, 4*(3), 333. http://dx.doi.org/10.5901/jesr.2014.v4n3p333

Stanišić, J., & Maksić, S. (2014). Environmental education in Serbian primary schools: Challenges and changes in curriculum, pedagogy, and teacher training. *The Journal of Environmental Education*, *45*(2), 118-131. https://doi.org/10.1080/00958964.2013.829019

Steg, L., & Vlek, C. (2009). Encouraging pro-environmental behaviour: An integrative review and research agenda. *Journal of Environmental Psychology*, *29*(3), 309–317. https://doi.org/10.1016/j.jenvp.2008.10.004

Sukma, E., Ramadhan, S., & Indriyani, V. (2020). Integration of environmental education in elementary schools. *Journal of Physics: Conference Series*, *1481*, Article 012136. https://doi.org/10.1088/1742-6596/1481/1/012136

Tilbury, D. (1992). Environmental education within pre-service teacher education: The priority of priorities. *International Journal of Environmental Education and Information*, 11(4), 267-280. https://eric.ed.gov/?id=EJ466060

Treagust, D. F., Amarant, A., Chandrasegaran, A. L., & Won, M. (2016). A case for enhancing environmental education programs in schools: Reflecting on primary school students' knowledge and attitudes. *International Journal of Environmental and Science Education*, *11*(12), 5591-5612. https://files.eric.ed.gov/fulltext/EJ1115645.pdf

Türkoğlu, B. (2019). Opinions of preschool teachers and pre-service teachers on environmental education and environmental awareness for sustainable development in the preschool period. *Sustainability*, *11*(18), Article 4925. http://dx.doi.org/10.3390/su11184925

Received: *April 01, 2023*   Accepted: *May 15, 2023*

Cite as: Lamanauskas, V., & Makarskaitė-Petkevičienė, R. (2023). Environmental education in primary school: Meaning, themes and vision. In V. Lamanauskas (Ed.), *Science and technology education: New developments and Innovations. Proceedings of the 5th International Baltic Symposium on Science and Technology Education (BalticSTE2023)* (pp. 122-136). Scientia Socialis Press. https://doi.org/10.33225/BalticSTE/2023.122

THE DURABILITY OF FORMAL KNOWLEDGE AND ITS RESTRUCTURING DURING LIFELONG LEARNING

Małgorzata Nodzyńska-Moroń , Vladimír Sirotek
University of West Bohemia in Pilsen, Czech Republic
E-mail: nodzynsk@kch.zcu.cz, sirotek@kch.zcu.cz

Abstract

Formal science education is the last stage of acquiring scientific knowledge for most people. They rely on the knowledge acquired at school for the rest of their lives. Therefore, it is important that formal education changes students' colloquial knowledge into scientific knowledge and is correct. The study decided to test three situations. In the first one, it was examined whether formal education actually displaces colloquial knowledge of students. In the second, the level of knowledge acquired at school was compared with the level of extracurricular knowledge. The third examined the durability of knowledge acquired at school, i.e. can school knowledge be changed, e.g. through advertising or popular science publications? The main hypothesis of the research was the assumption that school knowledge eliminates erroneous, clichéd beliefs and is permanent over time. The study tested chemical knowledge related to cooking. 472 people participated in the study and an online questionnaire was used. The research built on previous research on the correlation between scientific knowledge and non-scientific beliefs and pedagogical theories on knowledge transfer. The obtained results did not confirm the main hypothesis. Formal school education turned out to be less effective than non-formal education. It seems, therefore, that school education should not focus on facts that students forget and that change during their informal (lifelong) education. Rather, it should focus on the ability to independently construct knowledge.
Keywords: *common knowledge, lifelong learning, pedagogical theories, science education*

Introduction

Despite the prevalence and availability of education in Europe, both formal and informal, many people still have misconceptions about science. International studies on the correlation between scientific knowledge and non-scientific beliefs most often concern the relationship between science and religion, i.a. belief in creationism or Darwinism (Allmon, 2011; Bishop, 2007; Branch, 2008; Cornish-Bowden & Cárdenas, 2007; Brown, 2010; Plutzer & Berkman, 2008; Williams, 2009) or belief in the origin of the universe (De Carvalho, 2013; Fisher, 2006; Gleiser, 2005). Other non-scientific approaches are studied less frequently - one of them is chemical vs natural opposition (Choueka & Friedman, 2012; Li & Chapman, 2012; Nodzyńska, 2021; Rozin et al., 2004). On the other hand, research on the impact of everyday life habits on determining the taste of substances among students of grades 2-6 of primary school was conducted by Nodzyńska and Paśko (2003).

Because, the results of these studies show that many people do not believe in the scientific description of the world, therefore, it seems that teaching science is not effective. It was decided to examine the effectiveness of science education in Poland.

https://doi.org/10.33225/BalticSTE/2023.137

Children, before they start learning science, have extensive knowledge of this subject. In WoS there are 46 articles on the research of children's colloquial knowledge. However, they mainly deal with research in the field of geography (Siegal et al., 2011), astronomy (Venville et al., 2012; Siegal et al., 2004), biology (Gatt et al., 2007) or environmental protection (Schumannhengsteler & Thomas, 1994). Only one article deals with chemical knowledge (Peleg & Baram-Tsabari, 2011). The source of children's knowledge is non-formal education (e.g. family, media). However, their knowledge is sometimes too simplistic and sometimes wrong. The role of the school is to transform common knowledge into scientific knowledge (Nordine et al., 2010). Therefore, the first area of research was to check how effectively formal school education supersedes the everyday, common knowledge of students.

Only some elements of everyday knowledge are included in the Polish Core Curriculum (CC). For example, students do not learn all physical or chemical phenomena, some of them are omitted in the CC. Therefore, it was decided to compare the knowledge of adults in two areas. The first - is the information contained in the Polish Core Curriculum, and the second - is information that is not present in CC.

An important problem in education is retaining and consolidating knowledge. The process of durability and solidity of the acquired knowledge was examined by, among others, (Custers, 2010; De Corte, 2000; Václavík, 1964). It is believed that reliable and lasting knowledge helps to understand new phenomena and their relationships, general laws governing natural and social phenomena, and helps to find the right answers in various situations of everyday life (Custers, 2010; De Corte, 2000; Gilbert, 1976). The process by which knowledge becomes solid and enduring requires a system that includes both formal and informal learning (Affeldt et al., 2016; Bidwell, 2001; Tolppanen et al., 2015).

Research Problems

Compulsory general education ends in Poland at the age of 18. Most people rely on the knowledge gained from this education for the next 50 years. Considering the speed of development of science and scientific progress (Saatsi, 2016) that is being made all the time, it seems that the knowledge obtained at school may not be enough to be a source of true facts for the rest of a person's life. In this connection, two questions arise. First, how persistent and precise school knowledge is. Is formal school knowledge not forgotten or deformed? Secondly, to what extent can this school knowledge be replaced with new facts, e.g. from the media or advertisements? (Affeldt et al., 2016; Bidwell, 2001; Custers, 2010; De Corte, 2000; Gilbert, 1976; Tolppanen et al., 2015). Answering these questions will allow us to reflect on the effectiveness of the current way of teaching science subjects.

The main hypothesis concerned the overall effectiveness of formal school education and was: formal education is more effective than non-formal education.

The research concerned three types of concepts which led to three detailed hypotheses.

The first part concerns concepts known to children from everyday life, which should change their scope in the course of their education from colloquial to scientific ones. The aim of this part of the research was to investigate the effectiveness of school education in reducing imprecise common knowledge and changing it into scientific knowledge. It is considered that formal school education is an effective tool to reduce imprecise common knowledge.

The second part of the research compares the level of knowledge concerning phenomena explained during school education to similar phenomena that were not explained at school. The aim of this part of the research was to test and compare the effectiveness of formal school education to non-formal education. The premise was that students gain more information in formal school education and therefore are better able to explain phenomena described in school than those that were not explained in school.

The third part of the research checks the durability of the knowledge acquired at school. Is it possible to change the school knowledge, e.g. through advertising, or popular science publications? The aim of this part of the research was to examine the sustainability of formal school education. It was assumed that the knowledge acquired at school is permanent and is difficult to change under the influence of new information.

As a common argument in favour of teaching science subjects is the statement that they are useful in everyday life, it was decided to refer to such situations that are also known to people on a daily basis, but on the other hand, appear in the curricula. Therefore, the focus was on questions related to cooking. Since in Poland most people do not buy ready-made products but prepare them themselves, they have a good working knowledge of kitchen issues.

Research Methodology

Theoretical Background

Salmeron in his article (2013) writes that “A major goal of formal education is to foster the transfer of learning, defined as the application of some knowledge learned in a particular context to a different situation. However, too often students are not able to apply what they have learned at school to real life situations.” This sentence is the starting point of this research. The theoretical basis for the research were theories in the field of cognitive psychology. In particular, transfer (Bransford, & Schwartz, 1999; Garcia, 2013; Gomez, Sanjose, & Solaz-Portoles, 2012) both positive and negative (Schwartz, Chase, & Bransford, 2012).

Research Group

Participants of open lectures at the university took part in the study. They were students of bachelor's, master's and doctoral studies, children from primary and secondary schools participating in educational projects at the university, and participants of the University of the 2nd Age (people over 30) and participants of the University of the 3rd Age (people over 50). Participation in the research was voluntary. The study covered 472 people. The research was carried out from December 2019 to March 2020. 65.3% of the respondents were women (which is consistent with statistical data in Poland, women constitute 58% of students, and as much as 86% at universities of the 2nd and 3rd age). Most of the respondents are undergraduate students (48.9%) and graduates (25.0%). 37.4% of the respondents had education in the humanities, 34.4% in science or

https://doi.org/10.33225/BalticSTE/2023.137

technology, and 16.8% in natural sciences. Generation Z (C) accounted for 48.9% of the study participants, generation Y - 33.1%, and generation X - 18.0% (Wrzesień, 2007).

Instruments and Procedures

An online survey created in Google Form was used for the study. The subjects completed the survey during their classes, the survey was anonymous and participation in it was voluntary. The survey contained 22 questions, 5 on student information and 13 on knowledge transfer to cooking processes. 10 questions were closed, single-choice questions, 6 questions were open-ended questions and one was of the "grid of choice" type (8 questions). The questions in the open part partly checked the answers to the closed questions. This article describes only part of the questions: 4 closed and 4 open. In accordance with the division into 3 research areas described above.

The obtained results were subjected to statistical analysis and correlations between the respondents' answers and their characteristics (age, sex, level and type of education) were sought. Due to the fact that the answers given by the respondents were assigned to an ordinal scale, the Kendall test was used for statistical calculations. This test also does not require testing assumptions about the similarity of the distributions of variables to the normal distribution and testing sphericity. Therefore, it is the non-parametric equivalent of analysis of variance. In practice, it is sometimes used to assess the compatibility of rankings, assessments coming from different sources, but concerning the same thing, the same phenomenon. While examining the correlation between the answers given and the characteristics of the respondents, the non-parametric rho-Spearman correlation was used. In the case of this correlation, it does not matter whether the analysed variables have distributions close to normal.

Research Results

Statistical analysis did not show any correlations between gender, age, belonging to a generation (X, Y, Z), education and its type among the respondents (Spearman's correlation coefficient below .2). The only moderate correlations (ρ = .65 and .59) are the quite obvious correlation between the level of education and age, and belonging to a generation (X, Y, Z).

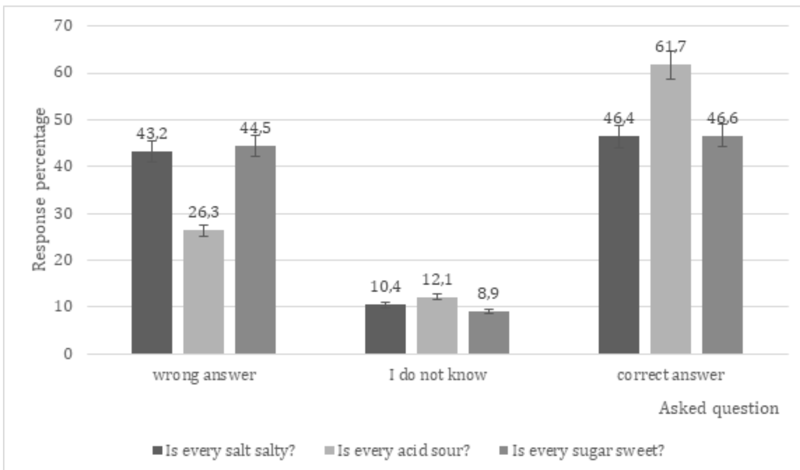
Part 1.

The terms salt and sugar in everyday life refer to table salt and food sugar. The term acid appears less frequently, for example in the case of vinegar or citric acid (although in this case in Poland the term is not "kwas" but "kwasek" which can be translated into English as "little acid"). However, in chemistry, these concepts extend to whole groups of compounds, and table salt (NaCl), food sugar (sucrose) or acids (acetic, citric) are only their representatives and are not the most typical. The Polish core curriculum devoted 10 hours to 'salts', 8 hours to 'acids' and 4 hours to 'sugar'. It seems that this amount of time should eliminate misconceptions among students about these concepts. Hypothesis H_0: Chemistry education does not change the determination of the taste of groups of chemical compounds (salts, acids and sugars) on the basis of representatives known

https://doi.org/10.33225/BalticSTE/2023.137

from everyday life. Alternative hypothesis: Chemistry education influences the change in determining the taste of groups of chemical compounds, most of the respondents do not identify the taste of table salt, table sugar or citric acid with the taste of particular groups of chemical compounds.

Figure 1
Answers of Respondents to Questions About Beliefs About the Taste of Sugar, Salt and Acid



In the questionnaire, the respondents were asked three questions about common beliefs about the taste of sugar, salt and acid. The questions were closed. The respondents had three answers to choose from: Yes, I don't know, No. The obtained results are shown in Figure 1.

It was noted that the percentage of correct answers obtained for the terms "salt" and "sugar" is clearly lower than the percentage of correct answers for the term "acid". This is due to the fact that the names "table salt" and "food sugar" are used directly in this form, and the terms "salt" and "sugar" are written on the packaging. However, for the term "acid" in everyday life, we use products labelled "vinegar" and "citric acid".

Table 1
The Results of the Statistical Analysis for the Answers to the Questions in the First Part

Questions from part 1 of the research	Is every salt salty?	Is every acid sour?	Is every sugar sweet?
Group average	1.037	1.35	1.02
Group standard deviation	.95	.87	.95
χ^2	422.52	355.91	429.79
p-value	.11	**.000044**	.17

Note: (Using the PQStat program, the Chi-square test of single-sample variance was calculated for nominal data (group size 472, significance level 0.05, hypothetical deviation 1, degrees of freedom 471)

Statistical calculations in the case of acid only refute the hypothesis H_0. Therefore, the alternative hypothesis is true - during chemical education, the false image "all acids taste sour" is replaced with the correct "not all acids taste sour". The same cannot be said for salt and sugar.

No correlation was found between the personal data of the respondents and their correct or incorrect answers. A moderate correlation (.51) was noted between the responses regarding the taste of salt and sugar. Weaker relationships exist for the relationship between the term's acid and sugar (.41) and acid and salt (.38).

Part 2.

The Polish Core Curriculum includes 8 hours of lessons on acids, acid-base indicators and pH. This should be enough for primary school graduates to know the subject well.

The study compared the knowledge of information on the indicator known to primary school students from formal education (red cabbage) with the knowledge of information on the indicator known from everyday life (tea). The null hypothesis assumed no differences between the answers to the questions regarding the explanation of the change in the colour of tea and red cabbage. Four questions were asked on this topic. Two closed: *Is every acid sour? To make the cooked red cabbage have a 'nice' red colour, once add vinegar or lemon. Do you know why this is happening?* And two open ones: *Briefly explain why the colour of cooked red cabbage changes when we add vinegar to it. Briefly explain why the colour of black tea changes when we add lemon to it.*

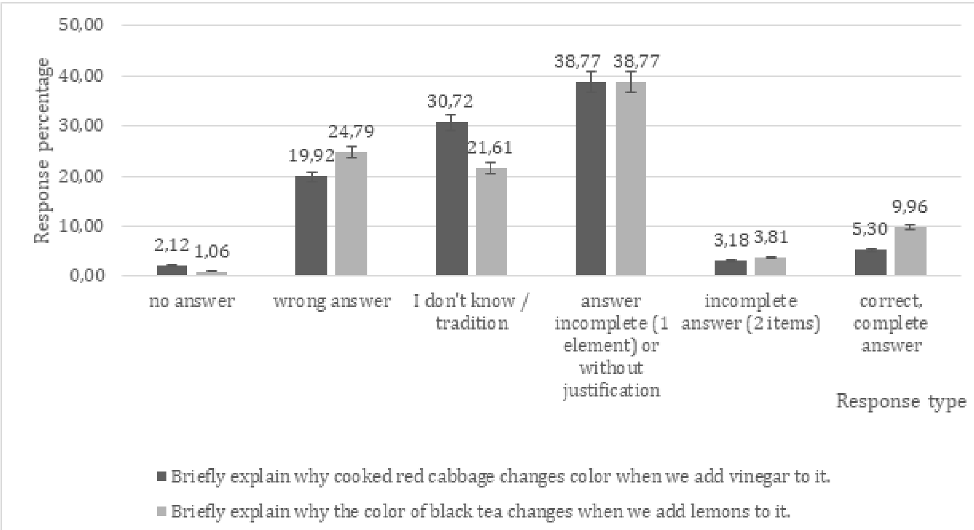
Slightly more than half of the respondents (57.2%) declared that they knew why acid was added to red cabbage. Despite the declaration in the closed question that they know the answer to this question, the answers to the open question show a different situation. As shown in Figure 2, most of the answers in this question are incomplete. Only 5.3% of the respondents explained the complete process that was taking place. The vast majority of respondents wrote one word instead of an explanation (e.g. acid, indicator, pH, chemical reaction). It is hardly an "explanation". It can be said that the respondents overestimate their knowledge.

As students provided many and varied answers, they were divided into 6 categories: full, correct answers explaining the process; incomplete answers (some information missing, 2 items provided); incomplete answers (1 explaining item) or no explanation; "I don't know" or "tradition"; wrong answer; no answer (shown in Figure 2).

A comparison of the respondent's responses to the colour change of red cabbage (an indicator discussed in school) and tea (an indicator not discussed in school) shows little difference between the responses in favour of tea. Although the properties of tea as an indicator do not appear in the Polish CC, almost 10% of respondents correctly explain the ongoing process. In the case of red cabbage, it is just over 5%. Particularly noteworthy is the difference in the answers "I don't know". Almost every third of respondents declares that they do not remember this fragment of school knowledge. The difference in incorrect answers is due to the fact that many respondents claimed that adding a light-yellow lemon to a dark brown tea will "physically lighten it" (the concentration of tea in the solution would be lower as if water or another solvent had been added).

https://doi.org/10.33225/BalticSTE/2023.137

Figure 2
Comparison of Respondents' Responses to the Colour Change of Red Cabbage (an Indicator Discussed at School) and Tea (an Indicator not Discussed at School)



The Kendall test was used for statistical calculations because the answers given by the respondents were assigned to a six-point ordinal scale (see Table 2).

Table 2
The Results of the Statistical Analysis for the Answers to the Questions in the Second Part

Kendall test results for four questions from the second part of the study.	χ^2	*p*-value
Do all acids have a sour taste?	355.91	.000044
To make the cooked red cabbage have a 'nice' red colour, once add vinegar or lemon. Do you know why this is happening	468.20	.79
Briefly explain why the colour of cooked red cabbage changes when we add vinegar to it.	537.86	.035
Briefly explain why the colour of black tea changes when we add lemon to it.	699.98	< .000001

Note: Using the PQStat program, the Chi-square test of single-sample variance was calculated for nominal data (group size 472, significance level 0.05, hypothetical deviation 1, degrees of freedom 471).

Responses to questions "Briefly explain why the colour of cooked red cabbage changes when we add vinegar to it." & "To make the cooked red cabbage have a 'nice' red colour, once add vinegar or lemon. Do you know why this is happening" were assumed to be coherent, however Kendall's Significance Test shows a lack of agreement (*p*-value <.000001). On the other hand, the comparison of answers to two questions concerning red cabbage and tea ("Briefly explain why the colour of cooked red cabbage changes when we add vinegar to it." & "Briefly explain why the colour of black tea changes when we add lemon to it.") shows no significant differences in the answers (p-value = .25).

The study examined Spearman's correlation between the answers to individual questions and gender, age, type and level of education. Only if the answer to the question "To make the cooked red cabbage have a 'nice' red colour, add vinegar or lemon. Do you know why this is happening?" a low correlation (clear relationship) was found between the answer to this question and age (.22), level of education (.23) and generation (.20).

However, these collections are practically 0 for the answer to the open question "Briefly explain why the colour of cooked red cabbage changes when we add vinegar to it".

It was also decided to examine whether there is a correlation between the answers to individual questions. A low correlation was found between the individual questions (see Table 3). A correct answer to a given question usually did not affect the correct answer to another question.

Table 3
Spearman's Correlation Coefficient between Individual Questions

No	Question no	1.	2.	3.	4.
1.	Is every acid sour?		.03	.02	.04
2.	To make the boiled red cabbage have a 'nice' red colour, add vinegar or lemon. Do you know why this is happening?	.03		.26	.22
3.	Briefly explain why the colour of cooked red cabbage changes when we add vinegar to it.	.03	.26		.36
4.	Briefly explain why the colour of black tea changes when we add lemons to it.	.04	.22	.36	

Part 3.

In the Polish CC, fats as chemical compounds are devoted to only 2 hours. The division into animal (saturated) and vegetable (unsaturated) fats is introduced. Students are told that saturated fat is bad for their health. In chemistry textbooks, lard appears among the examples of animal fats. This school knowledge is not precise. Lard, although it is animal fat, contains 57% of unsaturated acids. On the other hand, coconut oil, although vegetable fat, contains 87% of saturated acids. In recent years, coconut oil has been touted as a healthy fat. Recently, there are also publications that disprove this claim. The questions concerning both fats were to verify the knowledge of the respondents:

- Answer the question of whether lard is healthy. Justify your answer.
- Answer the question of whether coconut oil is healthy. Justify your answer.

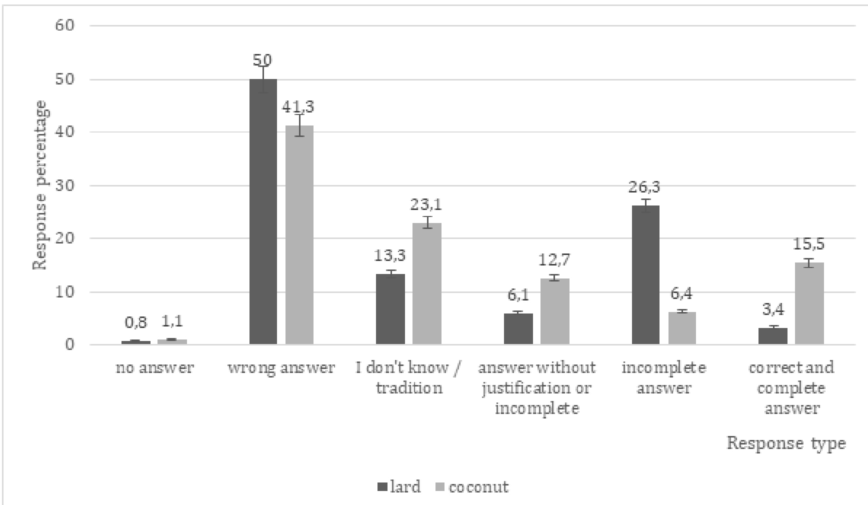
The aim of the question was to check whether the respondents had verified their school knowledge. Has knowledge from advertising, and magazine articles changed their incorrect school knowledge about lard? And whether there is a difference between the knowledge of the respondents about lard (which they learned about in school) and coconut oil (which they did not learn about). Null hypothesis - there are no differences between knowledge acquired at school and knowledge coming from informal education.

https://doi.org/10.33225/BalticSTE/2023.137

Open responses are broken down into six categories (Figure 3):

- no answer,
- wrong answer,
- I don't know / tradition,
- answer without justification or incomplete,
- incomplete answer,
- correct and complete answer.

Figure 3
Comparison of the Correctness of Answers Concerning Lard and Coconut Oil



The answer "tradition" included phrases such as "it is healthy/unhealthy because mum/grandma used to say so", and "everyone says so". It was found that the respondent did not have an opinion, which is tantamount to the statement "I don't know". The percentage of such responses was negligible (less than 1%), therefore it was concluded that there is no need to create a separate category.

The answer "answer without justification or incomplete" includes answers in which the respondent correctly stated that the given fat is healthy or not, but did not provide any justification for his statement. And also answers in which only one argument was given (e.g. it is "healthy fat because unsaturated", or "unhealthy because fat").

The answer "incomplete answer" includes answers in which the respondent correctly stated that the given fat is healthy or not and additionally justified his statements, but these statements related to medical aspects (e.g. increasing cholesterol, the energy value of fats, problems with being overweight ...). There was no reference in these responses to information in the field of chemistry (having or not having double bonds).

In "correct and complete answer", the respondents not only correctly defined the belonging of fat to the group of saturated and unsaturated fats but also commented on the situations in which it is better to use a given fat and referred to changing information about the "health" of individual fats.

As shown in Figure 3, as many as 50% of respondents have incorrect knowledge about lard originating from school. They believe that lard is harmful because it is animal

https://doi.org/10.33225/BalticSTE/2023.137

fat and as such is saturated fat. Only 3.4% of the respondents verified their knowledge and answered fully correctly. It is different from coconut oil. It is true that a large proportion of respondents (41.3%) incorrectly answer that coconut oil is a healthy oil because it is a vegetable oil, i.e. it has a lot of unsaturated fats, but many people (15.5%) give full, correct explanations (often with the discussion that the sentences on coconut oil have changed several times).

It can therefore be concluded that school knowledge blocks new information. This is in accordance with the laws of psychology, in this case one speaks of proactive inhibition or negative transfer.

Table 4
Compare Grouped Responses

Type of fat	Wrong answer	I don't know	Correct answer
Lard	50.8	13.3	35.8
Conut	42.4	23.1	34.5

Due to the large variety of answers, they were grouped into three categories (Table 4). In this case, there is no statistically significant differences in the correct answers. However, there is a very big difference in the case of incorrect answers. It can be stated that the respondents are confident in their school knowledge of animal fats and do not intend to change it. Kendall's test of significance also shows no significant differences in responses (p-value .10). Therefore, it can be concluded that there are no differences between the knowledge acquired at school and the knowledge derived from informal education.

Discussion

The research did not confirm the main hypothesis. Formal school education turned out to be less effective than non-formal education.

In the first part of the research, we checked whether chemicals familiar to people from everyday life change their conceptual scope from every day to scientific in the course of education (Nordine et al., 2010). The obtained results show that this change does not occur. Common knowledge about the flavors of popular substances is permanent and blocks scientific knowledge. We can talk here about the phenomenon of negative transfer (Garcia, 2013; Schwartz et al., 2012) or proactive inhibition. These phenomena occur when previous experience makes it difficult to master new ones.

Thus, we can conclude that formal education does not sufficiently change incorrect colloquial notions into correct scientific ones. Incorrect association of flavours of whole groups of chemical compounds with their typical representatives occurs both in adults and in the earlier study of children (Nodzyńska & Paśko, 2003). The biggest change was in the concept of "acid". This is due to the fact that no product used in everyday life is called "acid" (the names vinegar and citric acid are used). Concepts such as "salt" or "sugar" are present in our daily lives, therefore the properties of their everyday representatives are transferred to the whole group of chemical compounds. This part of the research shows that well-established common knowledge is difficult to change as a result of school education.

In the second part of the study, the level of knowledge about the phenomena explained during school education was compared with similar phenomena that were not explained at school. It examined whether there was a transfer of knowledge, defined as the application of some knowledge acquired in a certain context to another situation. That is, whether students are unable to apply what they learned at school in real life situations (Salmeron, 2013). In this case, we can talk about a very close transfer (Haskell, 2001) because it was examined whether knowledge concerning one of the indicators (red cabbage) is used in a similar case (tea). It turned out that the respondents declare that they know how indicators work, but explaining the presented processes on their own exceeds their skills. Respondents know "WHAT" they don't know "HOW" and "WHY". And because in the subjective aspect, three types of knowledge are distinguished: declarative knowledge (“I know that”), procedural knowledge (“I know how”) and meta-knowledge (“I know that I know”), it can be concluded that the respondents did not reach the level of meta-knowledge (Nęcka et al., 2020).

The number of correct but incomplete answers is similar in both cases. However, twice as many correct answers were obtained for a process not covered in school. This calls into question the effectiveness of formal school education.

The third part of the research checks the durability of the knowledge acquired at school. It turned out that the knowledge about coconut oil, which is not included in the Core Curriculum, is broader and more up-to-date than the knowledge about animal fats acquired at school. The lard results show how long-lasting knowledge acquired in school can be. It is a pity that in this case the stimulus was generalized and the properties of most animal fats were "transferred" to lard. The results obtained, only 35.8% correct answers for the fat discussed in school, are comparable to the results of Custers (2010), which suggests that about two-thirds to three-quarters of the knowledge will be retained after one year, with a further decrease to just under fifty percent in the following year.

It turns out that formal school knowledge does not supersede the colloquial knowledge of students, it is not stable over time (Custers, 2010; De Corte, 2000; Václavík, 1964) and often adults have broader knowledge acquired in their adult life than that acquired at school.

The obtained results show that despite several years of learning chemistry in a formal way at school, the respondents still have erroneous ideas taken from early informal education and often their informal knowledge is broader and more correct than that remembered at school.

Conclusions and Implications

At the beginning of the research, questions were asked about the durability and accuracy of school knowledge compared to informal knowledge acquired throughout life. The purpose of these questions was to reflect on the effectiveness of the current way of teaching science (in this case, chemistry). The obtained results showed that school education does not effectively correct the earlier misconceptions of students. It is no more effective than non-formal education and sometimes causes misconceptions in students. The results show a large impact of various types of knowledge transfer on the achieved results.

The practical implication from the first part of the research is: since well-established common knowledge is difficult to change as a result of formal education, it seems that correct scientific knowledge should be introduced as early as possible. In this particular case, it seems that a good solution would be to use the names "table salt" and "food sugar" in formal education (even in kindergarten) to make children aware of the difference between a representative and his entire family. In school education, however, there should be a return to the name carbohydrates for the sugar family.

The second and third part of the research showed the advantage of informal knowledge over formal knowledge acquired at school. It seems, therefore, that formal education should focus more on competences related to scientific thinking than on facts that are forgotten.

In the third part of the research, it also turned out that too generalized school knowledge blocks further acquisition of knowledge. It seems, therefore, that teachers should carefully introduce generalizations or simplifications.

It seems that further research should go in two directions. A broader study of knowledge transfer in particular topics and how to teach students how transfer can be used in education.

Declaration of Interest

The authors declare no competing interest.

References

Affeldt, F., Tolppanen, S., Akselab, M., & Eilks, I. (2017). The potential of the non-formal educational sector for supporting chemistry learning and sustainability education for all students – a joint perspective from two cases in Finland and Germany. *Chemistry Education Research and Practice, 18*(1), 13-25. https://doi.org/10.1039/c6rp00212a

Allmon, W. D. (2011). Why don't people think evolution is true? Implications for teaching, in and out of the classroom evolution. *Evolution: Education and Outreach, 4*(4), 648–665. https://doi.org/10.1007/s12052-011-0371-0

Bidwell, Ch. E. (2001). Analyzing schools as organizations: Long-term permanence and short-term change. *Sociology of Education, 74*(Extra Issue), 100-114. https://www.jstor.org/stable/2673256

Bishop, G. (2007). Polls apart on human origins. *Reports of the National Center for Science Education*, *27*, 35–41.

Branch, G. (2008). Creationism as a global phenomenon. In R. Robbins, & M. Cohen, (Eds.), *Darwin and the bible: the cultural confrontation* (pp. 137–151). Allyn, & Bacon.

Bransford, J. D., & Schwartz, D. L. (1999). Rethinking transfer: A simple proposal with multiple implications. *Review of Research in Education, 24*, 61-100.

Brown, C. M. (2010). Hindu responses to Darwinism: Assimilation and rejection in a colonial and post-colonial context. *Science & Education*. *19*, 705–738.

Byrne, J. (2011). Models of micro-organisms: Children's knowledge and understanding of micro-organisms from 7 to 14 years old. *International Journal of Science Education*, *33*(14), 1927–1961. https://doi.org/10.1080/09500693.2010.536999

Cornish-Bowden, A., & Cárdenas, M. L. (2007). The threat from creationism to the rational teaching of biology. *Biological Research, 40*, 113–122.

Choueka, J., & Friedman, A. (2012). Herbal medicine in dermatology: Does natural = safe? *Journal of Drugs in Dermatology*, *11*(6), 774-776.

Custers, E. J. F. M. (2010). Long-term retention of basic science knowledge: A review study. *Advances in Health* Sciences Education, *15*, 109–128. https://doi.org/10.1007/s10459-008-9101-y

De Carvalho, R. (2013). The Big Bang theory – coping with multi-religious beliefs in the super-diverse science classroom. *School Science Review, 95*(350), 119-126. https://eric.ed.gov/?id=EJ1016067

De Corte, E. (2000). Marrying theory building and the improvement of school practice: A permanent challenge for instructional psychology. *Learning and Instruction, 10*(3), 249–266.

Fisher, B. (2006). Making an impact with the Big Bang. *School Science Review, 88*(323), 75–79.

Gatt, S., Tunnicliffe, S. D., Borg, K., & Lautier, K. (2007). Young Maltese children's ideas about plants. *Journal of Biological Education*, *41*(3), 117–122. https://doi.org/10.1080/00219266.2007.9656080

Garcia, A., B., S. (2013). Algorithmic errors. Cognitive processes and educational actions. *Teoria De La Educacion, 25*(1), 215-235.

Gilbert, G. N. (1976). The transformation of research findings into scientific knowledge. *Social Studies of Science*, *6*(3/4), 281-306. https://www.jstor.org/stable/284685

Gleiser, M. (2005). *The dancing universe: From creation myths to the Big Bang*. Darthmouth College.

Gomez, C., B., Sanjose, V., & Solaz-Portoles, J., J. (2012). A review of the transfer processes for the learning and teaching of sciences. *Didactica De Las Ciencias Experimentales Y Sociales*, (26), 199-227.

Haskell, R. (2001). *Transfer of learning: Cognition, instruction and reasoning*. Academic Press.

Impey, Ch., Buxner, S., & Antonellis, J. (2012). Non-scientific beliefs among undergraduate students. *Astronomy Education Review, 11*(1). https://eric.ed.gov/?id=EJ999215

Li, M., & Chapman, G. B. (2012). Why do people like natural? Instrumental and ideational bases for the naturalness preference. *Journal of Applied Social Psychology, 42*(12), 2859-2878. https://doi.org/10.1111/j.1559-1816.2012.00964.x

Nordine, J., Krajcik, J., & Fortus, D. (2010). Transforming energy instruction in middle school to support integrated understanding and future learning. *Science Education, 95*(4), 670–699. https//doi.org/10.1002/sce.20423

Nęcka, E., Orzechowski, J., & Szymura, B. (2020). *Psychologia poznawcza* [Cognitive psychology]. PWN.

Nodzyńska, M. (2021). Chemical vs. natural: Common misconceptions. In. V. Lamanauskas (Ed.), *Science and technology education: Developing a global perspective. Proceedings of the 4th International Baltic Symposium on Science and Technology Education (BalticSTE2021)* (pp. 126-134). https://www.ceeol.com/search/chapter-detail?id=981553

Nodzyńska, M., & Paśko, J. R. (2003). Wpływ nawyków z życia codziennego na określanie smaków substancji wśród uczniów klas 2-6 szkoły podstawowej [The influence of daily habits on the identification of the flavours of substances among pupils in grades 2-6 of primary school]. In R. Gmoch, (Ed.), *Jakość kształcenia a kompetencje zawodowe nauczycieli przedmiotów przyrodniczych* [Quality of education and professional competence of teachers of natural subjects]. (pp. 69-74).Wydawnictwo Uniwersytetu Opolskiego.

Peleg, R., & Baram-Tsabari, A. (2011). Atom surprise: Using theatre in primary science education. *Journal of Science Education and Technology*, *20*, 508–524. https://doi.org/10.1007/s10956-011-9299-y

Plutzer, E., & Berkman, E. (2008). Evolution, creationism, and the teaching of human origins in schools. *Public Opinion Quarterly, 72*(3), 540–553. https://www.jstor.org/stable/25167646

Rozin, P., Spranca, M., Krieger, Z., Neuhaus, R., Surillo, D., Swerdlin, A., & Wood, K. (2004). Preference for natural: Instrumental and ideational/moral motivations, and the contrast between foods and medicines. *Appetite*, *43*(2), 147-154.

Saatsi, J. (2019). What is theoretical progress of science*? Synthese, 196,* 611–631. https://doi.org/10.1007/s11229-016-1118-9

Salmeron, L. (2013). Activities that promote transfer of learning: A review of the literature. *Revista De Educacion*, Special Issue. 34-53. http://dx.doi.org/10.4438/1988-592X-RE-2013-EXT-253

Siegal, M., Nobes, G., & Panagiotaki, G. (2011). Children's knowledge of the earth. *Nature Geoscience, 4*, 130–132. https://doi.org/10.1038/ngeo1094

Siegal, M., Butterworth, G., & Newcombe, P. A. (2004). Culture and children's cosmology. *Developmental Science, 7*(3), 308-324.

Southerland, S. A., Sinatra, G. M., & Matthews, M. R. (2001). Belief, knowledge, and science education. *Educational Psychology Review*, *13*(4), 325-351.

Schumannhengsteler, R., & Thomas, J. (1994). What do children know about environmental-protection. *Psychologie in Erziehung Und Unterricht, 41*(4), 249-261.

Schwartz, D., L., Chase, C., C., & Bransford, J., D. (2012). Resisting overzealous transfer: Coordinating previously successful routines with needs for new learning. *Educational Psychologist*, *47*(3), 204-214. https://doi.org/10.1080/00461520.2012.696317

Tolppanen S., Vartiainen J., Ikävalko V. M., & Aksela M. (2015). Relevance of non-formal education in science education. In Eilks I., & Hofstein A. (Eds.), *Relevant chemistry education: From theory to practice* (pp. 335–354). Sense.

Topliss, J. G., Clark, A. M., Ernst, E., Hufford, C. D., Johnston, G. A. R., Rimoldi, J. M., & Weimann, B. J. (2002). Natural and synthetic substances related to human health. (IUPAC Technical Report) *Pure and Applied Chemistry, 74*(10), 1957–1985.

Václavík, V. (1964). Upevňovanie vedomostí a jeho miesto v systéme vyučovania [Consolidating knowledge and its place in the teaching system]. *Pedagogika, 1*, 7-16.

Venville, G. J., Louisell, R. D., & Wilhelm, J. A. (2012). Young children’s knowledge about the moon: A complex dynamic system. *Research in Science Education, 42*, 729–752. https://doi.org/10.1007/s11165-011-9220-y

Williams, J. D. (2009). Belief versus acceptance: Why do people not believe in evolution? *BioEssays, 3*, 1255–1262.

Wrzesień, W. (2007). Czy pokoleniowość nam się nie przydarzy? [Won't posterity happen to us?]. *Nauka, 3,* 131-151.

Received: *March 30, 2023* Accepted: *May 12, 2023*

Cite as: Nodzyńska-Moroń, M., & Sirotek, V. (2023). The durability of formal knowledge and its restructuring during lifelong learning. In V. Lamanauskas (Ed.), *Science and technology education: New developments and Innovations. Proceedings of the 5th International Baltic Symposium on Science and Technology Education (BalticSTE2023)* (pp. 137-150). Scientia Socialis Press. https://doi.org/10.33225/BalticSTE/2023.137

UNIVERSITY STUDENTS' OPINIONS ON THE USE OF 3D HOLOGRAMS IN LEARNING ORGANIC CHEMISTRY

Stanislava Olić Ninković , Jasna Adamov
University of Novi Sad, Republic of Serbia
E-mail: stanislava.olic@dh.uns.ac.rs, jasna.adamov@dh.uns.ac.rs

Abstract

3D holograms are an effective tool for visualization, and their utilization in chemistry teaching can be beneficial in improving learning outcomes. However, studies on students' opinions about holograms in chemistry teaching and learning are scarce. The research aimed to examine the views of chemistry students on the application of 3D holograms in organic chemistry learning at the university level. In this cross-sectional study, 55 first-year chemistry students at the University of Novi Sad (Serbia) participated. The sample consisted of students aged 18-20, of which 85.5% were female and 14.5% were male. An online questionnaire designed for this research was used to collect quantitative data. Data obtained after an eight-week application of 3D holograms in organic chemistry classes revealed that students have a positive opinion about the application of 3D holograms in organic chemistry classes. Therefore, the research results imply that teachers should apply 3D holograms in chemistry classes.
Keywords: *augmented reality, 3D holograms, chemistry education, students' opinion*

Introduction

New generations of students, which are called Generation Z or Millennial students, have grown up in digital environments, developing specific attitudes, beliefs, social norms, and behaviors. Working with these students demands of educators a change in the strategies and design of teaching and learning. Therefore, teachers are constantly looking for new approaches to motivate and engage new generations of students in learning. Technological development plays a very important role in improving the educational process, which increased interest in the application of virtual and augmented reality (Cheng & Tsai, 2013). The potential of augmented reality for improving students' domain-specific knowledge and general skills (that is, collaboration) has been increasingly acknowledged (Ke & Hsu, 2015). The 3D hologram is one of the most advanced technologies recognized as an effective visualization tool (Hoon & Shaharuddin, 2019), which is based on the use of a computer system or smartphone to create the illusion of a three-dimensional image and mimic the real world (Moro et al., 2021). The representation of images goes beyond the two-dimensional (2D) screen to the 3D space through light diffusion, which allows a high sense of reality (Yoo et al., 2022). This projection of virtual content is mediated by the aid of technological devices and transparent surfaces.

Hologram technologies are applicable to a variety of industries (Yoo et al., 2022). In recent years, the application of 3D holograms has become more popular

https://doi.org/10.33225/BalticSTE/2023.151

in various fields such as medicine (Barsom, et al., 2016; Mishra, 2017), architecture and engineering (Behzadan et al., 2015), and education (Akçayır et al., 2016; Hoon & Shaharuddin, 2019). In the field of education, 3D holograms aim to help students and teachers see objects from different angles that are not available in traditional teaching and learning environments (Hoon & Shaharuddin, 2019). Several empirical studies have confirmed that the application of 3D holograms in education has positive effects on students: it contributes to a better understanding of the material (Moro et al., 2021), improves learning outcomes (Akcaiır et al., 2016; Hoon & Shaharuddin, 2019), and increases student motivation (Akcaiır et al., 2016; Hoon & Shaharuddin, 2019; Moro et al., 2021). It can be said that the 3D holograms in the classroom represent a futuristic way to improve teaching and learning (Ramachandiran et al., 2019). One essential advantage of 3D holograms is their suitability for learners of all ages. Several studies have reported on the use of holograms in preschool, elementary, and high school education, and studies that specifically examined teachers' and students' perceptions of the use of technology in education are limited (Yoo et al., 2022). However, the use of 3D holograms in the classroom has limitations such as the costs of purchasing additional equipment, maintenance, and the costs of teacher training for their creation and implementation. Since the hologram is a major technological advance, its implementation and maintenance will not be cheap because resources are limited depending on institutions or countries (Ramachandiran et al., 2019).

The number of studies concerning the application of 3D holograms in the teaching of natural sciences is thin and relates primarily to the development of visualization tools for scientific spatial understanding: the understanding of the geometric structure of molecules (Hinsen, 2000; Cheng & Tsai, 2013), laboratory work (Akçayır et al., 2016), inquiry-based learning (Squire & Klopfer 2007). The great potential of applying 3D holograms in education has been recognized. However, the application of augmented reality and holograms in education is still in its infancy, and studies on this issue are still rare (Cheng & Tsai, 2013). Few existing studies have focused on the development, usability, and initial implications of 3D holograms (Akçayır et al., 2016; El Sayed et al., 2011). Yoo et al (2022) found that there was a lack of examining the educational effects in a more structured, generalized, and replicable manner. These questions require further attention to stably apply the new technology and maximize the benefits of the 3D holograms for enhancing students’ learning experience, outcomes, and performance.

Research Problem

With the increased interest and application of 3D holograms in teaching, the need for research into the effectiveness and perception of teachers and students increases. Furthermore, their users must also be asked for their opinion on their usefulness and usability. The focus of this research was the students' opinions about the possibilities of applying 3D holograms in chemistry classes. The contribution of this research is to provide insight into students’ feedback on the integration of 3D holograms into the chemistry learning environment, understanding the factors for motivating and engaging students to improve their skills at the higher education level. Due to the complexity of the chemical contents, every support in overcoming the problems and understanding the chemical contents is necessary.

https://doi.org/10.33225/BalticSTE/2023.151

Research Aim and Research Questions

This research aimed to examine chemistry students' opinions about the application of 3D holograms in learning organic chemistry at the university level. The following research questions were posed:

1. To what extent have students used 3D holograms in education so far?
2. How much do students perceive the values of 3D holograms in learning organic chemistry?
3. What are the students' perceptions of possibilities for using 3D holograms in other chemistry disciplines?

Research Methodology

General Background

This research examined the perceptions of chemistry students about the application of 3D holograms in university organic chemistry learning. The research was conducted during the 2021-2022 school year on a sample of 55 first-year students (aged 18-20). We conducted a preliminary study to examine students' opinions on the application of 3D holograms in chemistry classes. During the eighth week, holograms were used in theory classes, which were made for research purposes following the curriculum of Organic Chemistry I. After the course, students were surveyed with an online questionnaire on the role and importance of 3D holograms in organic chemistry classes using their mobile phones.

Sample

The convenience sample consisted of first-year students of one study program– Bachelor in Chemistry at the Department of Chemistry, Biochemistry, and Environmental Protection of the Faculty of Science, University of Novi Sad in Serbia. In the first year of study, 60 students enrolled in this program, while in the present research, 55 students participated and filled out the survey. The research was conducted during the summer semester of the 2021/2022 school year. The age of the students was in the range of 18 to 20 years. The sample consisted of 14.5% male and 85.5% female students. The students were informed that the research was anonymous and that their participation was voluntary so that they could withdraw from the research at any time without consequences.

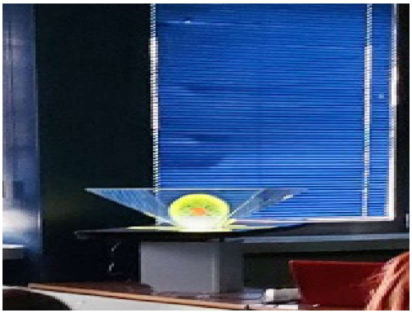
Instrument and Procedures

This research was conducted on the subject of Organic Chemistry I. The course is compulsory, and it is conducted during the summer semester with 4 theoretical hours and 3 hours of laboratory work per week. This course includes teaching content on characteristic functional groups in organic molecules, structure, and bonds, nomenclature, and their physical and chemical properties. Due to their complex nature and study at the micro level, the above contents are often very difficult for students to understand. Understanding the structure of molecules is often abstract to students, so it is much easier to represent them with the help of holograms.

https://doi.org/10.33225/BalticSTE/2023.151

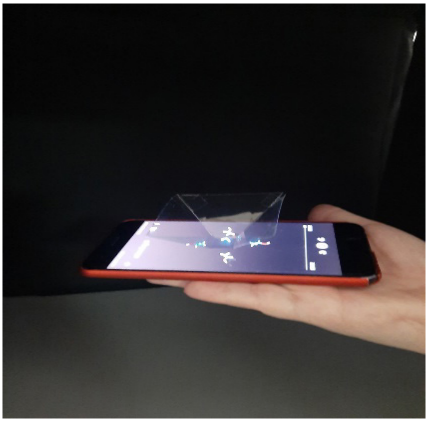
The 3D holograms used were created in Filmora's Wondershare program as 1- to 3-minute non-narrated videos (Figure 1). Two university professors from the field of organic chemistry and one professor from the field of educational technology participated in the videos. They consulted and relied on the opinion of pedagogues during the drafting process.

Figure 1
Examples of 3D Holograms for Teaching Organic Chemistry



During the summer semester of the 2021/2022 academic year, holograms were used in organic chemistry classes during the new material processing. 3D Holograms were used every week, for 8 weeks of lecture classes. During work, there were no technical problems such as connection problems, power outages, etc. The students watched the 3D holograms with the teacher's explanation, with the possibility of rewatching the holograms during the lesson. The students received mini prisms that they could also use when studying at home via their own mobile devices (Figure 2). In this way, it was ensured that students see the 3D holograms over and over again while studying the course content at a pace that suits them.

Figure 2
Students' 3D Holograms for Smartphones



https://doi.org/10.33225/BalticSTE/2023.151

After the course, students were surveyed about the role and importance of 3D holograms in chemistry classes. To collect quantitative data, a questionnaire that was constructed for this research was used. The survey consisted of six questions that were asked to students through an electronic voting system accessed through their mobile phones. The questions were of different types; three questions were given in the form of multiple choices, two questions in the form of a 5-point Likert scale, and one open-ended question. All survey questions are provided in Appendix.

Data Analysis

Descriptive statistics were used in the analysis of the collected data. Students' answers to open-ended and multiple-choice questions were analyzed by calculating frequencies and percentages. In addition to that, the mean values for students' answers to questions in the form of a 5-point scale were calculated. The analysis was done in MS Excel.

Research Results

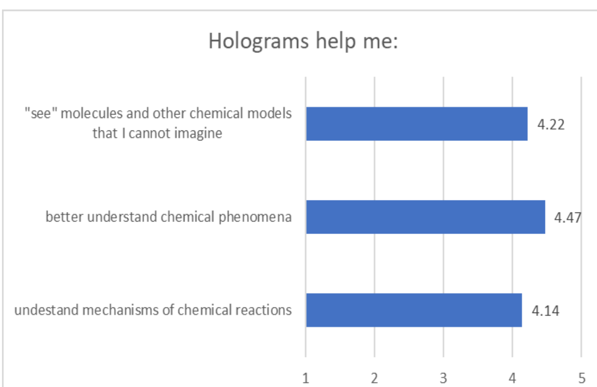
Students' answers to the first question provided information on their previous experience and the opportunity to see 3D holograms. Of the total sample of students, 90.9% had never had the opportunity to see live three-dimensional 3D holograms before. The other 9.1% of students have seen them but never used them during teaching/learning.

After the organic chemistry classes were held using 3D holograms, the majority of students (49 students, i.e., 89.1%) liked the use of 3D holograms in classes. Only 3.6% of the sample (that is, 2 students) had a negative opinion about their application, while the other 4 students (7.3%) did not have a certain attitude towards 3D holograms.

The reasons provided by the students for their opinion are given in Figure 3. Students rated the three offered statements on a 5-point Likert scale, where 1 means complete disagreement, and 5 - complete agreement. Figure 3 displays the mean values of the students' responses.

Figure 3

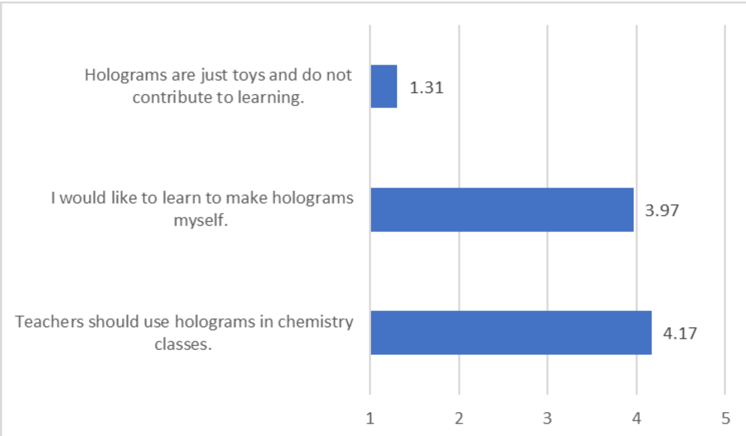
Students` Opinions Regarding Usefulness of Holograms in Learning



Note: 1 means complete disagreement, and 5 - complete agreement

When asked about the applicability and role of 3D holograms in teaching, the students rated the statements on the same Likert scale. Figure 4 displays the mean values of the students' responses.

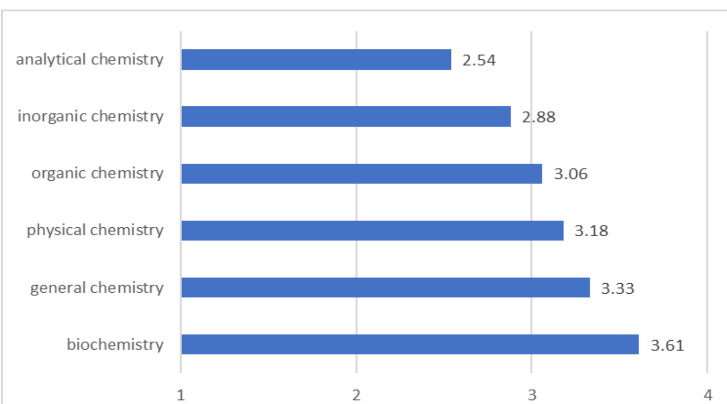
Figure 4
Students` Opinions about the Applicability and Role of 3D Holograms in Learning



Note: 1 means complete disagreement, and 5 - complete agreement

In the fifth question, students were asked to arrange the offered chemical disciplines in descending order according to the possibilities and the need to apply 3D holograms within classes in the courses in those fields. Their opinions are shown in Figure 5. In the first place there is the discipline in which the implementation of 3D holograms, according to the students, was the most useful, and in the sixth place - is the discipline for which holograms are the least important.

Figure 5
Students` Opinions about the Application of 3D Holograms in Differences Chemical Disciplines



In response to the sixth open-ended question, students reported which 3D holograms they would like teachers to make and use in explanations during lectures and exercises. The students could provide multiple answers to this question. More than a third of the students (34,5%) reported that they would like to see teachers present chemical reaction mechanisms. Furthermore, 23.6% of the participants reported that they would like to see holograms of the 3D structures of molecules and the spatial arrangement of the atoms in them. 11% of students indicated that holograms provided the possibility of isomerism, while 9% of students indicated that they were interested in the rotation of molecules by a certain angle to better understand the structural characteristics of the molecule. According to the students, holograms should show the formation of chemical bonds and hybridization (9%), the structure of crystal lattices (9%), as well as the development of some technological processes (9%).

Discussion

Chemistry is a complex subject for many students because it contains many abstract concepts (Santos & Arroio, 2016). Understanding these phenomena is often difficult without the use of various visualization tools (Jones et al., 2005). Given that 3D holograms are one of the most advanced technologies for visualization (Hoon & Shaharuddin, 2019), this research was conducted to examine the opinions of chemistry students about the application of 3D holograms in the learning of organic chemistry at the university level.

The obtained results indicated that none of the students included in this research had ever had the opportunity to use or see 3D holograms during learning before. However, few students have had the opportunity to see live 3D holograms outside of an educational context. This result unequivocally confirms that 3D holograms are a new teaching tool and that their application is in its infancy in education environments and other fields (Cheng & Tsai, 2013).

The majority of students said that they liked the use of 3D holograms in classes. The obtained results showed that students had a coherent opinion that the application of 3D holograms in the learning of organic chemistry was useful. The results of other research have mostly shown positive attitudes (satisfaction or perceived usefulness) of students towards augmented reality and the application of 3D holograms (Akçayır et al., 2016; Cheng & Tsai, 2013; Hoon & Shaharuddin, 2019, Moro et al., 2021).

All student responses indicated a high level of agreement with the given statements. Surveyed students reported that 3D holograms made it easier for them to visualize models of molecules and mechanisms of chemical reactions, and thus helped them to gain a better understanding of various abstract concepts, phenomena, and processes encountered in chemistry classes. According to scientific studies, organic chemistry concepts are burdensome for many students and are the source of numerous misconceptions (Duis, 2011).

In summarizing the students' responses about the applicability and role of 3D holograms in chemistry classes, it can be concluded that most students consider them very useful in regular classes. Furthermore, many students who participated in the survey expressed a desire to learn how to make 3D holograms themselves. Only a small number of students felt that in chemistry classes, holographic technology was an expensive toy that did not contribute to learning.

https://doi.org/10.33225/BalticSTE/2023.151

According to the results, students believe that 3D holograms can be applied in other chemical disciplines as well. The students indicated that holograms would be most useful for studying the biochemical structures and mechanisms of metabolic transformations of biomolecules. The following are the contents of general and physical chemistry, which include numerous abstract concepts. In the fourth place are the contents of organic chemistry. In the last two places, students put analytical and inorganic chemistry. These disciplines require practical laboratory work and experimental acquaintance with the properties of various substances and methods for their qualitative and quantitative determination. According to students' perceptions, 3D holograms cannot significantly help them to improve their laboratory skills.

Despite the importance of the obtained findings, the following limitations should be kept in mind. The sample included only first-year students, so the research results cannot be generalized to the entire student population. Potential future research should include students from other years, and the topics covered with the application of holograms should be from other chemical disciplines such as biochemistry and general chemistry, etc.

Conclusions and Implications

Based on the results obtained in the conducted research, a general conclusion can be drawn that chemistry students have a positive opinion about the application of 3D holograms in learning organic chemistry at the higher education level. Although the students did not have the opportunity to see 3D holograms before this research, they believe that they are useful for understanding the content of organic chemistry and that they help them visualize models of molecules and mechanisms of chemical reactions and thus help them to gain a better understanding of various abstract concepts, phenomena, and processes encountered in chemistry classes. In addition, they believe that the implementation of 3D holograms would be useful for other chemical disciplines such as biochemistry, general chemistry, etc. Also, the students pointed out that they would like to learn how to make 3D holograms. All the above results suggest that the application of 3D holograms in the teaching and learning of chemistry should be implemented and that this is an area that will be followed by further accelerated development and implementation in the educational system.

Acknowledgements

The authors gratefully acknowledge the financial support of the Ministry of Science, Technological Development and Innovation of the Republic of Serbia (Grant No. 451-03-47/2023-01/200125).

Declaration of Interest

The authors declare no competing interest.

References

Akçayır, M., Akçayır, G., Pektaş, H. M., & Ocak, M. A. (2016). Augmented reality in science laboratories: The effects of augmented reality on university students' laboratory skills and attitudes toward science laboratories. *Computers in Human Behavior*, *57*, 334-342. https://doi.org/10.1016/j.chb.2015.12.054

Barsom, E. Z., Graafland, M., & Schijven, M. P. (2016). A systematic review on the effectiveness of augmented reality applications in medical training. *Surgical Endoscopy*, *30*, 4174-4183. https://doi.org/10.1007/s00464-016-4800-6

Behzadan, A. H., Dong, S., & Kamat, V. R. (2015). Augmented reality visualization: A review of civil infrastructure system applications. *Advanced Engineering Informatics*, *29*(2), 252-267. https://doi.org/10.1016/j.aei.2015.03.005

Cheng, K. H., & Tsai, C. C. (2013). Affordances of augmented reality in science learning: Suggestions for future research. *Journal of Science Education and Technology*, *22*, 449-462. https://doi.org/10.1007/s10956-012-9405-9

Duis, J. M. (2011). Organic chemistry educators' perspectives on fundamental concepts and misconceptions: An exploratory study. *Journal of Chemical Education*, *88*(3), 346-350. https://doi.org/10.1021/ed1007266

El Sayed, N. A., Zayed, H. H., & Sharawy, M. I. (2010). Augmented reality student card. *Computer & Education*, *56*, 1045-1061. https://doi.org/10.1016/j.compedu.2010.10.019

Hinsen, K. (2000). The molecular modelling toolkit: A new approach to molecular simulations. *Journal of Computational Chemistry*, *21*(2), 79-85. https://doi.org/10.1002/(SICI)1096-987X(20000130)21:2%3C79::AID-JCC1%3E3.0.CO;2-B

Hoon, L. N., & Shaharuddin, S. S. (2019). Learning effectiveness of 3D hologram animation on primary school learners. *Journal of Visual Art and Design*, *11*(2), 93-104. https://doi.org/10.5614/j.vad.2019.11.2.2

Jones, L. L., Jordan, K. D., & Stillings, N. A. (2005). Molecular visualization in chemistry education: the role of multidisciplinary collaboration. *Chemistry Education Research and Practice*, *6*(3), 136-149. https://doi.org/10.1039/B5RP90005K

Ke, F., & Hsu, Y. C. (2015). Mobile augmented-reality artefact creation as a component of mobile computer-supported collaborative learning. *The Internet and Higher Education*, *26*, 33-41. https://doi.org/10.1016/j.iheduc.2015.04.003

Mishra, S. (2017). Hologram the future of medicine – From Star Wars to clinical imaging. *Indian Heart Journal*, *69*(4), 566–567. https://doi.org/10.1016/j.ihj.2017.07.017

Moro, C., Phelps, C., Redmond, P., & Stromberga, Z. (2021). HoloLens and mobile augmented reality in medical and health science education: A randomized controlled trial. *British Journal of Educational Technology*, *52*(2), 680-694. https://doi.org/10.1111/bjet.1304

Ramachandiran, C. R., Chong, M. M., & Subramanian, P. (2019). The 3D hologram in the futuristic classroom: A review. *Periodicals of Engineering and Natural Sciences*, *7*(2), 580-586. http://dx.doi.org/10.21533/pen.v7i2.441.g325

Santos, V. C., & Arroio, A. (2016). The representational levels: Influences and contributions to research in chemical education. *Journal of Turkish Science Education*, *13*(1), 3-18.

Squire, K., & Klopfer, E. (2007). Augmented reality simulations on handheld computers. *The Journal of the Learning Sciences*, *16*(3), 371-413. https://doi.org/10.1080/10508400701413435

Yoo, H. W., Jang, J. H., Oh, H. J., & Park, I. W. (2022). The potential and trends of holography in education: A scoping review. *Computers & Education*, 186, 104533. https://doi.org/10.1016/j.compedu.2022.104533

Appendix - Instrument

1. Have you seen/used a hologram in learning before this class?
   - □ Yes
   - □ Used them during teaching/learning
   - □ No

2. Do you like the holograms made for chemistry classes?
   - □ Yes
   - □ No
   - □ I do not know

3. How much do you agree with the following statements?
   1 - means complete disagreement
   5 - complete agreement

Holograms help me					
"see" molecules and other chemical models that I cannot imagine.	1	2	3	4	5
better understand chemical phenomena.	1	2	3	4	5
understand mechanisms of chemical reactions.	1	2	3	4	5

4. How much do you agree with the following statements?
   1 - means complete disagreement
   5 - complete agreement

Holograms are just toys and do not contribute to learning.	1	2	3	4	5
I would like to learn to make holograms myself.	1	2	3	4	5
Teachers should use holograms in chemistry classes.	1	2	3	4	5

5. In what disciplines of chemistry would holograms be most useful? Rank the given areas from most important (6) to least important (1).
   - □ General chemistry
   - □ Inorganic chemistry
   - □ Analytical chemistry
   - □ Physical chemistry
   - □ Organic chemistry
   - □ Biochemistry

6. If you have any suggestions for holograms that you would like teachers to use in their explanations, please write them here.

Received: *April 04, 2023* Accepted: *May 13, 2023*

Cite as: Olić Ninković, S., & Adamov, J. (2023). University students' opinions on the use of 3d holograms in learning organic chemistry. In V. Lamanauskas (Ed.), *Science and technology education: New developments and Innovations. Proceedings of the 5th International Baltic Symposium on Science and Technology Education (BalticSTE2023)* (pp. 151-161). Scientia Socialis Press. https://doi.org/10.33225/BalticSTE/2023.151

INCREASING THE STUDENTS' INTEREST IN SCIENCE BY IMPLEMENTING A SCIENCE ACTION DEDICATED TO PLASTICS BIODEGRADABILITY

Radu Lucian Olteanu , Gabriel Gorghiu
Valahia University of Targoviste, Romania
E-mail: radu.olteanu@valahia.ro, ggorghiu@gmail.com

Abstract

Science actions represent specific initiatives and demarches that involve investigation, experimentation, and even research, for raising the interest of the young generation in science, through particular approaches of STEM education. Important topics are promoted to students in various approaches, addressing nowadays problems, answering scientific questions, or trying to make them aware of sensible issues. In this respect, the topic of plastics biodegradability embraced the clothes of a Science action, a format based on the Care-Know-Do model, proposed in the frame of the CONNECT project. Having the view to evaluating the students' interest in science after the implementation of the project-designed science actions, the partnership proposed a 5-point Likert scale instrument. In Romania, 373 students who participated in the Biodegradable Plastics action expressed their feedback, underlining - in an important proportion - their strong confidence in science, being ready to participate in collaborative science projects or benefit from their family support who consider that understanding and knowing science is useful for the entire life. Moreover, the students offered positive feedback related to teachers' ability to emphasize the importance of science for their life and future, but also in society, in general.
Keywords: *STEM education, science action, plastics biodegradability, students' feedback, CONNECT project*

Introduction

Plastics have been widely used since the day they were invented because of their remarkable properties in terms of durability, lightness, stability, and low cost, with global plastics production reaching 348 million tons in 2017 (PlasticsEurope, 2018). The durability and strength of plastics are two-sided; those properties can not only improve the performance of the material but also pose a serious threat to the environment by making the material resistant to natural degradation. This resistance has become a big challenge in the waste management process, especially in the field of sustainable waste management. A large amount of plastic waste has been and is being dumped into the environment worldwide causing the current problem of "white pollution" (Dauvergne, 2018). "White pollution" represents a term associated with the image of the phenomenon of environmental pollution by plastic waste and refers to the pollution of the ecosystem caused by using plastic products such as packaging bags, mulch film, disposable tableware, plastic bottles, etc. made of polyethylene (PE), polypropylene (PP), polyvinyl chloride (PVC) and other high molecular weight compounds that constitute solid waste (Shen et al., 2020).

The growing awareness and concern over plastic pollution led to an interest in making plastics that have the potential to degrade the environment (Guillet, 2002). The term "biodegradation" is still not firmly defined, and the field of study covers many interdisciplinary aspects. Moreover, experimentation and testing are challenging because research studies need to address complex and long-term phenomena in natural environments that are extremely variable (SAPEA, 2020). At the heart of the issue is the contrast between polymers made in nature and those that have been developed by human society. Biodegradable, compostable, and bio-based plastics are increasingly promoted as a solution to some of those challenges. The growth in biodegradable plastics is related to the growing societal concern about the accumulation of conventional plastics in the open environment and the associated ecological risks, and impacts on ecosystem services and society (SAPEA, 2020).

There are still questions as to whether biodegradable plastics can be a promising solution to the problem of waste disposal and global pollution due to plastic. Accordingly, there can be pointed out three main scientific arguments/evidence (SAPEA, 2020). Firstly, it is well known that biodegradable plastics are not currently a substitute for most conventional plastics. Secondly, the production of biodegradable plastics appears to be much easier than their treatment. Third, awareness of human behaviour is important. The solution to global plastics pollution requires a change in awareness of human behaviour combined with promising viable approaches, and the latter will be largely ineffective without the former. There is considerable confusion regarding the public understanding surrounding the terminology used to describe bioplastics in general and biodegradable plastics. The generic term "bioplastics" is used to refer to plastics that are partly or fully produced from biological raw materials ("bio-based plastic") as well as to those that are considered biodegradable, including plastics that are compostable or home-compostable ("biodegradable plastic") (SAPEA, 2020). The "bio" prefix draws consumers' attention and is suggestive of sustainability and environmental protection (Yeh et al., 2015). Accordingly, consumers associate the terms "bioplastics" and "bio-based plastics" with vague notions of renewability, natural origins, and "environmental friendliness". They also confuse or conflate them with end-of-use characteristics, such as biodegradability, compostability, and recyclability (Notaro et al., 2022). Consumers expect products or packaging that are labelled as bioplastic to have a renewable resource base and to fully degrade under home composting conditions, and that they can help with climate change mitigation and plastic waste reduction (Magnier & Crié, 2015; Dilkes-Hoffman et al., 2019b; Neves et al., 2020). While consumers generally know something about the availability and production of bioplastics, they lack a detailed understanding of different material types as well as their applications and environmental impacts (Dilkes-Hoffman et al., 2019a). This can partially be attributed to the limited relevance of bioplastics in consumers' day-to-day lives (Klein et al., 2019).

Behavioural aspects are important both in respect of the uptake and disposal of biodegradable plastics. Gabriel and Menrad (2015) showed that most consumers will choose the standard/conventional plastic one, even when biodegradable and conventional plastic products are offered side-by-side with clear displays. In terms of the disposal of biodegradable plastic products, Taufik et al. (2020) found that, while compostable bio-based packaging is perceived positively in terms of its environmental benefits, consumers are more likely to dispose of it incorrectly. This suggests that there may be unintended behavioural consequences when more biodegradable plastic products are introduced. It must be noted that recycling behaviour is not purely an individual action reflecting a person's attitude towards the environment (Van Birgelen et al., 2008), but that it is also determined by the available recycling infrastructure.

The context of solving real-world problems is one method to appreciate the interrelationships between the content areas of science, technology, engineering, and mathematics (STEM) that are inextricably linked. Most societies have STEM knowledge and the capacity to integrate those resources to find solutions for new problems as a fundamental capability (Hasanah et al., 2022); a society's collective ability to develop STEM knowledge affects its global standing. As a result, there has been a surge in interest in integrated STEM education (Hoeg and Bencze, 2017). One aspect of such recognition would be the requirement to train teachers who are versed in STEM disciplines and even engineering design. Furthermore, engineering content and methods are unfamiliar to teachers (Nadelson et al., 2013). As a result, there is a definite demand for STEM education teachers' training. Additionally, research indicates that students learn more effectively when involved in meaningful activities that result in authentic artefacts (Fortus et al., 2005). Awareness of the impact of plastics, both conventional and bioplastics, on the environment, must be brought to attention in time, mainly through education. In this case, the teacher - as a facilitator in the classroom - plays a vital role in appropriately conveying the message to preserve the environment (Kalimullina et al., 2021). To adequately conveyed the message, an attractive learning design with a STEM approach is needed for students.

Research Problem and Context

The CONNECT approach takes the form of a "scientific action". It includes a set of activities that integrate a real-life science problem into an existing topic, one of them being oriented on "*Biodegradable plastics - a solution to "white pollution"?*". The addressed problem gives students the motivation to learn science concepts. Moreover, the activity tries to stimulate students to discuss science with their families. During the science action activity, students apply scientific ideas in new contexts, having also the opportunity to involve a scientist or engineer to work with them. In the end, students are challenged to use their knowledge and skills, which provides an authentic evaluation of the activity. CONNECT targets secondary schools and teachers offering an inclusive and sustainable model to increase students' confidence towards using science, bringing them together with science professionals and engaging family members to improve their attitudes toward science careers, in this sense, installing the conviction that "science is for me".

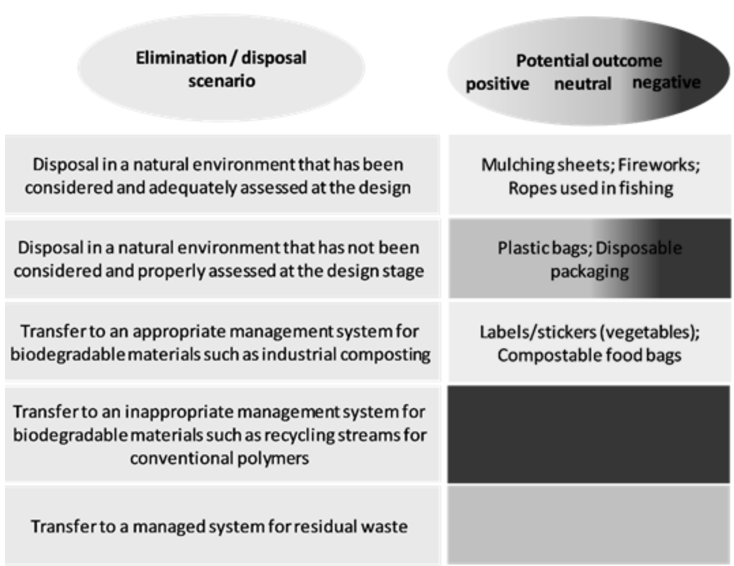
The "Biodegradable plastics - a solution to "white pollution"?" science action activity is supported by a set of educational resources (CONNECT, 2022) that contribute to the completion of the mentioned scientific activity: *Teacher's guide*, *STEM Specialist guide*, *Student's sheets*, *Experiment sheet*, *Homework family sheet*.

The Teacher's Guide document provides from the start a supportive background related to the following issues: "White pollution"; What are biodegradable plastics?; Can biodegradable plastics solve the problem of 'plastic' accumulating in the environment?; What are the potential environmental risks associated with the use of biodegradable plastics?; What is the role of biodegradable plastics in reducing "white pollution"?; What are the opportunities and challenges of using biodegradable plastics? There is also included the integration of three additional activities (I CARE - "White pollution", I KNOW - Biodegradability of plastics in the environment, and DO - Awareness campaign) from the scientific action "Biodegradable plastics - a solution to solve "white pollution"?" related to existing lessons from the curriculum content. For each additional activity, learning objectives are specified, such as what students do and who can be involved (the teacher, the STEM specialist, and the family).

The *STEM Specialist guide* also provides supportive information related to the biodegradability of plastics in the environment and notes on the implementation of activities. It is important to note that while the material illustrates examples where biodegradable plastics can bring benefits as well as those where the benefits are less obvious, there is no universal solution. To obtain a net benefit from the use of biodegradable plastics as part of the circular economy, also considering the environmental risk perspective, the potential advantages of biodegradable plastics over conventional plastics need to be considered on a case-by-case, application-by-application basis. Potential benefits in terms of biodegradability are only likely to be realized if, at the end of its lifetime, the plastic object reaches a receiving environment suitable for biodegradation of the specific plastic material and its composition/formulation. The proposed disposal scenarios (Figure 1) are determined by the application associated with the plastic material, the waste management system, the regulations in place, the information or labelling to guide the user on appropriate disposal, and the end-user actions or behaviour concerning that information.

Figure 1

Alternative End-of-Life Disposal Scenarios for Biodegradable Plastics and the Potential Outcome over Conventional Plastics



Note: Adapted from (SAPEA, 2020)

The examples provided through the *STEM Specialist guide* consider some current applications of biodegradable plastics concerning several potential considerations in assessing in terms of the waste hierarchy and the potential environmental benefits or risks associated with the use of existing or new biodegradable plastics compared to conventional plastics.

The *Experiment sheet* ("Obtaining a biodegradable plastic from renewable sources") proposes to the students an experimental activity in which the family is also involved. One of the major challenges today is the development/design of cheap and sustainable biodegradable plastics from renewable sources. In this experiment the students will try to make a "bioplastic" that is both biodegradable and compostable; they must keep in mind that if biodegradable plastics are mixed with other conventional plastics for recycling, the recovered plastic is not recyclable because of the variation in properties and melting temperatures. The students are encouraged to involve a family member(s) to help in running and following up on the results of the experiment as well as completing an observation/monitoring sheet. Last but not least they can be creative and use their imagination but try to scientifically justify their chosen options.

Research Focus and Aim

Taking into consideration the fact that science actions represent new didactic approaches in Romanian science education, it is important to assess how such demarches are received by students. In this respect, the science action dedicated to plastics biodegradability (having its particular format, as designed in CONNECT project) represented an important opportunity to measure the students' feedback considering how confident they became with science or doing science projects in collaboration with others, how they perceived their family support, how much input made the teachers (in their perception - in terms of giving explanations and promoting discussions), and how important is the scientific knowledge and related skills for their lives and future careers. As Romanian secondary students are more and more non-interested in science - their lack of interest being mainly a result of how science is taught (Ciascai et al., 2014) -, such approaches can be widely introduced in lower and upper secondary education, having the aim to improve their performance in science and raise their interest in pursuing careers in science-related fields.

Research Methodology

General Background

The science action oriented on "*Biodegradable plastics - a solution to "white pollution"?*" has been proposed to be implemented in schools since the second semester of the 2021-2022 school year. The action was promoted to teachers in several workshops from October 2021 to January 2022 and enjoyed the interest of lower- and upper-secondary teachers from seven Romanian Counties. The implementation was carried out in a hybrid format, in schools and outside them, taking into account the pandemic situation recorded in that period. Both teachers and students were able to access the CONNECT platform and benefited from the support of researchers and specialists who assisted them and interacted when necessary.

Since the beginning of the implementation process, the promoters of science action expressed the desire to assess the impact of such an approach on students' interest related to science. In this sense, favourable feedback from students made the promoters consider an important impetus for extending the implementation of science action to more Romanian counties.

Sample

The sample was constituted of secondary students who participated in the implementation process of science action, at the schools (and related teachers) who expressed their availability for adopting that new format with the view to spreading scientific knowledge. In general, the entire group of students from a classroom was involved in the action activities, and their feedback was collected at the end of the action. The data was gathered during the second semester of the 2021-2022 school year. More than 500 students who participated in the implementation process of the science action filled in a specially designed questionnaire related to the student's interest in science. A total of 373 feedbacks have been kept (74.6%), the rest of the records being rejected to inconsistent or incomplete data. The gender distribution of the sample was sensible equal: 195 female students (52%) and 178 male students (48%).

Instrument and Procedures

The questionnaire designed for students' feedback analysis was developed by the CONNECT Project evaluation team, being recommended to all the partners who implemented the project-proposed science action units. For one question, a 5-point Likert scale was used (*Never - Rarely - Sometimes - Frequently - Very frequently*), and for the other 5 questions a different 5-point Likert scale was proposed (*Totally disagree - Disagree - Neither disagree nor agree - Agree - Totally Agree*).

Data Analysis

Data analysis was performed using Microsoft Excel, mainly by characterizing the students' answers and examining their distribution. The sets of data that were taken into consideration for the analysis were oriented on the students' confidence in science, their involvement in participating in collaborative science projects, doing science activities together with their families, feedback related to teachers' ability to emphasize the importance of science for their life and future, and in society.

Research Results

The science action oriented on "*Biodegradable plastics - a solution to "white pollution"?*" raised the interest of science teachers in seven Romanian counties where the action was proposed to be implemented. Consequently, the students expressed their enthusiasm, but a general picture of their feedback was known after the implementation process, being offered in Table 1.

Table 1
Students' Feedback Related to Their Interest in Science - Collected After the Implementation of the Biodegradable Plastics Science Action (n=373)

Items	Totally disagree	Disagree	Neither disagree nor agree	Agree	Totally Agree
			(%)		
Feeling confident talking about science	1	9	30	43	17
Feeling confident doing science projects with other people (with other colleagues)	1	6	22	50	21
Benefit from family support who consider that science is useful for personal future	2	5	29	42	22
Considering the teachers' explanations sufficiently related to the importance of science in their life and in society	2	4	10	54	30
Considering that scientific knowledge and related skills represent real help to get a job	2	5	27	46	20

Discussion

Even though it is difficult to appreciate the extent to which the students are confident when talking about science, since many variables can influence their answers (Han et al., 2021), it seems that nowadays they feel more confident considering the increased importance of STEM education in schools, but also in the society. In this respect, 60% of the questioned students *agreed* or *totally agreed* with being confident when talking about science. The implemented science action played an important role, making STEM education and its actual cutting-edge topics more accessible and open to all students, no matter what their backgrounds or abilities are. However, it remains an important percentage of students still need more didactic work from teachers in order to become confident when talking about science.

In addition, as collaboration represents an important part of nowadays didactics, teachers are asked to involve students in collaboration projects (Le et al. 2018), not only to develop their scientific skills but also to increase their capacities to work in a team, take proper decisions and develop communication skills. On the other hand, the student's confidence in working collaboratively on science projects depends on some crucial variables such as their experience gained in team-working, their level of interest in the scientific project, or their strengths/weaknesses. In our analysis, the science action raised the level of confidence concerning the participation and implication in projects that require collaboration. In this respect, 71% of the questioned students *agreed* or *totally agreed* with being confident when doing science projects in collaboration. On the other hand, it remains approximately 30% of questioned students still have problems when considering collaboration in groups, either due to a lack of experience or a lack of confidence in their abilities. However, working in groups remains an important key to understanding science and makes students more confident in collaborating on science projects. In addition, students who expressed a strong interest in science projects are very motivated to work collaboratively and discuss with colleagues their ideas and opinions.

In general, family involvement has a positive impact on students in STEM education (Ing, 2014). In this sense, the involvement of families in students' STEM education can reinforce the importance of science for their present and future lives and careers, several ways being exploited by families to illustrate science as a vital area to be understood and learned, through: (a) encouraging exploration and experimentation scientific concepts at home, by performing hands-on activities; (b) attending - with the entire family - different scientific events in dedicated institutions (science museums, science centres, botanical gardens, zoological gardens, etc.); (c) supporting STEM learning in the classroom, by providing additional resources or volunteering help the implementation of science projects; (d) modelling STEM-related behaviours, by expressing an interest in STEM and encouraging students to embrace STEM careers. The implemented science action proved to have an important proportion of family implication (66% of the feedback is in the category *agree* or *totally agree*) on considering that science is useful for students' future. As the science action proposed a strong interaction with the student's family, it comes normal to discuss inside the family issues concerning the usefulness of science for the future career.

As a teacher, it is a crucial issue to offer students sufficient information and explanations in order to help them understand the importance of science in their life and in society. Students need arguments and pieces of evidence to understand the world around us with the laws of physics, chemistry, and biology that govern it. On the other hand, students must be aware that science is the basis of progress, by driving innovation and leading to the development of new technologies, offering also solutions to societal problems (Rull, 2014). The teacher's explanations and support must converge to make students understand that science is essential for a sustainable future. The proposed science action tries to convince students to think sustainably. Discussion on "white pollution" issues, biodegradable plastics, or potential environmental risks associated with the use of biodegradable plastics are found at the centre of the topics related to environmental protection. In this respect, it is commendable that the proposed science action is well-framed in the sustainability debates, 84% of students *agreed* or *totally agreed* on the sufficiency of teachers' explanations regarding the importance of science in their life and society. More, science knowledge and related skills can represent a significant advantage for getting a future job. Students with a powerful scientific background can be more attractive candidates and can make them assets in developing new products, processes, and technologies. The proposed science action demonstrated its importance in that direction - 73% of students *agreed* or *totally agreed* on the fact that scientific knowledge and related skills represent real help to get easier a job.

Of course, not just the teacher and school support remain important, by guiding and orienting students and setting up a positive and inclusive environment where they feel comfortable working together. As discussed, involving families in STEM education represent a crucial help for defining a supportive and engaging environment for their children, by encouraging them to discuss important scientific subjects, and - why not? - trying to offer decisions on important issues. In this way, it is clear that students appreciate how important is science for their lives and future, but also for solving real-life problems, by valorising the acquired scientific knowledge for their personal and social development (Drăghicescu et al. 2015).

Conclusions and Implications

As the presented action - proposed and implemented in the frame of the CONNECT project - offered to teachers and students an approach that was different from how teaching and learning science look in the traditional format, the students' feedback collected immediately after the action implementation proved to be importantly related to how such actions need more attention and should be included in general practice for bringing the students near science.

The research offers empirical results related to students' interest in science, expressing that such actions raise the students' confidence in science, their involvement in participating in collaborative science projects, or their readiness to perform science activities together with their families. Even though there are still some barriers that may prevent some students from feeling confident in discussing science, teachers need to continue to work with students with the view to extending the students' trust in science.

On the other hand, analysing the students' feedback related to teachers' ability to emphasize the importance of science for their life and future, it can be concluded clearly that just through understanding science, learning, and deepening scientific concepts, making connections between them and the environment, and trying to find a sense of life (from the scientific point of view), the students can be fully ready for their future careers, for innovating and expressing their creativity, for thinking critically and solving local or widespread problems, but also for using the technology effectively, considering that at the moment, there are plenty of available resources to learn about and engage with science, and many initiatives coming from schools and teachers to promote science and its wonderful world.

Acknowledgements

This work was funded through the Project "*CONNECT - Inclusive open schooling through engaging and future-oriented science*", in the frame of the HORIZON 2020 - EU.5.d. Programme - "Encourage citizens to engage in science through formal and informal science education, and promote the diffusion of science-based activities, namely in science centres and through other appropriate channels", Topic: "SwafS-01-2018-2019-2020 - Open schooling and collaboration on science education", Grant agreement ID: 872814.

The CONNECT project's goal is to create an inclusive, sustainable model that will facilitate the adoption of open schooling by a large number of secondary schools by implementing science-action gamification projects in the core curriculum.

Declaration of Interest

The authors declare no competing interest.

References

Ciascai, L., Haiduc Șuteu, L. D., & Felezeu, C. (2014). How science is taught in the secondary and high school levels in Romania? *Hacettepe Üniversitesi Eğitim Fakültesi Dergisi*, *29*(1), 74-86. http://efdergi.hacettepe.edu.tr/yonetim/icerik/makaleler/102-published.pdf

CONNECT. (2023). *Inclusive open schooling through engaging and future-oriented science. Biodegradable plastics - a solution to "white pollution"?* https://connect-eu.exus.co.uk/ro/2022/02/22/bioplastic-en/

Dauvergne, P. (2018). Why is the global governance of plastic failing the oceans? *Global Environmental Change*, *51*, 22-31. https://doi.org/10.1016/j.gloenvcha.2018.05.002

Dilkes-Hoffman, L. S., Pratt, S., Laycock, B., Ashworth, P., & Lant, P. A. (2019a). Public attitudes towards plastics. *Resources, Conservation and Recycling*, *147*, 227-235. https://doi.org/10.1016/j.resconrec.2019.05.005

Dilkes-Hoffman, L. S., Ashworth, P., Laycock, B., Pratt, S., & Lant, P. (2019b). Public attitudes towards bioplastics - knowledge, perception and end-of-life management. *Resources, Conservation and Recycling*, *151*, 104479. https://doi.org/10.1016/j.resconrec.2019.104479

Drăghicescu, L. M., Cristea, S., Petrescu, A. M. A., Gorghiu, G., & Gorghiu, L. M. (2015). The Learning to Learn Competence - Guarantor of Personal Development. *Procedia Social and Behavioral Sciences*, *191*, 2487-2493. https://doi.org/10.1016/j.sbspro.2015.04.571

Fortus, D., Krajcik, J., Dershimer, R. C., Marx, W. R., & Mamlok-Naaman, R. (2005). Design-based science and real-world problem-solving. *International Journal of Science Education*, *27*(7), 855-879. https://doi.org/10.1080/09500690500038165

Gabriel, A., & Menrad, K. (2015). Market acceptance and consumers' willingness-to-pay for plants in biodegradable pots. *Acta Horticulturae*, *1099*, 297-305. https://doi.org/10.17660/ActaHortic.2015.1099.34

Guillet, J. E. (2002). Degradable Polymers. In G. Scott (Ed.), *Degradable polymers: Principles and applications* (2nd ed.), (pp. 413-448), Kluwer Academic Press.

Han, J., Kelley, T. & Knowles, J. G. (2021). Factors influencing student STEM learning: Self-Efficacy and outcome expectancy, 21st century skills, and career awareness. *Journal for STEM Education Research*, *4*, 117-137. https://doi.org/10.1007/s41979-021-00053-3

Hasanah, S. S., Riandi , Permanasari, A., & Kaniawati, I. (2022). STEM Training for lesson plan on bioplastic and environment: Does it affect the teachers? *Morrocan Journal of Chemistry*, *10*(3), 564-575. https://doi.org/10.48317/IMIST.PRSM/morjchem-v10i3.33144

Hoeg, D. G., & Bencze, J. L. (2017). Values underpinning STEM education in the USA: An analysis of the next generation science standards. *Science Education*, *101*(2), 278-301. https://doi.org/10.1002/sce.21260

Ing, M. (2014). Can parents influence children's mathematics achievement and persistence in STEM careers? *Journal of Career Development*, *41*(2), 87-103. https://doi.org/10.1177/0894845313481672

Kalimullina, O., Tarman, B., & Stepanova, I. (2021). Education in the context of digitalization and culture: Evolution of the teacher's role, pre-pandemic overview. *Journal of Ethnic and Cultural Studies*, *8*(1), 226-238. http://dx.doi.org/10.29333/ejecs/347

Klein, F., Emberger-Klein, A., Menrad, K., Moehring, W., & Blesin, J. M. (2019). Influencing factors for the purchase intention of consumers choosing bioplastic products in Germany. *Sustainable Production and Consumption*, *19*, 33-43. https://doi.org/10.1016/j.spc.2019.01.004

Le, H., Janssen, J., & Wubbels. T. (2018). Collaborative learning practices: teacher and student perceived obstacles to effective student collaboration, *Cambridge Journal of Education*, *48*(1), 103-122. https://doi.org/10.1080/0305764X.2016.1259389

Magnier, L., & Crié, D. (2015). Communicating packaging eco-friendliness: An exploration of consumers' perceptions of eco-designed packaging. *International Journal of Retail & Distribution Management*, *43*(4/5), 350-366. https://doi.org/10.1108/IJRDM-04-2014-0048

Nadelson, L. S., Callahan, J., Pyke, P., Hay, A., Dance, M., & Pfiester, J. (2013). Teacher STEM perception and preparation: Inquiry-based STEM professional development for elementary teachers. *Journal of Education Research*, *106*(2), 157-168. https://doi.org/10.1080/00220671.2012.667014

Neves, A. C., Moyne, M. M., Eyre, C., & Casey, B. P. (2020). Acceptability and societal impact of the introduction of bioplastics as novel environmentally friendly packaging materials in Ireland. *Clean Technologies*, *2*(1), 127-143. https://doi.org/10.3390/cleantechnol2010009

Notaro, S., Lovera, E., & Paletto, A. (2022). *Journal of Cleaner Production*, *330*, Article 129870. https://doi.org/10.1016/j.jclepro.2021.129870

PlasticsEurope (2018). *Plastics - the Facts 2018*, An analysis of European plastics production, demand and waste data. Brussels: PlasticsEurope AISBL. https://plasticseurope.org/wp-content/uploads/2021/10/2018-Plastics-the-facts.pdf

Rull V. (2014). The most important application of science: As scientists have to justify research funding with potential social benefits, they may well add education to the list. *EMBO Reports*, *15*(9), 919-922. https://doi.org/10.15252/embr.201438848

SAPEA, Science Advice for Policy by European Academies. (2020). Biodegradability of plastics in the open environment. SAPEA. https://www.sapea.info/wp-content/uploads/bop-report.pdf

Shen, M., Song, B., Zeng, G., Zhang, Y., Huang, W., Wen, X., & Tang, W. (2020). Are biodegradable plastics a promising solution to solve the global plastic pollution? *Environmental Pollution*, *263*, Part A, 114469. https://doi.org/10.1016/j.envpol.2020.11446

Taufik, D., Reinders, M. J., Molenveld, K., & Onwezen, M. C. (2020). The paradox between the environmental appeal of bio-based plastic packaging for consumers and their disposal behaviour. *Science of The Total Environment*, *705*, Article 135820. https://doi.org/10.1016/j.scitotenv.2019.135820

Van Birgelen, M., Semeijn, J., & Keicher, M. (2008). Packaging and proenvironmental consumption behavior: Investigating purchase and disposal decisions for beverages. *Environment and Behavior*, *41*(1), 125-146. https://doi.org/10.1177/001391650731114

Yeh, C. -H., Luecke, F. -K., & Janssen, J. (2015). Bioplastics: Acceptable for the packaging of organic food? A policy analysis. *Journal of Agriculture Food Systems and Community Development*, *6*(1), 95-105. https://doi.org/10.5304/jafscd.2015.061.009

Received: *April 11, 2023* Accepted: *May 16, 2023*

Cite as: Olteanu, R. L., & Gorghiu, G. (2023). Increasing the students' interest in science by implementing a science action dedicated to plastics biodegradability. In V. Lamanauskas (Ed.), *Science and technology education: New developments and Innovations. Proceedings of the 5th International Baltic Symposium on Science and Technology Education (BalticSTE2023)* (pp. 162-172). Scientia Socialis Press. https://doi.org/10.33225/BalticSTE/2023.162

THE PUBLIC'S UNDERSTANDING OF "EVOLUTION" AS SEEN THROUGH ONLINE SPACES

Hyoung-Yong Park
Gyeongin National University of Education, Republic of Korea
E-mail: hypark@ginue.ac.kr

Hae-Ae Seo
Pusan National University, Republic of Korea
E-mail: haseo@pusan.ac.kr

Abstract

Evolution is a central concept that unifies all areas of life sciences. Despite longstanding scientific efforts in science education, the public's scientific awareness of evolution still needs to improve. Furthermore, teaching evolution is subject to recurring controversy. This study aimed to investigate the gap between public understanding of evolution seen through online spaces and contents in a school curriculum and explore its reasons. A content analysis was conducted using data mining on a major online portal in Korea. It examined the characteristics of creating and consuming content on evolution through the online portal service based on analyzing the number of posts related to biological evolution and active participants. It also discussed the feasibility of automatic document classification to distinguish between scientific understanding and non-scientific beliefs on the evolution and related online circulating contents. The results show that there are tactics for public exposure and dissemination of creationism through online discussions.
Keywords: *automated classification, machine learning, network analysis, public understanding of evolution*

Introduction

It has been widely acknowledged that no life phenomenon can be understood without an evolutionary perspective (Dobzhansky, 1973). For many scientists and science educators today, evolution is accepted as a unifying paradigm for the life sciences and a central idea that unifies many single concepts in biology. In line with this view, national curricula in many countries propose to cover evolution as the most important unifying concept in biology, and many studies have emphasized the importance of an integrative perspective based on the concept of evolution (AAAS, 1993; Fredrick et al., 1994; Rutledge & Warden, 2000; Scharmann & Harris, 1992).

Even though the scientific community in many countries around the world recognizes and supports evolution as a scientific theory that explains the history of life, public awareness of evolutionary theory remains low. Although evolution is a paradigm that unifies the life sciences, there is much resistance and controversy to the basic explanatory framework of evolution in education (Young & Strode, 2009).

https://doi.org/10.33225/BalticSTE/2023.173

Therefore, many students learn life science in a social context that hinders their scientific understanding of the history of nature (Kahan et al., 2011). It is reflected in the controversy over the revision of textbooks.

The Society for the Revision of Evolution Theory in Textbook (Gyojinchu; an anti-evolution group in Korea) made waves in the Korean science education community in 2011 by their petition. They are campaigning to remove content about “the evolution of humans” and “the adaptation of finch beaks based on habitat and mode of sustenance”, a reference to one of Darwin’s most famous observations (Park, 2012). As such, creationists have long attempted to change the public perception of evolution by stirring up controversies (Park, 2001).

On the other hand, with the development of information technology, learners increasingly rely on online media, such as searching for knowledge through the Internet, rather than traditional media. In particular, the influence of information on the Internet is expanding, such as online question/answer and encyclopedia services that pursue collective intelligence based on very high accessibility. However, because online content can be written and read by anyone, there are many concerns about whether publicly shared online information is scientifically correct or not. Moreover, non-scientific information and texts widely propagated online can be a reproduction tool that misleads students who need to be discerning. Therefore, it is necessary to have measures in place to monitor and discern the circulation of such information in a non-school context.

Research Aim and Research Questions

In this context, it is necessary to study how the public's understanding of "evolution" in online space differs from the content covered in life science education. Furthermore, based on the results, it is also necessary to draw educational implications for the correct understanding of the evolution of life. Therefore, according to the context and need for such a study, the research conducted in this study is as follows.

1) Analyzing aspects of online writing (question/answer) activities related to 'evolution'

2) Analyzing features of 'evolution' related posts registered in online knowledge services

3) Exploring the possibility of automated classification and filtering of 'evolution' related online posts

Research Methodology

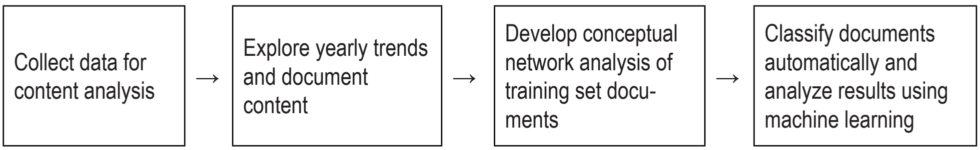
General Background and Procedures

To explore the public’s understanding of evolution, the researchers targeted Jisik-iN (The same pronunciation as "intellectual" in Korean). As a representative online communication space, this service supports the exchange of information by asking and answering questions among the users in Korea (like Quora).

This service was started in 2002 by N company, which has the highest share of Internet search engine users in Korea at about 55%. Since it has the largest number of users, much information has been accumulated. However, unlike Wikipedia, the viewer cannot modify it, so incorrect knowledge is often left unattended, and this is also where the problems of knowledge search services are most prominent.

The study employed descriptive content analysis, text network analysis, and AI-based document classification techniques to analyze data collected from a specific online space over eighteen years, from 2002 to 2019. The data was gathered and analyzed following the research procedure depicted in Figure 1.

Figure 1
Procedure of the Study



Sample

The researchers collected questions and answers through data mining on Q&A services of the major search portals selected for analysis. In the data collection process, the categories were limited to 'biology' and 'life science', and the keyword 'evolution' was used to search for questions/answers, open bases, and posts (documents). Through the data collection process, 12,130 answers to 4,051 online questions and 438 open-encyclopedia articles were collected for content analysis.

Data Analysis

To analyze the trend of 'evolution' related online writing activities, a frequency analysis was conducted to explore trends and document contents by year. Then for the automatic classification process of the collected document data, documents corresponding to 10% (1,278) of the full documents were randomly selected and used as a training data set for automatic classification. Through the researchers' review of the documents in the training data set, the documents were classified into 'Scientific (SC)', 'Non-scientific (NS)', and 'Other (OT)', and representative documents were selected centering on the posts of authors with high activity. The classification of the training data showed that 61 documents contained scientific (SC) ideas about evolution, 68 documents contained non-scientific (NS) ideas, and the remaining 1,149 documents fell into the other (OT) category.

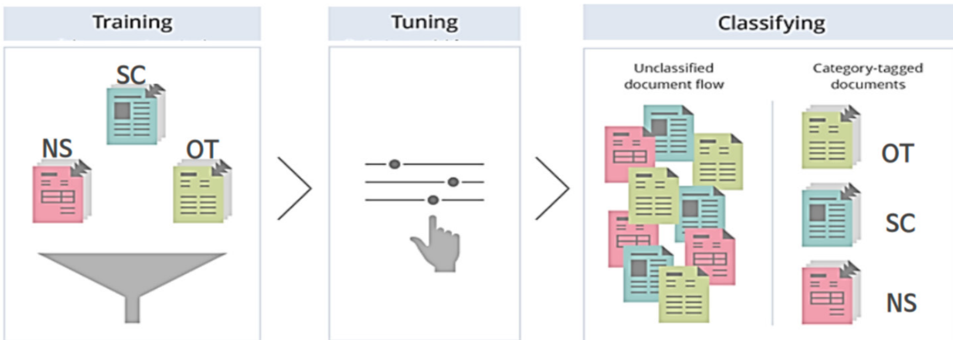
Next, a conceptual network analysis was conducted for the Korean national curriculum documents (Ministry of Education, 2015) and documents representing SC and NS groups. The features and meanings of the networks' relationship were extracted by analyzing the conceptual networks. Then, based on the network analysis results, machine learning (ML) features were extracted for an artificial intelligence system that can automatically classify online documents on evolution into SC and NS groups.

Finally, a supervised machine-learning approach was employed for each document class using the training set to classify the collected documents. This process involved TF-IDF-based automatic classification of all the documents. Principal Component Analysis

https://doi.org/10.33225/BalticSTE/2023.173

(PCA) was used to visualize and interpret the results of the document classification, grouping the documents into distinct categories.

Figure 2
Autonomative Classification Process of Online Documents Related to "Evolution"



Research Results

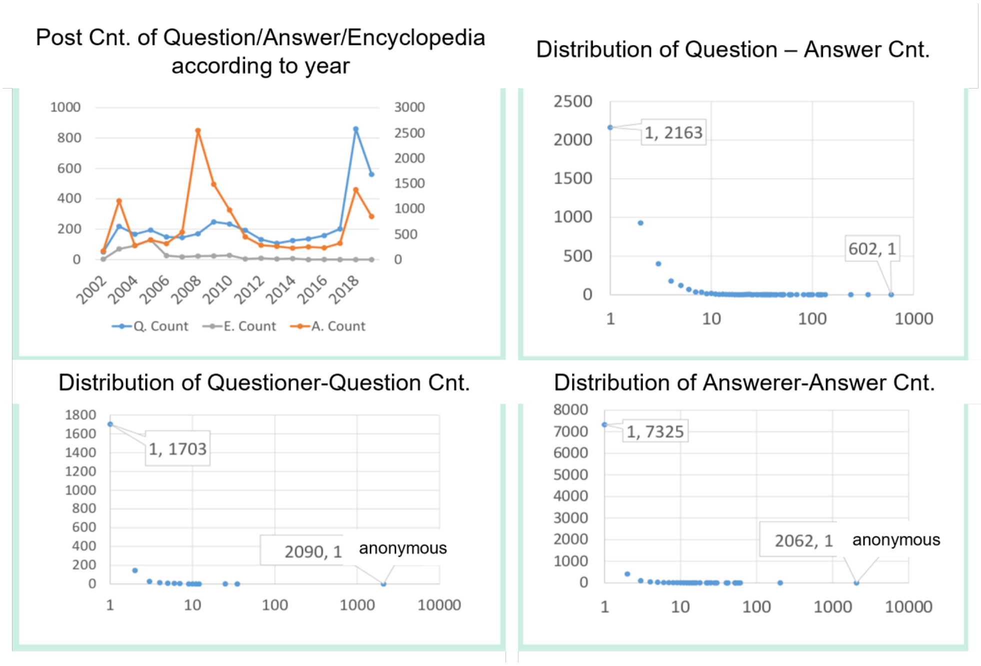
Trends in Online Authoring (Question/Answer) Activity Related to "Evolution"

The frequency analysis results on 'evolution' related to online writing activities was shown in Figure 3. Evolution-related online question/answer activity has been cyclical and volatile, with a recent upward trend. It is thought that online question/answer activity tends to increase around periods of heightened public interest in evolution, such as curriculum revisions and *the petition of the Society for the Revision of Evolution Theory in Textbook (Gyojinchu)* controversy.

Over 75% of the questions received two or fewer replies, and less than 3% received ten or more. Excluding anonymous posters, less than 1% of users have written six or more questions or answers about "evolution", and less than 1% of users have written more than 5% of total questions and 10% of total answers. This result shows that some users are highly active. Therefore, it is crucial to focus on the documents created by these users to determine whether they reflect scientific knowledge about evolution or contain non-scientific content such as religious beliefs. The trends in creating online articles about evolution suggest that online knowledge about evolution is likely to be heavily influenced by a small number of highly active users and anonymous authors.

Figure 3

Trend of "Evolution" Related Online Q&A Activities



Conceptual Network of Online Answer Threads Related to "Evolution"

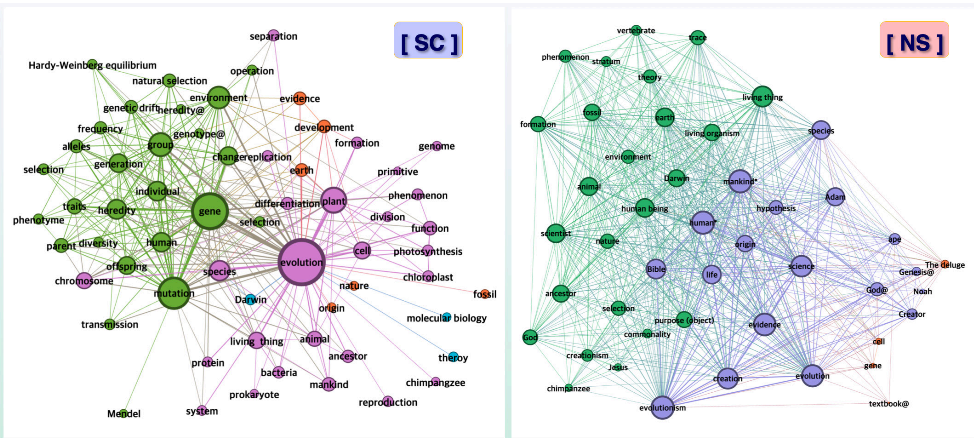
Figure 4 shows a text network of two groups' evolution related documents in the online space. Among the online responses, documents containing scientific knowledge (SC) about evolution showed a high centrality of concepts necessary to explain how life evolves by natural selection, such as "genes", "mutations", "populations", "alleles", and changes in the gene pool of a population, such as the "Hardy-Weinberg equilibrium". It is clear that the concept of "evolution" is a crucial concept that integrates several concepts related to the continuity and diversity of life. On the other hand, the concept relationship network for documents containing non-scientific knowledge (NS) showed a high centrality of concepts related to religious beliefs, such as "Bible", "God", and "Genesis". It formed a dense relationship network around these concepts. Contrasts such as 'evolution' and 'creation' were identified, as well as relationships indicating an objectivist worldview based on 'human' thinking. The appearance of concepts such as 'textbook' suggests that these documents are related to creationist arguments.

Compared to SC documents, NS documents were characterized by a higher density and relatively low modularity, suggesting that NS documents tend to have a higher degree of thematic cohesion. Therefore, the differences in the structural features of the relationship network and conceptual organization of the two types of documents can be used as good features for automatic document classification.

https://doi.org/10.33225/BalticSTE/2023.173

Figure 4

"Evolution" Related Online Post Contents' Conceptual Network



* *Notes*. Visualization of only the top 15% based on the frequency of relationships, which indicates the degree of each concept appeared together in the documents

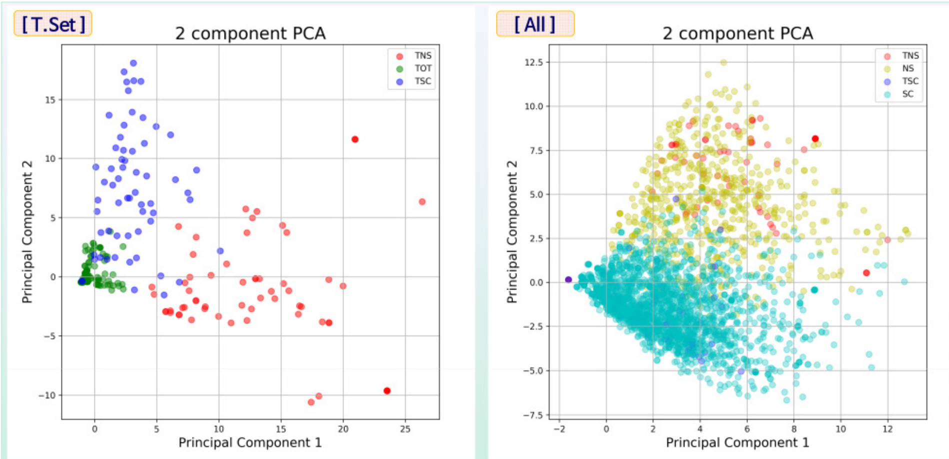
Automated Classification of "Evolution" Related Online Posts Using Machine Learning

Finally, to explore the possibility of automated classification and filtering of 'evolution' related online posts, the researchers selected training data through the analysis of highly active users' answer posts and frequently answered questions. As a result, 200 keywords were identified through concept network analysis. Then, TF-IDF values of the online documents were used as features to vectorize the documents. As a result, a supervised machine learning model for automated classification – Scientific, None-Scientific, Others - was created using the vectorized document data.

In Figure 5, documents are distributed in as many dimensions as the number of features is reduced to two dimensions through principal component analysis (PCA) and visualized. It can be seen that the classification results of the training documents form unique groups by type. The trained model was used to classify the entire online answer posts. The PCA analysis showed that documents containing scientific knowledge (SC) and documents containing non-scientific content (NS) formed separate groups around the respective training data set. Therefore, the automatic classification of online documents on evolution can reduce the public's unprotected exposure to non-scientific content online.

Furthermore, the results of the document classification showed that the number of documents over time increased and decreased, with 5-10% of online responses classified as containing non-scientific explanations of evolution across almost all periods. It is necessary to refine the automatic document classification model through further analysis of the documents classified as Other (OT). It may be possible to distinguish between scientific and non-scientific documents using unsupervised learning methods.

Figure 5
"Evolution" Related Online Post Contents' Conceptual Network



Discussion

As a result of this study, the information about evolution shared online contains non-scientific information. It also reveals that a few active users play a central role in producing and distributing such non-scientific information. Online media has risks because communication in such an online public space is exposed to the unspecified majority without filtering and refinement process. It is also dangerous because it can cause the illusion that a small group's non-professional thoughts are those of the majority.

So, it is necessary to understand the nature of the 'double-edged sword' that online collective intelligence services such as Wikipedia and Quora, which are operating as platforms for effective knowledge sharing today, can have (Wang et al., 2013). Moreover, many new technologies, such as data mining and artificial intelligence, can be effectively utilized (Shu et al., 2017). The research needed to identify and filter non-scientific contents and users who abuse the open attributes of online communities should be continued.

In addition, the cyclical volatility of evolution-related discussions in the online space suggests that an attempt is being made to give equal status to creationism and evolutionism through online space concerning revising the national curriculum. However, online campaigns that reproduce such non-scientific viewpoints are a kind of media manipulation (Fitzpatrick, 2018) that exploits the open nature of Internet media. In the long run, it will become a significant obstacle to the public's scientific understanding of evolution.

Park (2001) already argues that creationists use debates to disseminate their ideas and create the impression that they are on equal footing with the scientific community. Creationists can gain attention and legitimacy by participating in public debates, even if their arguments lack scientific evidence. Additionally, debates can be used to sow confusion and doubt among the general public, ultimately hindering the acceptance of scientific theories. Thus, scientists and educators should recognize this tactic and take steps to counter it through effective communication and education.

https://doi.org/10.33225/BalticSTE/2023.173

Conclusions and Implications

This study explored the public's understanding of evolution and the potential for filtering out non-scientific information by analyzing the texts generated and communicated in online spaces. The conclusions from this study can be summarized as follows.

First, the number of online posts related to evolution has recently shown some fluctuations, with 5% and 10% of posts containing non-scientific beliefs, depending on the period. Given that a small number of highly active or anonymous users can significantly influence public perceptions of evolution through the question/answer process. It seems necessary to continue monitoring the generation of relevant knowledge online.

Second, the conceptual network of documents related to evolution was visualized and analyzed to compare those containing non-scientific knowledge based on religious beliefs with those containing scientific explanations. The analysis revealed significant differences in the structure and conceptual organization of the two networks. Based on these findings, replacing concepts that form the non-scientific understanding of evolution and developing educational measures to promote a correct understanding of the topic will be necessary.

Third, this study explored the possibility that information processing technologies such as data mining, natural language processing, and machine learning can be effectively used to classify knowledge (documents) in specific science-related areas. This outcome can be a robust tool for filtering learning materials to provide learners with reliable scientific knowledge and for building artificial intelligence (AI) systems that can continuously and automatically assess learners' understanding. So, further research should be conducted in this area.

Declaration of Interest

The authors declare no competing interest.

References

AAAS. (1993). *Benchmarks for science literacy: A project 2061 report*. Oxford University Press.

Dobzhansky, T. (1973). Nothing in biology makes sense except in the light of evolution. *The American Biology Teacher, 35*(3), 125–129. http://www.jstor.org/stable/4444260

Fitzpatrick, N. (2018). Media manipulation 2.0: The impact of social media on news, competition, and accuracy. *Athens Journal of Mass Media and Communications, 4*(1), 45-62. https://doi.org/10.30958/ajmmc.4.1.3

Frederick, A., Swarts, O., Roger A., & Frank J. (1994). Evolution in secondary school biology textbook of the PRC, the USA, and the latter stages of the USSR. *Journal of Research in Science Teaching, 31*(5), 475-505. https://doi.org/10.1002/tea.3660310505

Gess-Newsome, J., & Lederman, N. (1993). Pre-service biology teachers' knowledge structures as a function of professional teacher education: A year-long assessment. *Science Education, 77*(1), 24-45. https://eric.ed.gov/?id=EJ458314

Kahan, D. M., Jenkins-Smith, H., & Braman, D. (2011). Cultural cognition of scientific consensus. *Journal of Risk Research, 14*, 147–174. https://doi.org/10.1080/13669877.2010.511246

Ministry of Education. (2015). General overview of the 2015 revised curriculum. Ministry of Education Notice No. 2017-74 [Annex 1].

Park, H. J. (2001). The creation-evolution debate: Carving creationism in the public mind. *Public Understanding of Science, 10*(2), 173. https://doi.org/10.1088/0963-6625/10/2/302

Park, S. B. (2012). South Korea surrenders to creationist demands: Publishers set to remove examples of evolution from high-school textbooks. *Nature, 486*(7401), 14-15.

Rutledge, M. L., & Warden, M. A. (2000). Evolutionary theory, the nature of science & high school biology teachers: Critical relationships. *The American Biology Teacher, 62*(1), 23-31. https://doi.org/10.2307/4450822

Scharmann, L. C., & Harris, W. M. (1992). Teaching evolution: Understanding and applying the nature of science. *Journal of Research in Science Teaching, 29*(4), 375-388. https://doi.org/10.1002/tea.3660290406

Shu, K., Sliva, A., Wang, S., Tang, J., & Liu, H. (2017). Fake news detection on social media: A data mining perspective. ACM SIGKDD *Explorations Newsletter, 19*(1), 22-36.

Wang, G., Gill, K., Mohanlal, M., Zheng, H., & Zhao, B. Y. (2013, May). Wisdom in the social crowd: an analysis of Quora. *In Proceedings of the 22nd international conference on World Wide Web* (pp. 1341-1352). http://dx.doi.org/10.1145/2488388.2488506

Young, M., & Strode, P. (2009). *Why evolution works (and creationism fails)*. Rutgers University Press.

Received: *April 16, 2023* Accepted: *May 14, 2023*

Cite as: Park, H.-Y, & Seo, H.-A. (2023). The public's understanding of "Evolution" as seen through online spaces. In V. Lamanauskas (Ed.), *Science and technology education: New developments and Innovations. Proceedings of the 5th International Baltic Symposium on Science and Technology Education (BalticSTE2023)* (pp. 173-181). Scientia Socialis Press. https://doi.org/10.33225/BalticSTE/2023.173

THE NATURAL SCIENCES CURRICULUM OF PUBLIC NETWORK OF SÃO PAULO: CONCEPTIONS OF TEACHERS WHO TEACH NATURAL SCIENCES IN THE EARLY YEARS OF PRIMARY SCHOOL

Giovanni Scataglia Botelho Paz , Solange Wagner Locatelli
Federal University of ABC, Brazil
E-mail: giovanni.scataglia@ufabc.edu.br, solange.locatelli@ufabc.edu.br

Abstract

Science education objectives in Brazil have evolved over time. Initially, the focus was on creating scientifically literate citizens who could relate scientific concepts to their daily lives. In 2017, the São Paulo City Curriculum for Natural Sciences was introduced to teach students scientific literacy through inquiry-based teaching methods. This study focused on the perceptions of teachers from an primary school in São Paulo who participated by filling out a Google Forms questionnaire. The findings revealed that the majority of participating teachers had undergone curriculum implementation training. While they considered the organization of disciplinary content to be similar to their previous teaching methods, they struggled with implementing inquiry-based teaching strategies and linking scientific content to the United Nation Foundation 2030 sustainable development goals.
Keywords: *qualitative research, primary school, science curriculum, scientific literacy, teachers' conceptions*

Introduction

The curriculum is a dynamic and complex process that encompasses the selection, organization, and articulation of information, skills, and values that are taught and learned in school and in life rather than merely a set of content or subjects (Sacristán, 2013). The curriculum is not a neutral and objective reality but a social and cultural construction reflecting the power relations and dominant worldviews in society. Furthermore, Sacristán (2013) has emphasized the importance of a critical and reflective approach to the curriculum, which considers the needs and interests of students, the demands and challenges of contemporary society, and the democratic and humanistic values that should guide education. He has argued that the curriculum should not be an instrument for reproducing social inequalities, but rather a means of transformation and emancipation for individuals and society as a whole.

Specifically in the field of Natural Sciences Education, in the Brazilian context, there have been different curricula over the years, mainly based on the policies of the current government of the time (Krasilchik, 2000). At the beginning of the twentieth century, the teaching of science aimed primarily at the transmission of information about

https://doi.org/10.33225/BalticSTE/2023.182

scientific facts, theories, and laws. The emphasis was on the memorization of concepts and the understanding of the fundamental principles of natural sciences. From the 1930s onwards, the teaching of science focused on preparing students for technical work and practical life in general. The objectives included the development of observation, analysis, and problem-solving skills. Official documents on the teaching of science only became concerned with the formation of a scientifically literate and critical citizens, capable of linking science to their daily life to position themselves regarding socio-scientific issues, from the 1990s onwards (Machado & Meirelles, 2020).

The Natural Sciences curriculum of the city of São Paulo (São Paulo, 2017) has been a document published in 2017, structured to meet the objectives of basic education, which include the formation of critical and conscious citizens of their role in society. The teaching of Natural Sciences in the city of São Paulo focuses on understanding natural phenomena, and promoting the development of scientific skills and competencies such as observation, critical analysis, and experimentation.

The document is organized around three major themes: a) cosmos, space, and time; b) life, health, and the environment; c) matter, energy, and their transformations. Each theme is approached in an interdisciplinary way, connecting natural sciences with other areas of knowledge, such as mathematics, history, and geography. Additionally, the curriculum seeks to promote environmental education, encouraging students to reflect on their relationship with the environment and to adopt sustainable practices.

According to the curriculum guidelines, Natural Sciences classes should be developed using active methodologies that value the active participation of students in the learning process. In this way, students are encouraged to construct their knowledge based on their own experiences, making observations, investigating problems, and proposing solutions. Therefore, the curriculum indicates that teaching science by inquiry is a coherent approach to these principles.

The promotion of scientific literacy has also been proposed as an ideal formation for students, as it "enables the construction of meaning about the world and allows for the development of critical sense for evaluating and making conscious decisions about situations in their surroundings, whether they are local or global" (São Paulo, 2017, p. 64). The promotion of scientific literacy is indicated as essential for all citizens in modern society, as it enables a critical stance based on scientific knowledge (Özdem et al., 2010). Thus, this is a key concept in the document, explored at various points throughout its writing.

The Natural Science curriculum of the city of São Paulo also provides for the implementation of extracurricular activities such as science fairs, visits to museums and research centers, and scientific research projects. These activities aim to broaden students' repertoire and encourage interest in Natural Sciences.

Thus, the Natural Science curriculum of the city of São Paulo seeks to educate students capable of understanding science as an ever-evolving process that contributes to understanding and transforming reality. Students are encouraged to adopt a critical stance toward scientific knowledge.

To ensure the quality of Natural Science education in the city of São Paulo, teachers undergo continuous training, including courses and qualifications in various areas such as active methodologies, the use of digital technologies, and formative assessment. In addition, the curriculum is constantly reviewed and updated, considering changes and advances in the field of Natural Sciences.

https://doi.org/10.33225/BalticSTE/2023.182

The year after its publication, a course was held to implement the Curriculum of the City of São Paulo for Natural Sciences (and other curriculum components) to align teachers' practices with the theoretical and methodological assumptions proposed in the document. This training was promoted by teachers who worked on the development and writing of the curriculum. In this way, is relevant to know what these teachers think about this new idea of curriculum and how its relation to educational science practices in primary classrooms.

Based on the above, this work has aimed to identify "what are the conceptions of primary school teachers in the municipal network of São Paulo who teach Natural Sciences about the Curriculum of the City?"

Research Methodology

The research is of a qualitative nature. It is characterized as a research method that seeks to understand complex and multifaceted phenomena, often of a subjective nature, by exploring the participants’ perspectives in the study. It aims to understand how people experience, interpret, and make sense of the world around them. Thus, it is an approach especially useful for investigating social, cultural, and behavioral phenomena (Creswell, 2010).

One of the main advantages of qualitative research is its flexibility and adaptability. Unlike quantitative research, which relies on standardized methods of data collection and analysis, qualitative research allows researchers to adjust their techniques and strategies according to the specific needs of each project. Additionally, qualitative research is capable of capturing nuances and complexities that are often lost in the quantitative approach. This is especially important when studying subjects such as subjectivity, cultural diversity, and interpersonal relationships (Crotty, 1998).

The general context of the data was part of a continuous formation course applied in a municipal school of São Paulo city as a part of doctoral research. In this way, the selection of the participants was based on the school level they have classes (primary school level) and the participation in this course. For this reason, being limited to teachers working in one school, there was a methodological limitation of having few participants. The school was researched present very experienced teacher, which majority of this professionals have more than fifteen years of experience in primary classes.

The data collection analyzed in this work involved the response to an online questionnaire (Google Forms) by primary school teachers from the municipal network of São Paulo who work at a school on the outskirts of the city, as shown in Table 1.

Table 1
Questions to Research Participants about Teachers' Conceptions of the São Paulo City Natural Sciences Curriculum

Questions
1. How many years of experience do you have as a teacher?
2. Did you participate in the implementation course for the São Paulo City Natural Sciences Curriculum?
3. If you participated, did the course help your teaching practice?
4. Do you find a discrepancy between the organization of content you used before the City Curriculum and the way it proposes now?
5. What difficulties do you face when teaching Natural Sciences?
6. Can you relate the content of Natural Sciences to the Sustainable Development Goals proposed by the Agenda 2030?
7. Had you heard of the term "Scientific Literacy" before meeting the São Paulo City Natural Sciences Curriculum?
8. If you answered yes to question 7, where did you first come across this term?
9. What are the main difficulties you face in your teaching practice to promote scientific literacy?

Due to the relatively recent idea of the São Paulo city Natural Sciences curriculum, the literature does not yet have a reported and validated instrument for analyzing and understanding teachers' conceptions of this document. Therefore, it was decided to develop this questionnaire based on a survey of curriculum conceptions from teachers used in other scientific studies with already validated instruments (Ring, 2017).

The data analysis was carried out according to Bardin's content analysis approach (Bardin, 1977), in which the analysis categories emerge from the floating reading of the data, seeking to group them according to their similarities and differences.

Research Results

The participation of these teachers in the courses for implementing the Curriculum of the City of São Paulo, which took place throughout the year 2018, the year following the publication of the Curriculum of the City of São Paulo, most respondents (62.5%) indicated having participated in this implementation course. Most of the teachers who participated in this implementation (5 out of 8 respondents) indicated that, to some extent, this training helped them in their work in the classroom and to better understand the assumptions of the Curriculum of the City of Natural Sciences.

The organization of disciplinary content before and after the Curriculum of the City was indicated by only 1 of the 8 teachers as being very different from what was practiced before the publication of this document. Therefore, most teachers noted that the organization of content still follows a similar logic to what they did throughout their careers.

https://doi.org/10.33225/BalticSTE/2023.182

The main difficulties indicated by the participating teachers during the teaching of Natural Sciences were highlighted as material difficulties (books, instruments, laboratory) and the possibility of organizing experimental classes.

Regarding the correlation between the UN's Agenda 2030 and the possible connections with Natural Science content, the majority of participating teachers (5 out of 8) indicated that it was not satisfactory in relation to the 17 Social Development Goals outlined by the Agenda 2030. Thus, these teachers indicate facing difficulties in observing these relationships during their lessons.

Regarding their knowledge of "Scientific Literacy" prior to encountering the Curriculum of the City of São Paulo, most teachers (5 out of 8) indicated that they were unfamiliar with the term before coming across the document. Two teachers stated that they became familiar with the term through continuing education courses offered by the municipal education network, and one teacher indicated that they learned about the term while taking a course in a postgraduate education program offered by a state public university.

The last question asked the teachers to indicate the main daily difficulties in promoting Scientific Literacy during their Natural Science classes. Once again, 6 out of 8 teachers indicated material difficulties related to not having a laboratory to conduct experimentation activities with their students. Two other teachers cited learning gaps resulting from the pandemic and remote classes that occurred in the years 2020 and 2021.

Discussion

The group of teachers mostly have more than 15 years of experience in basic education. The results also indicate that more than 60% of the participants in this research completed the curriculum implementation course provided by the education network itself. According to the typology of moments in the teaching career proposed by Huberman (2009), these professionals are in the stage of emotional distancing from their teaching practice, disconnecting, to some extent, from engagement with their professionalization process. Therefore, having a lot of classroom experience, they have some crystallized conceptions and are more resistant to changes and interventions in their teaching practice.

The organization of the content was considered similar to the structure they followed before the publication of the document. Only one participant indicated that the changes were significant. Material difficulties were the most indicated obstacles to good teaching in natural sciences, followed by difficulties in planning experimental classes. This data confirms the conception that part of the teaching staff may have, that experimental activities are fundamental to the teaching of science (Munford & Lima, 2007). This data may also bring the hypothesis of a distorted view of science and scientific work brought by these teachers (Cachapuz et al., 2005) regarding an empirical-inductivist and atheoretical science, where concepts emerge from students' experimental work or strictly experimental, with the experiment having the role of confirming the theory.

Most of the group of teachers also recognizes difficulties in relating the disciplinary content of natural sciences to the sustainable development goals proposed by the UN's Agenda 2030. This result is in line with that found by Singhal and Wadhwa (2020),

https://doi.org/10.33225/BalticSTE/2023.182

who explored in-service science teachers and found that these professionals still have a lot of difficulties understanding sustainable development goals and applying them in their teaching practices. Agirreazkuenaga (2020) stated that basic education curricula are increasingly in demand to meet the sustainable development goals proposed by the Agenda 2030. Since an education based on ethical and moral values for social improvement has been shown to be an educational trend.

It is also noteworthy that most participants were unaware of the term "scientific literacy" before encountering the Natural Sciences curriculum of the city of São Paulo. Paz et al. (2019) investigated a group of teachers working in basic education and found very similar results. In addition to the lack of knowledge of the term, the researchers also obtained data levels of scientific literacy that were not very developed in this investigated group.

The absence of higher levels of scientific literacy among teachers may suggest that these professionals may also have greater difficulty in promoting scientific literacy in their basic education classes with their students (Listiani et al., 2022). This data also reinforces the importance of continuous training courses that assist basic education teachers, as it has been shown to be the main disseminator of the concept of scientific literacy (Paz et al., 2019).

The difficulties in promoting scientific literacy were pointed out by the participating teachers as related to learning gaps due to the pandemic and remote classes in the years 2020 and 2021, as well as difficulty in conducting experimental classes. This data brings to light a major problem: the learning gaps due to remote teaching during the pandemic (Engzell et al., 2021). Considering the socioeconomic reality of most students in the public education system, these difficulties in accessing education were even greater due to the lack of devices that could connect them and even internet services in their homes.

Conclusions and Implications

Based on the research results, it's possible to reflect that the conceptions of teachers in the early years who teach science are closely related to rigorously experimental science, where object manipulation is an essential part of sufficient science learning. Despite most participating teachers in this research being highly experienced, with over half having more than 15 years of classroom experience, they still have difficulties in promoting science lessons that can meet the assumption of promoting scientific literacy desired by the Curriculum of the City of São Paulo for Natural Sciences.

The results of this study indicate that greater initiatives are needed for primary school teachers focusing on science teaching, with a particular emphasis on promoting teaching that values students' scientific literacy. The formative gaps obtained because of this work are in line with those found in other studies conducted in different countries, highlighting the need to investigate with basic education teachers their conceptions and difficulties regarding the practice of curricula that focus on the development of skills rather than just the more traditional development of content.

In this sense, future studies with a larger number of participants are suggested to be conducted as quantitative studies, which evaluate the conceptions of public-school teachers about the curriculum and scientific literacy, since this theoretical framework is relevant not only in the Brazilian scenario but also on a global scale when related to science programs in basic education.

https://doi.org/10.33225/BalticSTE/2023.182

Declaration of Interest

The authors declare no competing interest.

References

Agirreazkuenaga, L. (2020). Education for agenda 2030: What direction do we want to take going forward? *Sustainability*, *12*(5), 2035, https://doi.org/10.3390/su12052035

Bardin, L. (1977). *Análise de conteúdo* [Content Analysys] (L. A. Reto & A. Pinheiro, Trads.). Edições 70.

Cachapuz, A., Gil-Pérez, D., Carvalho, A. D., Praia, J., & Vilches, A. (2005). *A necessária renovação do ensino das ciências* [The necessary renewal of science education]. Cortez.

Creswell, J. W. (2010). *Projeto de pesquisa – Métodos qualitativo, quantitativo e misto* [Research Project - qualitative, quantitative, and mixed methods]. Artmed.

Crotty, M. (1998). *The foundation of social research: Meaning and perspective in the research process.* Sage.

Engzell, P., Frey, A., & Verhagen, M. D. (2021). Learning loss due to school closures during the COVID-19 pandemic. *Proceedings of the National Academy of Sciences*, *118*(17), https://doi.org/10.1073/pnas.2022376118

Huberman, M. (2000). O ciclo de vida profissional dos professores [The professional life cycle of teachers]. In: NÓVOA, A. (Org.). *Vidas de Professores* [Teachers lives] (2nd., pp. 33-61). Porto.

Krasilchik, M. (2000). Reformas e realidade: O caso do ensino de ciências [Reforms and reality: The case of science education]. *São Paulo em Perspectiva*, *14*(1), 85-93, https://www.scielo.br/j/spp/a/y6BkX9fCmQFDNnj5mtFgzyF/?format=pdf&lang=pt

Listiani, I., Susilo, H., & Sueb, S. (2022). Relationship between scientific literacy and critical thinking of prospective teachers. *Al-Ishlah: Jurnal Pendidikan*, *14*(1), 721-730, http://dx.doi.org/10.35445/alishlah.v14i1.1355

Machado, M. H., & Meirelles, R. M. S. (2020). Da "LDB" dos anos 1960 até a BNCC de 2018: breve relato histórico do ensino de Biologia no Brasil [From the "DBL" of the 1960s to the BNCC of 2018: a brief historical account of Biology teaching in Brazil]. *Debates em Educação*, *12*(27), 1-19, https://doi.org/10.28998/2175-6600.2020v12n27p163-181

Munford, D., & Lima, M. E. C. D. C. (2007). Ensinar ciências por investigação: Em quê estamos de acordo? [Teaching science through inquiry: what do we agree on?]. *Ensaio Pesquisa em Educação em Ciências*, *9*, 89-111, https://www.scielo.br/j/epec/a/ZfTN4WwscpKqvwZdxcsT84s/?format=pdf&lang=pt

Özdem, Y., Çavas, P., Çavas, B., Çakıroğlu, J., & Ertepınar, H. (2010). An Investigation of elementary students' scientific literacy levels, *Journal of Baltic Science Education*, *9*(1), 6-19, http://oaji.net/articles/2014/987-1404740965.pdf

Paz, G. S. B., Avila Junior, P. D., & Leal, S. H. B. D. S. (2019). Indicadores de alfabetização científica de professores em serviço: a bioquímica como contexto formativo [Indicators of scientific literacy among in-service teachers: biochemistry as a formative context]. *Linhas Críticas*, *25, 252-276,* https://doi.org/10.26512/lc.v25.2019.21587

Paz, G. S. B., Molina, E. R., Rovay, R. P., Barbosa, F. F., & Locatelli, S. W. (2019). Atividades investigativas de química nos anos iniciais do ensino fundamental: a extensão universitária como espaço de formação continuada [Chemistry investigative activities in the early years of elementary school: university extension as a space for continuing education]. *Interfaces-Revista de Extensão da UFMG*, *7*(1), 192-207, https://periodicos.ufmg.br/index.php/revistainterfaces/article/view/19059/16133

Ring, E. A. (2017). *Teacher conceptions of integrated STEM education and how they are reflected in integrated STEM curriculum writing and classroom implementation* (Doctoral dissertation, University of Minnesota).

Sacristan, J. G. (2013). *Saberes e incertezas sobre o currículo* [Knowledge and uncertainties about the Curriculum]. Penso.

São Paulo. (2017). Currículo da Cidade de São Paulo: Ciências Naturais [Curriculum of the City of São Paulo: Natural Sciences]. São Paulo, SP: SME/COPED, https://acervodigital.sme.prefeitura.sp.gov.br/wp-content/uploads/2021/08/CC-Ciencias.pdf

Singhal, M., & Wadhwa, M. (2020). Vision of Science Education in National Education Policy-2020. *Voices of Teachers and Teacher Educators*, 9(1), 59-68, https://www.researchgate.net/profile/Priyamvada-Pandey/publication/366990302_Pre-service_Teachers'_Perceptions_on_Internship_in_Relation_to_Integrated_and_Specific_Professional_Teaching_Courses_A_Study/links/63bd7402c3c99660ebe42d8e/Pre-service-Teachers-Perceptions-on-Internship-in-Relation-to-Integrated-and-Specific-Professional-Teaching-Courses-A-Study.pdf#page=71

Received: *April 15, 2023* Accepted: *May 17, 2023*

Cite as: Paz, G. S. B., & Locatelli, S. W. (2023). The natural sciences curriculum of public network of São Paulo: Conceptions of teachers who teach natural sciences in the early years of primary school. In V. Lamanauskas (Ed.), *Science and technology education: New developments and Innovations. Proceedings of the 5th International Baltic Symposium on Science and Technology Education (BalticSTE2023)* (pp. 182-189). Scientia Socialis Press. https://doi.org/10.33225/BalticSTE/2023.182

SECONDARY SCHOOL STUDENTS' PERCEPTION OF BIOCHEMISTRY CONCEPTS BY USING WORD ASSOCIATION TEST

Tamara N. Rončević, **Saša A. Horvat**,
Dušica D. Rodić, **Ivana Z. Bogdanović**
University of Novi Sad, Republic of Serbia
E-mail: tamara.hrin@dh.uns.ac.rs, sasa.horvat@dh.uns.ac.rs, dusica.milenkovic@dh.uns.ac.rs, ivana.bogdanovic@df.uns.ac.rs

Abstract

A word association test was used to determine knowledge structures on biochemistry concepts of secondary school chemistry students, aged between 18-19 years. The basic biochemistry concepts related to the topic of Carbohydrates that take place in the International Baccalaurate Diploma Programme curriculum were determined as stimulus words: "Monosaccharides", "Glucose", "Cellular respiration", "Fructose", "Disaccharides", "Glycosidic bonds", "Polysaccharides", "Starch". Students were required to provide response words for each of the eight stimulus words within the pre-determined period of time. Analysis of data was done in order to find the stimulus words with the highest number of associations in students' knowledge structures and to calculate the relatedness coefficient between the stimulus words, in order to construct the relatedness networks that should model the students' knowledge structures. The results showed that students managed to relate most of the stimulus words with strong or medium strength links, however, "Cellular respiration" remained unconnected to other stimulus words in the students' knowledge structures.
Keywords: *biochemistry education, knowledge structures, secondary school students, word association test*

Introduction

It is well known that chemistry is a complex subject which deals with many abstract topics and concepts (Burrows & Reid Mooring, 2015) that, at the same time, represent fundamental ideas in chemistry courses. The students at both secondary and tertiary levels struggle with acquiring knowledge about the particulate nature of matter, chemical changes, chemical bonding, chemical equations and equilibrium, acids and bases (Treagust et al., 2000), energy in chemical reactions and the kinetics (Gegios et al., 2017), organic reaction types and mechanisms (Weber & Flynn, 2018).

In order to be understood, these concepts should be given a proper sense by the students. This could be achieved by making connections between the set of core concepts and fundamental ideas in order to develop a coherent and functional knowledge structure (Burrows & Reid Mooring, 2015). Knowledge structures are described as "mental structures of knowledge", while knowledge is organized around core concepts and big, fundamental ideas that guide the process of thinking (cited in Lopez et al., 2014).

https://doi.org/10.33225/BalticSTE/2023.190

There are different ways to analyze the underlying concepts in students' knowledge structures, as well as connections among them. Here, the knowledge structure is modelled as an associative or relatedness network of nodes (i.e., concepts, terms, words) linked together (Nakiboglu, 2008). The strength of such links depends on the frequencies with which they appear, or how often they are used by the students. In the literature, concept maps, analogies, and word association tests are proposed to explore students' knowledge structure. Certainly, word association test is one of the oldest techniques that has been used in a variety of chemistry topics, such as atomic structure (Nakiboglu, 2008), physical and chemical changes (Nakiboglu, 2016), dissolution (Derman & Eilks, 2016). In biology education, Özarslan and Çetin (2018) applied a word association test to investigate secondary school students' knowledge structures about basic components of the living organisms, such as minerals, salts, vitamins, proteins, fats, and carbohydrates. However, according to our knowledge, there are no empirical studies on students' knowledge structures on carbohydrates as biomolecules and word association tests.

Research Problem and Research Focus

Biochemistry is an interdisciplinary, content-laden discipline (Vanderlelie, 2013) that applies chemistry to biological processes at both molecular and cellular levels (Salame et al., 2022). Even before learning about metabolic pathways (e.g., glycogenesis, beta-oxidation, urea and citric acid cycles), students encounter with complex names and structures of important biomolecules, with their vital role for leaving organisms to grow, sustain and reproduce, and the diversity of their functions. Taking into consideration the significance of these issues, biochemistry and biomolecules have been introduced in the chemistry syllabus within many secondary schools worldwide. Also, in some of the secondary school programs, the students have the possibility to choose this discipline as the optional one.

Research Aim and Research Questions

The aim of this study was to analyze secondary school students' knowledge structures and perceptions of "Carbohydrates" using a word association test (WAT). The WAT technique was chosen in order to look at the connectedness between some of the key biochemistry concepts within International Baccalaureate (IB) Diploma Programme students' knowledge structures. The following research questions were intended to be answered:

(1) How do IB students shape the concept of "Carbohydrates" in their minds?
(2) Which terms evoke the concept of "Carbohydrates" to them?
(3) On which level is the connectedness of "Carbohydrates" keywords within the IB chemistry students' knowledge structures?

https://doi.org/10.33225/BalticSTE/2023.190

Research Methodology

General Background

The study was based on qualitative data collection, with the data analysis that combines both quantitative (i.e., analysis of frequencies) and qualitative data analysis procedures. The central research instrument was the word association test (WAT), and data gathered from WAT was subjected to content analysis in order to analyze how secondary school students perceive the key concepts of "Carbohydrates".

The processing of biochemistry contents and testing of International Baccalaureate (IB) Diploma Programme chemistry students with WAT were done at the beginning of the second semester of the 2022/2023 school year.

Sample

The secondary school students from the Gymnasium "Jovan Jovanović Zmaj", Novi Sad, Republic of Serbia participated in this study. The study sample consisted of the International Baccalaureate (IB) Diploma Program students who were taking their Chemistry course in English, which is not their native language, using an English textbook (Owen et al., 2014). The students were taught by one of the authors (T.R.).

The IB program is a rigorous pre-university two-year program dedicated to students aged 16 to 19. This study included only second-year students, and therefore, the research sample was small (N = 8, aged 18-19). It should be noted that regularly our second-year IB class consists of eleven students, however, on the day of testing with WAT, eight of them were present in chemistry classes. Two of the students have been taking chemistry course at a higher level (HL) and six of them at a standard level (SL). It should be highlighted that IB classrooms have a maximum of 25 students per class, as they should be equipped with modern and smart teaching aids and inquiry sources (https://www.modernschool.org/ib-curriculum/).

The IB program is different from the Serbian national program and national chemistry curriculum, not only in the contents learned but in the outcomes of learners' profiles. The IB students are encouraged to think critically and creatively, to develop and use conceptual understanding, to develop skills for inquiry, to design investigations and collect data, to apply practical approach, and to engage with issues of local and global significance (IB Diploma Programme, Chemistry Guide, 2016). Therefore, IB students are recognized worldwide as high standards achievers (Celestino & Marchetti, 2020).

Instrument and Procedures

The word association test (WAT) was used in this study as the data collection instrument for the teaching topic "Carbohydrates". IB Chemistry course syllabus has several components: core, additional higher level contents, options, and practical scheme of work. The core includes contents such as stoichiometric relationships, atomic structure, periodicity, chemical bonding and structure, etc., while options include materials, biochemistry, energy and medical chemistry (IB Diploma Programme, Chemistry Guide, 2016). At the beginning of the second year of the Diploma Programme, the IB students

https://doi.org/10.33225/BalticSTE/2023.190

selected Option B – Biochemistry which includes six teaching topics common for both SL and HL students (15 teaching hours), and four additional teaching topics for HL students only (additional 10 teaching hours) (see Table 1).

Table 1
IB Chemistry Cours Syllabus for the Option B – Biochemistry

No.	Teaching contents	Level
B.1	Introduction to biochemistry	SL/HL
B.2	Proteins and enzymes	SL/HL
B.3	Lipides	SL/HL
B.4	Carbohydrates	SL/HL
B.5	Vitamins	SL/HL
B.6	Biochemistry and the environment	SL/HL
B.7	Proteins and enzymes (inhibitors, amino acids, and proteins as buffers in solutions, UV-VIS spectroscopy)	HL
B.8	Nucleic acids	HL
B.9	Biological pigments	HL
B.10	Stereochemistry in biomolecules	HL

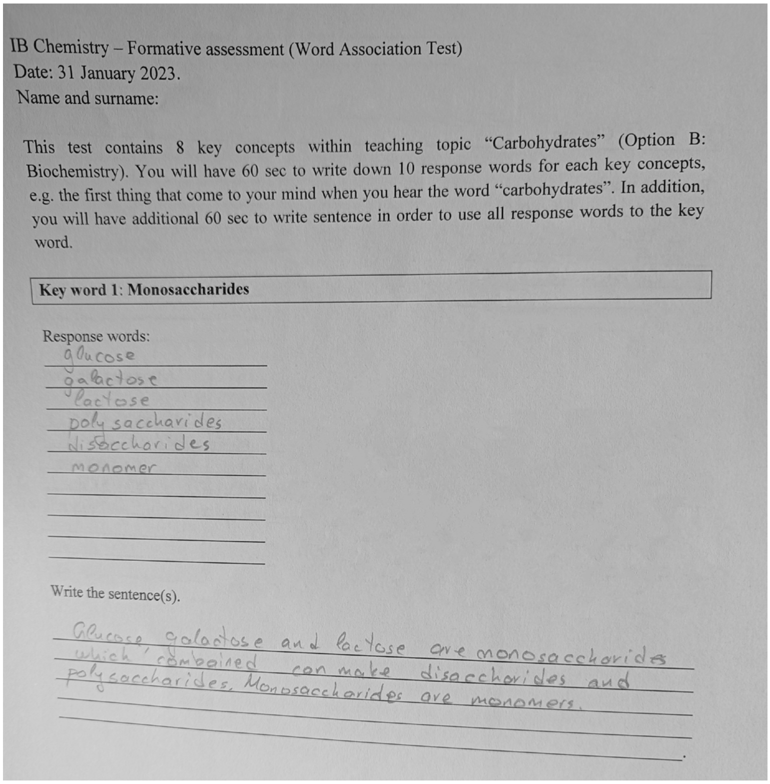
The WAT was applied after instruction on "Carbohydrates" in January 2023. Before starting the application, the students were informed about the purpose and structure of WAT. All students agreed to voluntarily participate in the research. A booklet with eight stimulus words (i.e., keywords) was provided to the IB students. Each stimulus word was noted on a separate page, according to the recommendations by Derman and Eilks (2016) and Nakiboglu (2008) with the aim to prevent a chain effect that has been explained as a distraction from the stimulus word (Nakiboglu, 2008). The stimulus words were presented in the following order: "*Monosaccharides*", "*Glucose*", "*Cellular respiration*", "*Fructose*", "*Disaccharides*", "*Glycosidic bond*", "*Polysaccharides*", "*Starch*". The concepts that have been included in WAT were terms noted in "IB points to understand the topic" and the terms that were bolded in the textbook.

After receiving the booklet, the students were asked to write the response words to each of the eight stimulus words. They were encouraged to write as many response words as they could in the limited time period of 60 seconds. There were blanks after each stimulus word on the paper left for the students to respond (Figure 1). The free WAT technique with a pre-specific period of time was used, in which the students had to write concepts (i.e., response words) which were brought to their mind by the stimulus words and to decide which response words were the most important in order to be related with the stimulus word (Tsai & Huang, 2002). Also, at the end of each page in the booklet, there were lines provided to students to write sentences related to the stimulus word by using written response words (Figure 1). The students were given an additional 60 seconds for writing the sentence(s) for each stimulus word. However, the analysis of these sentences is not part of this report.

https://doi.org/10.33225/BalticSTE/2023.190

Figure 1

The First Page of the WAT Booklet with the HL Student' Responses


IB Chemistry – Formative assessment (Word Association Test)
Date: 31 January 2023.
Name and surname:

This test contains 8 key concepts within teaching topic "Carbohydrates" (Option B: Biochemistry). You will have 60 sec to write down 10 response words for each key concepts, e.g. the first thing that come to your mind when you hear the word "carbohydrates". In addition, you will have additional 60 sec to write sentence in order to use all response words to the key word.

Key word 1: Monosaccharides

Response words:
glucose
galactose
lactose
polysaccharides
disaccharides
monomer

Write the sentence(s).
Glucose, galactose and lactose are monosaccharides which combined can make disaccharides and polysaccharides. Monosaccharides are monomers.

Data Analysis

Data obtained through WAT were analyzed in several stages. Firstly, the response words for each stimulus word and each student were examined. The list of response words was formed, and the number of different response words for each stimulus word was counted. The list of response words was used to create a frequency table.

In the next stage, Garskoff and Houston's relatedness coefficient, RC, was calculated for each pair of stimulus words. The relatedness coefficient (RC) between the stimulus words has been calculated using the formula and the mathematic procedure presented in the paper by Bahar et al. (1999):

$$RC = \frac{\bar{A} \text{ x } \bar{B}}{(\text{A x B}) - 1}$$

However, it should be highlighted that the modification was done in the mathematical procedure in comparison with the original source. In the paper by Bahar et al. (1999), in the formula, $\bar{A}$ represents the rank order of occurrence of terms under stimulus word A that are shared in common with stimulus word B, while $\bar{B}$ represents the rank order of occurrence of terms under stimulus word B that are shared in common with stimulus word A. In the procedure followed in this study, $\bar{A}$ represents the real frequencies of the response words that are shared in common with stimulus word B, while $\bar{B}$ represents the real frequencies of the response words that are shared in common with stimulus word A. In the original version "A x B" represents the sum of the products of the rank order of the terms noted within the stimulus word A multiplied by the rank order of terms noted within the stimulus word B (Bahar et al., 1999), and in the following procedure, "A x B" represents the sum of products of the frequencies of the response words noted within stimulus word A multiplied with sum of the products of the frequencies of the response words noted within stimulus word B.

At the final stage, students' knowledge structure was visualized by mapping technique – relatedness networks, which were drawn by using calculated values of RC.

Research Results

At the beginning of the data analysis, the total number of different response words was counted for each stimulus word. For the eight stimulus words, a total number of 102 response words was found. The number of different response words varied within different stimulus words. The stimulus words for which the IB students wrote the highest number of different response words were: "*Monosaccharides*" with the frequency f = 28, and "*Glucose*" (f = 28), and after that "*Starch*" (f = 27). On the other hand, for the stimulus words "*Polysaccharides*" (f = 16), "*Glycosidic bond*" (f = 18) and "*Fructose*" (f = 20) there were significantly lower numbers of diverse response words provided by the IB students.

Afterwards, a frequency table was formed including eight stimulus words (noted in columns in Table 2 as SW1 to SW8) and response words (noted in rows in Table 2), showing the frequency of response words associated with the stimulus words. The frequency table has been arranged by the alphabetical order of response words and Table 2 shows only one, a small part of the complete frequency table because of the numerous response words. It should be highlighted that some response words were actually the repeated stimulus words. For example, "*Disaccharides*" appeared 4 times as the response word for the SW1 ("*Monosaccharides*"), 4 times for SW4 ("*Fructose*"), 5 times for SW6 ("*Glycosidic bond*"), 3 times for SW7 ("*Polysaccharides*"), and 2 times as the response word for the SW8 ("*Starch*"). Therefore, it was found that some of the response words like "*Disaccharides*" appeared within several stimulus words, while for example, the response words like "*Aerobic*" (see Table 2) or "*Iodine test*" appeared only once as a response word for the stimulus word "*Cellular respiration*" and "*Starch*" respectively.

https://doi.org/10.33225/BalticSTE/2023.190

Table 2
A Frequency Table with WAT Frequency Values

Response words	Stimulus words (Frequency of response words)							
	SW1	*SW2*	*SW3*	*SW4*	*SW5*	*SW6*	*SW7*	*SW8*
Aerobic	-	-	1	-	-	-	-	-
Acid	-	-	-	-	-	1	-	-
Air	-	-	1	-	-	-	-	-
Alcohol	-	-	-	1	-	-	-	-
Allergic	-	1	-	-	-	-	-	-
Alpha helix	1	1	-	-	-	-	-	-
Alveoli	-	-	1	-	-	-	-	-
Amino group	1	-	-	-	-	-	-	-
Amylopectin	-	-	-	-	-	-	-	1
Amylose	-	-	-	-	-	-	-	2
Anaerobic	-	-	2	-	-	-	-	-
Anomeric hydroxyl group	1	-	-	-	1	-	-	-
Apple	-	-	-	1	-	-	-	-
ATP	-	-	4	-	-	-	-	-
Base	-	-	-	-	-	1	-	-
Beta pleated sheet	1	1	-	-	-	-	-	-
Between	-	-	-	-	-	1	-	-
Biose	-	-	-	-	1	-	-	-

Note: SW1: *Monosaccharides*; SW2: *Glucose; SW3: Cellular respiration; SW4: Fructose; SW5: Disaccharides; SW6: Glycosidic bonds;* SW7: *Polysaccharides; SW8: Starch.*

In addition, it was important to calculate and interpret the relatedness coefficient, RC, for each pair of the stimulus words and the results are presented in Table 3. An example of the calculation is presented below the text, observing the RC between the SW1 ("*Monosaccharides*") and SW2 ("*Glucose*"). The calculated value shows strong relatedness between these two stimulus words (interpreted according to Nakiboglu, 2008).

$$RC = \frac{\overline{\mathrm{A}} \times \overline{\mathrm{B}}}{(\mathrm{A} \times \mathrm{B}) - 1}$$
$$= \frac{(1,1,1,2,3,2,1,2,4,2,2,5) \mathrm{x} \ (1,1,1,1,2,1,3,1,1,1,1,6)}{(5,5,4,4,3,3,3,2,2,2,2,2,2,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1) \mathrm{x} (6,6,3,2,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1) - 1}$$
$$= 0.487$$

Table 3
Relatedness Coefficient, RC, Between the Stimulus Words

Stimulus words	**Relatedness coefficient, RC** (0 – 1)							
	SW1	*SW2*	*SW3*	*SW4*	*SW5*	*SW6*	*SW7*	*SW8*
SW1	-	0.487	0.096	0.375	0.467	0.355	0.265	0.341
SW2	0.487	-	0.078	0.659	0.750	0.288	0.677	0.292
SW3	0.096	0.078	-	0.076	0.047	0.110	0.033	0.141
SW4	0.375	0.659	0.076	-	0.516	0.487	0.537	0.333
SW5	0.467	0.750	0.047	0.516	-	0.192	0.602	0.263
SW6	0.355	0.288	0.110	0.487	0.192	-	0.481	0.400
SW7	0.265	0.677	0.033	0.537	0.602	0.481	-	0.366
SW8	0.341	0.292	0.141	0.333	0.263	0.400	0.366	-

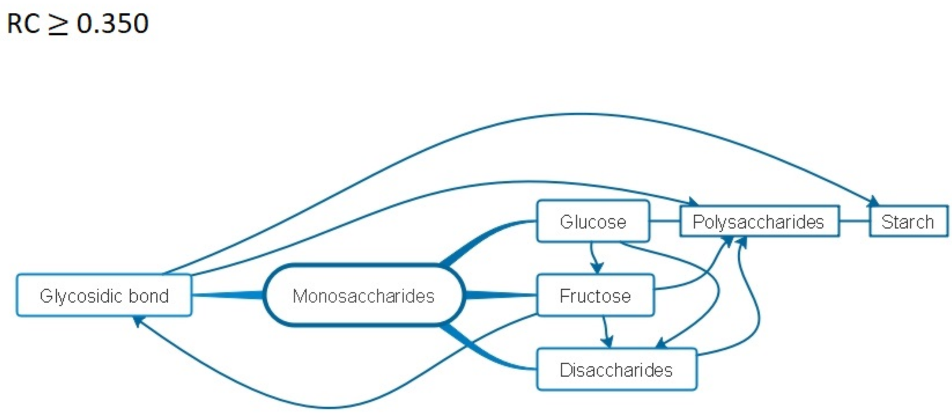
It can be seen from Table 3 that RC values ranged from 0.033 to 0.750. It was clearly perceived that RCs for the SW3 („*Cellular respiration*“) were really low for each pairing of SW3 with the other stimulus words. Namely, any of the calculated RC values did not exceed the required value of 0.200 (i.e. the lowest acceptable value of RC).

According to Nakiboglu (2008), RC≥0.350 was chosen as the starting cut-off point for drawing relatedness networks between stimulus words (Figure 2). The next cut-off point was done for the 0.350>RC≥0.300 (Figure 3), and the last one for the 0.300>RC≥0.250 (Figure 4). It should be noted that in the original paper (Nakiboglu, 2008) the last cut-off point was done for the 0.250>RC≥0.200, however, in the present study, there were no RC values in this range (see Table 3). The relatedness networks are presented in Figure 2, Figure 3 and Figure 4.

The strongest interconnectedness of stimulus words is presented in Figure 2. There were 14 RC values greater than 0.350 and such strong association was formed between (1) "*Monosaccharides*" – "*Glucose*", (2) "*Monosaccharides*" – "*Fructose*", (3) "*Monosaccharides*" – "*Disaccharides*", (4) "*Monosaccharides*" – "*Glycosidic bond*", (5) "*Glucose*" – "*Fructose*", (6) "*Glucose*" – "*Disaccharides*", (7) "*Glucose*" – "*Polysaccharides*", (8) "*Fructose*" – "*Disaccharides*", (9) "*Fructose*" – "*Polysaccharides*", (10) "*Fructose*" – "*Glycosidic bond*", (11) "*Glycosidic bond*" – "*Polysaccharides*", (12) "*Glycosidic bond*" – "*Starch*", (13) "*Polysaccharides*" – "*Starch*", and (14) "*Disaccharides*" – "*Polysaccharides*". It was interesting to note that even though IB students were not able to provide a higher number of diverse response words for the stimulus words "*Polysaccharides*" (*f*=16) and "*Fructose*" (*f*=20), these stimulus words achieved the strongest associations with other five stimulus words in students' knowledge structures.

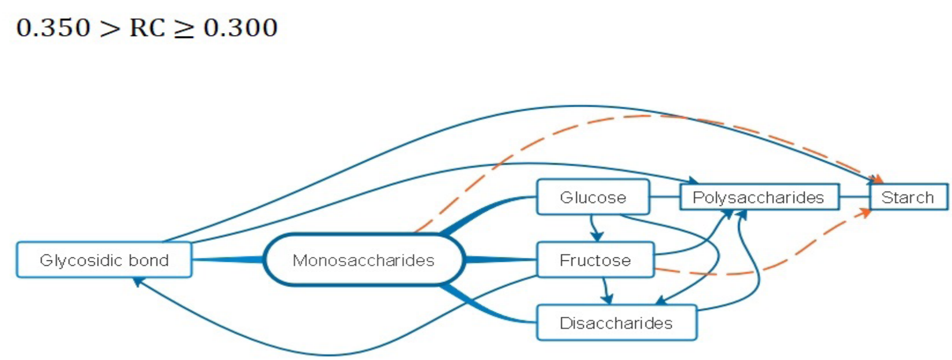
https://doi.org/10.33225/BalticSTE/2023.190

Figure 2
The Relatedness Networks between Stimulus Words for the RC≥0.350



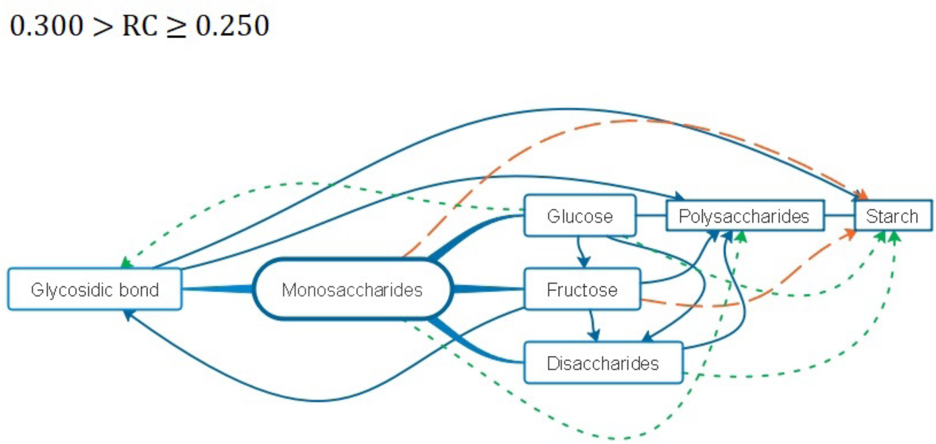
Further lowering of RC to 0.300 showed the other two connections of medium strength between the following stimulus words: (1) "*Monosaccharides*" – "*Starch*" and (2) "*Fructose*" – "*Starch*" (Figure 3, dashed, orange lines). Both connections were recorded for the stimulus word "*Starch*".

Figure 3
The Relatedness Networks between Stimulus Words for the 0.350>RC≥0.300



Additional lowering of RC to 0.250 provided three connections of weak strength. Looking at Figure 4 (dashed, green lines), these connections are formed between the stimulus words (1) "*Glucose*" – "*Glycosidic bond*", (2) "*Monosaccharides*" – "*Polysaccharides*", and (3) "*Disaccharides*" – "*Starch*".

Figure 4
The Relatedness Networks between Stimulus Words for the 0.300>RC≥0.250



Discussion

As the aim of this study was to determine the IB students' knowledge structure in the biochemistry discipline within the teaching topic "Carbohydrates", the frequency map was formed in order to reveal the richness of the response words for each of the eight stimulus words. If the number of different response words is considered a direct and significant indication of interlinks in students' minds (Nakiboglu, 2008), the assumption could be made that "*Monosaccharides*" and "*Glucose*" are better structured in students' knowledge structures than the other stimulus words. Even though the literature sources indicate that students' ability to provide a high number of different response words to the key or stimulus word is a good indicator of students' understanding (Atabek-Yigit, 2016), in our study, this was not accepted as a hundred per cent correct. Namely, the stimulus words for which the students provided a lower number of diverse response words (SW7 – "*Polysaccharides*" and SW4 – "*Fructose*"), showed the highest commonality with the other stimulus words in the students' knowledge structures. These results were found in the analysis of the relatedness coefficient and presented within the relatedness networks. Anderson and Schönborn (2008) noted that the biochemistry discipline passes through a constant increase in new knowledge, but primarily, it is crucial that students develop core conceptual knowledge of this specific discipline.

Taking into account the relatedness networks that show students' knowledge structures about teaching topic "Carbohydrates", it should be highlighted that there were no "isolated islands" or independent associations between the stimulus words (Nakiboglu, 2008), as even at the level of the strongest interconnectedness, each of the seven stimuli words is connected with two or more other stimulus words. According to Bahar et al. (1999) the meaning of the concept (i.e., stimulus word) is enriched as more connections are formed with other key concepts from the observed discipline. However, the stimulus word "*Cellular respiration*" (SW3) remained totally unconnected with other stimulus words from the teaching topic "*Carbohydrates*" as this stimulus word did not appear on any of the three relatedness networks. It could be said that stimulus word "*Cellular respiration*" remained static, non-interactive and limited in light of external connections (according to Derman & Eilks, 2016) with the other key words from the teaching topic "*Carbohydrates*".

Conclusions and Implications

In this study, WAT was successfully used as a tool in order to reveal the organization of key concepts in IB students' knowledge structures about "Carbohydrates". It must be emphasized that WAT was applied immediately after the instruction on Biochemistry contents and the IB students were not prepared for WAT in the way as they did for the real exams. Therefore, presented results show the "row state" before the deeper learning happened. In this point, it would be valuable to repeat the WAT now, after the exam on Biochemistry contents and to compare the results. Perhaps, we might expect better results from the repeated testing regarding the stimulus word that was totally isolated from the others (SW3 – "*Cellular respiration*"). Additionally, as each student was required to write sentences in order to use the response words for each of eight stimulus words, these sentences should be analyzed and put into categories as irrelevant (off topic sentences), misconceptions and correct scientific knowledge.

At the end, not many authors choose International Baccalaureate Diploma Programme students as a study sample for the empirical research. Certainly, in the literature, there are topics like preparing students for the IB program, or some results on the questionnaire why students choose to do the IB, or the analysis of learning outcome of national and IB program. Therefore, presented research results provide some new insights into IB students profiles and their patterns to corelate concepts in their minds.

Acknowledgements

The authors gratefully acknowledge the financial support of the Ministry of Science, Technological Development and Innovation of the Republic of Serbia (Grant No. 451-03-47/2023-01/200125).

Declaration of Interest

The authors declare no competing interest.

References

Anderson, T. R., & Schönborn, K. J. (2008). Bridging the educational research-teaching practice gap: Conceptual understanding, part 1: The multifaceted nature of expert knowledge. *Biochemistry and Molecular Biology Education*, *36*(4), 309–15. https://doi.org/10.1002/bmb.20209

Atabek-Yigit, E. (2016). Investigating cognitive structures in some basic chemistry concepts via word association test. *Elementary Education Online*, *15*(4), 1385–1398. http://dx.doi.org/10.17051/io.2016.12031

Bahar, M., Johnstone, A. H., & Sutcliffe, R. G. (1999). Investigation of students' cognitive structure in elementary genetics through word association tests. *Journal of Biological Education*, *33*(3), 134–141. http://dx.doi.org/10.1080/00219266.1999.9655653

Burrows, N. L., & Reid Mooring, S. (2015). Using concept mapping to uncover students' knowledge structures of chemical bonding concepts. *Chemistry Education Research and Practice*, *16*(1), 53–66. https://doi.org/10.1039/C4RP00180J

Celestino, T., & Marchetti, F. (2020). Surveying Italian and International Baccalaureate teachers to compare their opinions on system concept and interdisciplinary approaches in chemistry education. *Journal of Chemical Education*, *97*(10), 3575–3587. https://dx.doi.org/10.1021/acs.jchemed.9b00293

Derman, A., & Eilks, I. (2016). Using a word association test for the assessment of high school students' cognitive structures on dissolution. *Chemistry Education Research and Practice*, *17*(4), 902–913. https://doi.org/10.1039/C6RP00084C

Diploma Programme Chemistry Guide (2016). *The International Baccalaureate Organization*. Wales, United Kingdom.

Gegios, T., Salta, K., & Koinis, S. (2017). Investigating high-school chemical kinetics: The Greek chemistry textbook and students' difficulties. *Chemistry Education Research and Practice*, *18*(1), 151–168. https://doi.org/10.1039/C6RP00192K

Lopez, E. J., Shavelson, R. J., Nandagopal, K., Szu, E., & Penn, J. (2014). Ethnically diverse students' knowledge structures in first-semester organic chemistry. *Journal of Research in Science Teaching*, *51*(6), 741–758. https://doi.org/10.1002/tea.21160

Modern School. (2023, April 15). International Baccalaureate. https://www.modernschool.org/ib-curriculum/

Nakiboglu, C. (2008). Using word associations for assessing non major science students' knowledge structure before and after general chemistry instruction: The case of atomic structure. *Chemistry Education Research and Practice*, *9*(4), 309–322. https://doi.org/10.1039/B818466F

Nakiboglu, C. (2016). Probing high school students' cognitive structure about physical and chemical changes through word association test. *The Eurasia Proceedings of Educational & Social Sciences*, *4*, 486–489.

Owen, S., Ahmed, C., Martin, C., & Woodward, R. (2014). *Chemistry for the IB Diploma*. Cambridge University Press.

Özarslan, M., & Çetin, G. (2018). Biology students' cognitive structures about basic components of living organisms. *Science Education International*, *29*(2), 62–74. https://doi.org/10.33828/sei.v29.i2.1

Salame, I. I., Abid, M., & Simms, S. (2022). Examining some of the challenges that students face in learning about metabolic pathways in a traditional biochemistry course. *International Journal of Instruction*, *15*(4), 277–292.

Treagust, D., Duit, R., & Nieswandt, M. (2000). Sources of students' difficulties in learning Chemistry. *Educación Química*, *11*(2), 228–235. https://doi.org/10.22201/fq.18708404e.2000.2.66458

Tsai, C. C., & Huang, C. M. (2002). Exploring students' cognitive structures in learning science: A review of relevant methods. *Journal of Biological Education*, *36*(4), 163−169. https://doi.org/10.1080/00219266.2002.9655827

Vanderlelie, J. J. (2013). Improving the student experience of learning and teaching in second year biochemistry: Assessment to foster a creative application of biochemical concepts. *International Journal of Innovation in Science and Mathematics Education*, *21*(4), 46−57.

Webber, D. M., & Flynn, A. B. (2018). How are students solving familiar and unfamiliar organic chemistry mechanism questions in a new curriculum? *Journal of Chemical Education*, *95*(9), 1451−1467. https://doi.org/10.1021/acs.jchemed.8b00158

Received: *April 08, 2023* Accepted: *May 15, 2023*

Cite as: Rončević, T. N., Horvat, S. A., Rodić, D. D., & Bogdanović, I. Z. (2023). Secondary school students' perception of biochemistry concepts by using word association test. In V. Lamanauskas (Ed.), *Science and technology education: New developments and Innovations. Proceedings of the 5th International Baltic Symposium on Science and Technology Education (BalticSTE2023)* (pp. 190-202). Scientia Socialis Press. https://doi.org/10.33225/BalticSTE/2023.190

INTELLIGENT LEARNING IN STUDYING AND PLANNING COURSES – NEW OPPORTUNITIES AND CHALLENGES FOR OFFICERS

Kalle Saastamoinen , Antti Rissanen , Arto Mutanen
National Defence University, Finland
E-mail: kalle.saastamoinen@mil.fi, antti.rissanen@mil.fi, arto.mutanen@mil.fi

Abstract

There were two projects at the National Defence University of Finland (NDU), which both ended by the end of 2022. One of them tried to find the answers to the main question: How artificial intelligence (AI) could be used to improve learning, teaching, and planning? The other tried to find the answer to the main question: What new skills do officers need when artificial intelligence is coming?
We did literature reviews and found out that intelligent technology combined with data analytics can offer several improvements to traditional classroom teaching. From literature reviews, we also found some new skills that officers might need to be able to handle AI- based technologies.
This is a position paper presenting the arguable opinions of the writers.
We have found lots of benefits that the use of intelligent learning technology can bring, mainly by supporting individual learning paths. There is also an obvious need for AI officers who should have a deeper understanding of the AI-supported technology than normal officers.
This project and some other similar projects have raised a lot of discussions, one seminar series about artificial intelligence and we do have some trained AI officers as well.
Keywords: *artificial intelligence, intelligent learning, supported studying, intelligent planning, characteristics of war*

Introduction

Artificial intelligence (AI) forms the basis for intelligent learning and AI is possible by machine learning and reinforcement learning. New smart learning environments enhance the learning process, making it independent of time and place. The use of mobile devices as part of learning literally enables continuous learning through mobility and device independence. On the other hand, there are new requirements for learning, because new information is immediately available to everyone, in which case understanding and utilization of information become key competitive assets in terms of career development.

In the Finnish Defense Forces, we understand that artificial intelligence will bring changes and set new requirements for officers' skills. Learning becomes independent of place and time; lifelong learning becomes a permanent phenomenon. Officers must have sufficient knowledge to implement methods and tools utilizing artificial intelligence, as well as the wisdom to combine pedagogy and new intelligent systems. This study investigates the possibilities of using artificial intelligence in the training of officers from

https://doi.org/10.33225/BalticSTE/2023.203

a technical point of view. The focus is on the officers' technical competence requirements. The key skill requirement is technological literacy; the ability to review new technology; the ability to understand the technological process and communicate about it; the ability to detect and solve technological problems with support. All officers must have sufficient ability to understand intelligent technology as a part of military operations and sufficient ability to examine the impact of intelligent technologies on military operations as a whole.

This study provides grounds for revisions of officer training curricula at different course levels. Based on this, it is possible to identify the basic phenomena, concepts and technologies related to artificial intelligence, which should be taught at different course levels, so that the graduating officers have the skills to understand the impact of new phenomena emerging using artificial intelligence.

In this study, it is considered the following questions: What is intelligent learning? How will it change learning and how will it exchange course planning? What skill requirements do officers need to work in an AI operating environment and prepare for it? How the large-scale implementation of artificial intelligence will change the image of future war and combat, national defence and leadership?

Intelligent Learning

The term “intelligent learning” can refer as an example to the process of learning itself, where it would simply mean that an individual is learning in an intelligent way. One could also ask; “What is intelligence?” and this would lead to the philosophical study of intelligence itself. However, here intelligent learning is understood to be a discipline that follows from the use of intelligent technology in teaching and studying. Intelligent technology was at an early age called “Teaching Machines” (Smallwood, 1963). Nowadays the use of AI-powered tools and technologies are able to enhance the learning experience. Artificial intelligence (AI) powered with machine learning (ML) techniques are able to optimize and personalize the learning experience for individual students. In other words, technology can create a more efficient, effective, and engaging learning experience that can help individual learners to achieve their educational goals.

In order to provide individual learning experiences, the system has to identify the strengths and weaknesses of each student, to be able to track their progress. The system also has to be able to provide customized recommendations and feedback. Furthermore, the system can adapt to the learning style, preferences, and pace of each student, providing them with tailored resources, activities, and assessments. This can all be possible by the use of appropriate data with tailored algorithms.

The system can use multiple data sources like learning management systems, social media, and online interactions. The more data the learning system has, the more personal and targeted actions it can offer to the individual learner. They can also identify patterns and insights that can be used to inform the teacher or the teaching administrator to change instructional design in order to improve learning outcomes.

Mainly these systems are online and in blended learning environments, where students have access to digital resources and tools. These technologies are also present in traditional classroom settings, where teachers can leverage AI and ML to enhance their teaching and assessment practices. Intelligent learning has the potential to revolutionize

https://doi.org/10.33225/BalticSTE/2023.203

the way we teach and learn, making education more personalized, engaging, and effective. New intelligent learning technology represents a significant shift away from traditional one-size-fits-all approaches to education, towards a more personalized and adaptive model that is better suited to the needs of individual learners (Chaudhri, 2013; Essa, 2016; Mousavinasab, 2021; Zeide, 2019). A review article published online in 2018, based on inclusion criteria on 53 papers by Elham Mousavinasab, Nahid Zarifsanaiey, Sharareh R. Niakan Kalhori, Mahnaz Rakhshan, Leila Keikha & Marjan Ghazi Saeedi (Mousavinasab, 2021) provides a list of typical characteristics of the techniques used for Intelligent Tutoring systems (ITSs) in years 2007 to 2017. This list should be updated since it does not include for example reinforcement learning and neural networks (Fenza, 2017). From the literature about intelligent learning technology, we can pick the following expectations:

Identify learning objectives: Before designing a course, it's important to identify clear learning objectives. Intelligent learning systems can help to analyze learning data and identify meaningful objectives based on the knowledge and skills that students have (Castro, 2021).

Analyze learner data: Collect and analyze data on student performance, engagement, and progress to identify areas where students are struggling or where they are excelling. This information is to inform course content and pacing, as well as to design assessments and interventions that target individual learning needs (Ouyang, 2022). After this use adaptive learning technologies, which use algorithms that personalize the learning experience. By adapting course content and activities to each student's strengths, weaknesses, and learning style, we help learners to use the material more efficiently (Peng, 2019).

Provide personalized feedback and recommendations: Intelligent learning systems should provide targeted feedback and recommendations to help students improve their performance. By identifying areas for improvement system, one can deliver customized feedback and guidance that is tailored to each student's needs (Peng, 2019). Facilitation of collaboration and peer-to-peer learning by identifying opportunities for students to work together and provide tools (Al-Samarraie, 2018).

Incorporate gamification and interactive elements: Gamification and interactive elements make learning more engaging and enjoyable for students. Game-like features such as points, badges, and leaderboards, as well as interactive activities such as simulations and virtual labs, can create a more immersive and interactive learning experience for everybody (Kapp, 2012).

Officers' Skill Requirements for Operating with AI

Many skills may help officers to excel in an AI operating environment and to be effective in their roles to be models to their conscripts. Superficial knowledge about machine learning algorithms connected to some analytical skills is likely enough for most officers to understand if the AI systems are working as they should, and how reliable are the results they give in general. Likely, there is a need for AI officers who are comfortable working with programming languages, software tools, and other technical resources. Analytical skills that are enough for most officers are that they are able to interpret and make decisions based on visual analytics created by AI systems. AI officers,

https://doi.org/10.33225/BalticSTE/2023.203

on the other hand, should be able to analyze large amounts of data, identify patterns and be able to make the best possible tactical decisions and perform strategic planning.

AI officers need to have data communication fluency because they have to be the ones that translate complex technical information to the other officers and other team members who are likely to have a worse technical background. This means that they have to be able to explain AI and other technical concepts and outcomes in clear, concise language, and be able to work collaboratively with others to achieve common goals.

AI environments at least nowadays are evolving rapidly, so AI officers need to have a solid background of technical principles so they can distinguish valuable new technology from the hoax. They have to be able to work in an environment of uncertainty and ambiguity and be able to adapt their strategies and approaches as needed.

Ethical questions are crucial and can be in many ways confusing in the war zone. This means that all the officers need to have a solid understanding of ethical philosophy and understand the implications of the possible wrongdoings of the machines using AI. A minimal requirement is that they are aware of the ethical principles and legal requirements of the military actions performed with AI.

Changing the Image of Future War and Combat, National Defense and Leadership

Artificial intelligence (AI) will surely have a significant effect on the image of war and combat, national defence, and leadership (Allen, 2017; Cummings, 2017; Yu, 2021). AI is advancing and there does not seem to be any game where finally, it would not beat the human (Campbell, 2002; Moyer, 2016; Ontanón, 2013). What is war but a game with very high stakes? Of course, in war, there are many elements, which will likely be very hard for the intelligent machine to tackle like human factors, and ethical issues and to distinguish “the fog of war” from reality (Wallace, 2018). There are some fields where AI seems to fit naturally. One of these is surely autonomous weapons and autonomous weapon systems. These kinds of machines would ideally identify and engage targets without any human interaction. However, they are still actually quite easily misguided and therefore raise serious ethical and legal issues.

Cyber, in case it is understood as something that is related to computers, information technology and virtual reality can easily benefit from the use of AI in general and of course in cyber warfare. For example, online security, counter-terrorism and cyber-attacks are potential usages for AI.

Supportive decision-making and predictive analytics are also very original usages of AI, and their usage will increase in the future. For example, it is used to analyze data to identify patterns where future events can be predicted. This helps to anticipate and prevent threats before they occur. Decision-making can be enhanced by the provision of accurate and timely information for the leaders. This could lead to more efficient and effective decision-making processes in the context of national defence.

Overall, the implementation of AI is expected to have a significant impact on the image of future war and combat, national defence, and leadership. While AI has the potential to enhance capabilities and improve decision-making processes, it also raises important ethical, legal, and security concerns that must be addressed. As such, careful consideration and regulation will be necessary to ensure that the development and use of AI in these contexts is responsible and beneficial to society.

https://doi.org/10.33225/BalticSTE/2023.203

Final Remarks

In Finland, the public administration has outlined that we should be among the leading countries in the application of artificial intelligence since 2017. The goal is meaningful and according to some statements by successfully applying AI, Finland has the potential to double its economic growth rate by 2035. The Finnish government has launched several initiatives, including the Finnish Center for Artificial Intelligence (FCAI), FCAI comprises 60 professors and 300 researchers and has a EUR 250 million budget for the flagship term of 2019–2026. It is a community of experts from Aalto University, the University of Helsinki and VTT. According to Coursera's Global Skills Report 2022, Finland is the world's top data science nation. In a country of 5.5 million people, major universities offer more than 250 individual AI courses, 40 master-level programs, 19 bachelor-level programs and 3 doctoral programs. The universities of applied sciences provide an additional 26 study programs on the subject. The role of intelligent learning is to be learning with intelligent tools that enhance the learning process will become standard in teaching in Finland. Especially the role of analytics and real-time conclusions leading to system suggestions will increase rapidly. This will lead to more personal and better learning experiences.

The defence administration of Finland has outlined that it will develop its artificial intelligence expertise through research, training, and international networking. Officers will learn new skills that they need to be able to effectively use AI-based war technologies. In practice, most officers will learn the skills that they need to understand how systems work. The Defence Forces have to invest in additional training for officers, especially in the fields of science that support operational decision-making. In addition, it is worth investing in the utilization of practical and theoretical knowledge of AI decision processes from universities and industry by increasing cooperation and hiring. In artificial intelligence, reinforcement learning and its connection to already existing systems will be studied even more in the future. Artificial intelligence systems become even smarter when the systems really start to learn, and they are not built just relying on large amounts of data.

These results clearly point out that the use of intelligent technologies has a possibility to greatly change the characteristics of learning, teaching, and war. The change in the characteristics of war should also change the officers' curriculum for military technology majors. This project and some other similar projects have raised a lot of discussions, one seminar series about artificial intelligence and we do have some trained AI officers as well nowadays.

Declaration of Interest

The authors declare no competing interest.

https://doi.org/10.33225/BalticSTE/2023.203

References

Smallwood, R. D. (1963). A decision structure for teaching machines. *British Journal of Educational Studies 12*(1), 96-97. https://www.jstor.org/stable/3118942?origin=crossref

Chaudhri, V. K., Lane, H. C., Gunning, D., & Roschelle, J. (2013). Intelligent learning technologies Part 2: applications of artificial intelligence to contemporary and emerging educational challenges. *Ai Magazine, 34*(4), 10-12. https://ojs.aaai.org/index.php/aimagazine/article/download/2518/2401

Mousavinasab, E., Zarifsanaiey, N., R. Niakan Kalhori, S., Rakhshan, M., Keikha, L., & Ghazi Saeedi, M. (2021, 2018 online). Intelligent tutoring systems: A systematic review of characteristics, applications, and evaluation methods. *Interactive Learning Environments*, *29*(1), 142-163. https://doi.org/10.1080/10494820.2018.1558257

Zeide, E. (2019). Artificial intelligence in higher education: Applications, promise and perils, and ethical questions. *Educause Review, 54*(3). https://er.educause.edu/articles/2019/8/artificial-intelligence-in-higher-education-applications-promise-and-perils-and-ethical-questions

Essa, A. (2016). A possible future for next-generation adaptive learning systems. *Smart Learning Environments, 3*(1), 1-24. https://doi.org/10.1186/s40561-016-0038-y

Fenza, G., Orciuoli, F., & Sampson, D. G. (2017, July). Building adaptive tutoring model using artificial neural networks and reinforcement learning. In *2017 IEEE 17th international conference on advanced learning technologies (ICALT)* (pp. 460-462). IEEE. https://ieeexplore.ieee.org/document/8001832

Castro, M. D. B., & Tumibay, G. M. (2021). A literature review: Efficacy of online learning courses for higher education institutions using meta-analysis. *Education and Information Technologies, 26,* 1367-1385. https://doi.org/10.1007/s10639-019-10027-z

Ouyang, F., Zheng, L., & Jiao, P. (2022). Artificial intelligence in online higher education: A systematic review of empirical research from 2011 to 2020. *Education and Information Technologies, 27*(6), 7893-7925. https://doi.org/10.1007/s10639-022-10925-9

Peng, H., Ma, S., & Spector, J. M. (2019). Personalized adaptive learning: An emerging pedagogical approach enabled by a smart learning environment. *Smart Learning Environments, 6*(1), 1-14. https://doi.org/10.1186/s40561-019-0089-y

Al-Samarraie, H., & Saeed, N. (2018). A systematic review of cloud computing tools for collaborative learning: Opportunities and challenges to the blended-learning environment. *Computers & Education, 124*, 77-91. https://doi.org/10.1016/j.compedu.2018.05.016

Kapp, K. M. (2012). *The gamification of learning and instruction: Game-based methods and strategies for training and education.* John Wiley & Sons.

Cummings, M. (2017). *Artificial intelligence and the future of warfare* (pp. 01-26). Chatham House for the Royal Institute of International Affairs.

Allen, G., & Chan, T. (2017). *Artificial intelligence and national security*. Belfer Center for Science and International Affairs. https://www.belfercenter.org/sites/default/files/files/publication/AI%20NatSec%20-%20final.pdf

Yu, S., & Carroll, F. (2022). Implications of AI in National Security: Understanding the security issues and ethical challenges. In *Artificial Intelligence in Cyber Security: Impact and Implications: Security Challenges, Technical and Ethical Issues, Forensic Investigative Challenges* (pp. 157-175). Springer International Publishing. https://doi.org/10.1007/978-3-030-88040-8_6

Wallace, R. (2018). *Carl von Clausewitz, the fog-of-war, and the AI revolution: The real world is not a game of go*. Springer. https://doi.org/10.1007/978-3-319-74633-3

Campbell, M., Hoane Jr, A. J., & Hsu, F. H. (2002). Deep blue. *Artificial Intelligence*, *134*(1-2), 57-83. https://doi.org/10.1016/S0004-3702(01)00129-1

Moyer, C. (2016). *How Google's AlphaGo Beat a Go World Champion*. The Atlantic. https://www.theatlantic.com/technology/archive/2016/03/the-invisible-opponent/475611/

Ontanón, S., Synnaeve, G., Uriarte, A., Richoux, F., Churchill, D., & Preuss, M. (2013). A survey of real-time strategy game AI research and competition in StarCraft. *IEEE Transactions on Computational Intelligence and AI in Games, 5*(4), 293-311. https://doi.org/10.1109/TCIAIG.2013.2286295

Received: *April 12, 2023* Accepted: *May 15, 2023*

Cite as: Saastamoinen, K., Rissanen, A., & Mutanen, A. (2023). Intelligent learning in studying and planning courses – new opportunities and challenges for officers. In V. Lamanauskas (Ed.), *Science and technology education: New developments and Innovations. Proceedings of the 5th International Baltic Symposium on Science and Technology Education (BalticSTE2023)* (pp. 203-209). Scientia Socialis Press. https://doi.org/10.33225/BalticSTE/2023.203

THE APPLICATION OF INTERACTIVE LEARNING TASKS MADE BY USING DIGITAL HYBRID ILLUSTRATIONS IN THE TOPIC "HYDROCARBONS" IN EIGHTH-GRADE ORGANIC CHEMISTRY CLASSES

Agneš R. Sedlar
University of Novi Sad, Republic of Serbia
Agricultural School Dormitory – Futog, Republic of Serbia
E-mail: agnes.sedlar@gmail.com

Tamara N. Rončević , Saša A. Horvat
University of Novi Sad, Republic of Serbia
E-mail: tamara.hrin@dh.uns.ac.rs, sasa.horvat@dh.uns.ac.rs

Abstract

The content of organic chemistry is closely related to our everyday life, to nature, and to the human body. Illustrations play a big role in the acquisition of the course material, especially if those help to make the interpretation of the textual content easier. Hybrid illustrations are made up of combinations of realistic images (photographs, drawings) with abstract conventional elements (symbols, models, chemical equations). This type of illustration fuses difficult-to-interpret symbols often found in chemistry with everyday images that bring students closer to the content. The following study examines the use of digitally edited hybrid illustrations in interactive learning tasks that were used in the review and practice lessons on the Hydrocarbons topic in eighth-grade organic chemistry classes. The research took place in an experimental group of students from primary school in Novi Sad (Republic of Serbia), during which the students solved the given tasks on their cell phones via the Moodle platform. In the control group, teaching and learning took place in the traditional, or conventional way applying a lecture and a discussion method. After processing the Hydrocarbons topic, the experimental and control groups underwent the same testing process, the results of which prove the advantages of using the tasks created with the help of digital hybrid illustrations in the abstract parts of the curriculum.
Keywords: *digital learning, organic chemistry, hydrocarbons, hybrid illustrations*

Introduction

A visual learning strategy has three basic components: the teacher, the student, and the learning process. The teacher's role involves monitoring the learning process by considering the best way to develop higher-order thinking skills. Many studies show that students learn most effectively when they receive information in a visual format

https://doi.org/10.33225/BalticSTE/2023.210

as visual representations enhance students' learning (Ainsworth, 2006; Evagorou et al., 2015; Raiyn, 2016). Teachers can facilitate the communication of information in a visual format by showing, for example, pictures, diagrams, flow charts, and interactive simulations (Raiyn, 2016).

Representing abstract invisible objects, concepts, and processes helps to process data through visual perception, thus facilitating their understanding and learning (Mayer et al., 1995). In science education, pictures can be used not only as illustrations, as supplementary elements to the verbal elements of the text, but also as a central part of the content, to express the main ideas to be communicated (Ametller & Pintó, 2002). An example of the application of the illustrative-graphic method in the teaching of natural sciences is hybrid illustrations, which are defined in the work of Dimopoulos et al. (2003). The characteristic of hybrid illustrations is that these illustrations combine abstract hard-to-understand content (such as chemical formulas, structures, and alphanumeric characters) with realistic everyday elements known from everyday life, which people observe and understand through visual perception (Dimopoulos et al., 2003).

There has already been an example of examining the use of the illustrative-graphic method, including hybrid illustrations with eighth-grade students, during which biologically important organic compounds ("Amino acids and proteins") were presented. In the data analysis, it was revealed that in the case of certain tasks, it is useful to use hybrid illustrations created from the synthesis of conventional and realistic elements in the teaching of chemistry, in order to increase the performance of primary school students (Rončević et al., 2019a). In the present study, one step forward was taken, as up-to-date unexamined forms of hybrid illustrations, i.e., interactive digital hybrid illustrations were included as new teaching and learning tools. Also, organic chemistry as a different chemistry discipline was chosen on which interactive hybrid illustrations were used.

Research Problem

Today, it is widely accepted that textual content alone is not enough to help students recognize relationships, group objects, perceive big ideas, and solve problems. Facts must be conceptually framed in order to be understood and remembered. Teachers can facilitate conceptualization by making concepts and generalizations (rather than facts) the focus of activities, providing students with a variety of experiences, helping them learn how to observe and represent what they see and hear, and showing them many examples of what they are teaching (Birbili, 2007). Chemistry is considered a particularly abstract subject and students face many problems when learning its contents. The chemistry teacher must have appropriate teaching tools to process the content of the given material, apply methods that support higher-order thinking skills and help students master the content more easily.

Improving the process of learning and understanding is especially important in the eighth-grade chemistry curriculum in primary schools because it covers the concepts of organic chemistry. Organic chemistry generally includes carbon-based compounds, and students are faced with the chemical composition of organic compounds, their properties and the reactions they undergo (Salame et al., 2019). Recognizing formulas, functional groups, compounds found in nature, or logical connections between reactions

https://doi.org/10.33225/BalticSTE/2023.210

and properties of organic compounds exposes students to many abstract concepts and phenomena that increase the abstract nature of the course content. In this study, it was examined the possibilities of applying the illustrative-graphic method, more precisely digital hybrid illustrations in the form of interactive learning tasks that might improve the teaching and learning of organic chemistry contents at the primary school level.

Research Focus

Visual learning is the acquisition of information through a visual format. Students understand classroom information better when they see it. Visual information is presented in a variety of formats such as pictures, process diagrams, videos, simulations, graphs, cartoons, coloring books, slide shows/Powerpoint presentations, posters, movies, games, and flashcards (Rodger et al., 2009). A teacher can use the formats mentioned above to present a large amount of information in an easy-to-understand manner and help the students to discover relationships between concepts. According to various studies, students remember information better when it is presented both visually and verbally (Bobek & Tversky, 2016; Raiyn, 2016). These strategies help students of all ages better manage learning goals and achieve academic success (Raiyn, 2016).

Research Aim and Research Questions

The aim of the present study was to analyze the advantages of using digital hybrid illustrations in the form of interactive learning tasks that serve as an example in the lessons of repeating the teaching content of chemistry in the eighth grade of primary school. The study focuses on the lessons of the units "Review of saturated hydrocarbons and general properties of hydrocarbons" and "Systematization of materials from hydrocarbons" of the curriculum. Both teaching units are covered within the teaching module "Hydrocarbons" (Teaching and learning program for the eighth grade of basic education and upbringing, 2019). As one group of students was subjected to the illustrative-graphic method and digital hybrid illustrations, the goal of this study was to analyze the differences in the students' performances of two groups, one experimental (E group) and one control (C group) observing the Hydrocarbons teaching topic in eighth-grade organic chemistry classes.

In accordance with the goal, the study is conducted through the following research questions:

1. Are there statistically significant differences in students' overall performances on knowledge tests between the experimental and control groups?
2. Are there statistically significant differences in students' performances in test tasks with illustrations between the experimental and control groups?
3. Are there statistically significant differences in students' performances in test tasks without illustrations between the experimental and control groups?

https://doi.org/10.33225/BalticSTE/2023.210

Research Methodology

General Background

The research began with initial testing in January 2023, which evaluated the students' prior knowledge of inorganic chemistry. Based on the statistical analysis of the initial test results, the students were divided into experimental (E) and control (C) groups. After the initial testing, detailed ongoing discussions were held with the teacher in the E group, during which a coordinated joint plan was prepared to start the research.

It is important to mention that the Serbian basic curriculum provides two introductory lessons to organic chemistry, as students encounter this branch of chemistry for the first time. After that, there are twelve lessons for the processing of the new teaching content and revision of the relevant parts of the Hydrocarbons topic. Out of these twelve lessons, the experimental part of this study used up two revision lessons. These lessons took place after the processing of the new teaching contents. Based on consultation with the teacher in the experimental classes, the first revision lesson was held after the processing key concepts in organic chemistry: distinction of hydrocarbons based on their structural features, their occurrence in everyday life, their physical properties, and the presentation of the nomenclature of saturated hydrocarbons.

Sample

A total of 191 students from eighth-grade classes (14-15 years old students) were included in this study. The students attended two schools in Novi Sad, Republic of Serbia. It must be highlighted that in the Republic of Serbia, formal education covers preschool, primary school, secondary school, and higher education. The eighth-grade students are included in the second learning cycle of primary school. The research was done in the Serbian language, with the permission of the principals of the schools and the students included in the research.

Before the experimental teaching and according to the initial chemistry knowledge test results, the students were divided into two groups: experimental and control. After the statistical analysis of the results of the initial chemistry knowledge test, 4 eighth-grade classes from the primary school "Petefi Šandor" were included in the E group, while 4 eighth-grade classes from the primary school "Nikola Tesla" were included in the C group.

During the analysis of the students' performances on the initial chemistry knowledge test, the Shapiro-Wilk test was used on collected data and showed that the distribution of data in the E group departed significantly from normality ($W = 0.971$, $df = 91$, $p = .042$, $p < .05$), while in the C group, it showed a normal distribution ($W = 0.976$, $df = 91$, $p = .088$, $p > .05$). Based on this outcome, a non-parametric Mann-Whitney U test was used to compare the medians, which showed no statistically significant difference between the E group ($M = 10.16$, $SD = 2.79$) and C group ($M = 10.65$, $SD = 3.54$), as for $U = 4276.50$ p-value was greater than .05 ($p = .471$). During the statistical processing of the initial test results, special attention was also paid to the distribution of boys and girls, as well as to the number of students in the classes. Therefore, the E group consisted of 91 students and the C group consisted of 100 students.

https://doi.org/10.33225/BalticSTE/2023.210

Procedures

The activities in the experimental classes were carried out through the Moodle platform, which is available on the subdomain https://kurs.organskahemija.com/login/index.php (the main domain is on the website www.organskahemija.com). In compiling the task types on the Moodle platform, it was necessary to use the H5P plugin, which offers many interactive options for the editor. The home page of the interactive course includes a short guide to using the site and a general introduction to the history of organic chemistry. The contents of the site and the tasks are entirely in Serbian. During the first trial lesson, the students were able to familiarize themselves with the platform, for which they registered with their own account, thus making it available for them to access the site continuously from anywhere and anytime. The site also supports logging in as a guest if students encounter problems during login. The students followed the learning tasks on their cell phones, which the teacher leading the experimental class also projected on the whiteboard, so they worked on them together.

The first experimental lesson included five learning tasks to review the general properties of hydrocarbons with a special focus on saturated hydrocarbons. The first learning task (see Figure 1) is a find-the-hotspot task on the composition of hydrocarbons, in which the students had to select the parts of the illustration that represent carbon and hydrogen atoms. The hybrid illustration contains the atomic models of carbon, hydrogen, sulfur, oxygen, and nitrogen (based on the colors of atomic model kits used in organic chemistry), supplemented with a photograph of their elemental state. For carbon, an image of a briquette for a grill is used and in the case of hydrogen, the image used depicts the large amount of hydrogen found in outer space. For nitrogen, a photograph of the atmosphere is used. In the case of sulfur, a photograph taken near a volcano indicates its occurrence in an elemental state in the environment, while an oxygen tank indicates the popular use of elemental oxygen.

Figure 1
Find-the-Hotspot Task on the Composition of Hydrocarbons

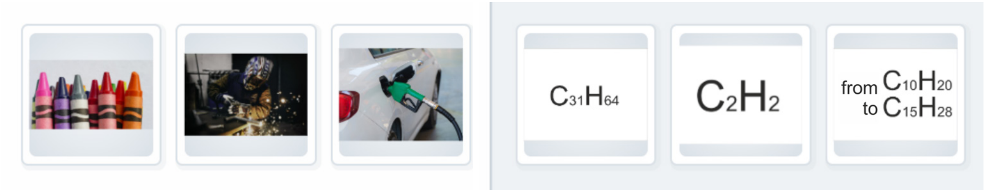
The second learning task deals with the division of hydrocarbons, in which the students had to place the specified groups on the concept map on the indicated green board. The symbol next to some parts of the division is helpful, for example, the representation of single, double, and triple bonds, the closed carbon chain, or Kekule's concept of benzene. The third, fourth and fifth learning tasks could be seen within the platform (www.organskahemija.com).

After the first experimental lesson, the teacher of the experimental classes continued the teaching and learning process with an evaluation, the processing of alkenes, alkynes, and the most important steps in their nomenclature, as well as the chemical properties of hydrocarbons, and finally the processing of crude oil, natural gas and polymers. After the processing of the new teaching contents, it was time for a revision lesson, which was implemented in the form of systematization (comprehensive review) by the teacher leading the E group through the Moodle platform (www.organskahemija.com).

The first learning task of the second experimental lesson is used to determine the state of hydrocarbons based on their use. The students matched images depicting the number of carbon atoms in a given hydrocarbon (molecular formulas) and their state of matter during industrial use - forming a hybrid illustration (Figure 2). For example, gas ethyne (C_2H_2) is suitable for welding, liquid hydrocarbon mixture (diesel) as fuel, and solid paraffin for making wax-containing objects.

Figure 2

Matching Images: The Number of Carbon Atoms in Hydrocarbons and Their State of Matter



The second learning task focuses on the three most important chemical reactions of hydrocarbons, where the students had to choose the name of the given reaction from those listed. Each task was solved based on a description with an assigned hybrid illustration. The substitution was introduced first, for which eighth-grade chemistry textbooks mainly use the process of methane halogenation as an example. The assignment shows an older type of refrigerator and the formula of dichlorodifluoromethane (CFC, Freon) next to it, for which the students listed refrigerators, air conditioners and other equipment as their primary use. The second part of the assignment contains a description of polymerization, and the assigned hybrid illustration shows several PET bottles and the monomer of the polyethylene molecule. The students mentioned many areas of use for polymers, such as the production of plastic foil and nylon. The last part of the task concerned the oxidation of hydrocarbons. The hybrid illustration shows the chimney of a crude oil refinery while the flammable gas is burned at the top. The description next to the flame in the picture also confirms that during the reaction the resulting products are carbon (IV) oxide and water. The other two learning tasks have also been introduced in the form of interactive hybrid illustrations.

https://doi.org/10.33225/BalticSTE/2023.210

With regard to the interactive content of both experimental lessons, it is worth highlighting that the platform allows access from an unlimited number of devices at the same time, so each of the students could work without interruption on their own device at school, or even at home from their computer. Each of the tasks can be repeated, and viewed again, and the solution key is also available for them, which helps the students in studying and reviewing at home.

Instrument

After the teaching and learning process within the topic of Hydrocarbons, both the E and C groups underwent uniform testing. A total of 89 (46 girls and 43 boys) eighth-grade students in the E group and 98 (42 girls and 56 boys) eighth-grade students in the C group were tested.

Students took a test consisting of 15 tasks of which 11 tasks were multiple-choice, 3 tasks were fill-in-the-blank, and one task was a matching question. The test included a total of 9 illustrations, 3 of which were realistic photographs that load to the solution, and 6 of which were conventional content to supplement the task (chemical reaction equation, molecular model, and structural formula). Examples of tasks number 4 and 13 are presented in Figure 3.

The students filled out the test in color printout in paper form and had a maximum of 45 minutes to solve it. The maximum possible performance score on the test was 28 points.

Figure 3
(A) Task without Illustration

4. Complete the sentences with the missing words.
According to the way of binding carbon atoms in strings, hydrocarbons are divided into ______________ and ______________. 2,4-dimethylhexane is an example of the ______________ hydrocarbon in whose molecule carbon atoms are connected by ___________________ bonds and form an _____________ chain.

(B) Task with Illustration

13. Fractional distillation of crude oil yields various products that have everyday and industrial uses as sources of energy. Circle the letter in front of the product obtained by fractional distillation of crude oil, which boils at 170ºC and is mostly used as fuel for passenger aiplanes.

А. diesel fuel;
Б. gasoline;
В. kerosene;
Г. bitumen.

https://doi.org/10.33225/BalticSTE/2023.210

Data Analysis

The statistical analysis of the results obtained during the testing of the groups revealed that the E group had a normal distribution ($W = 0.979$, $df = 89$, $p = .167$, $p > .05$), while the C group had a not normal distribution of collected data ($W = 0.951$, $df = 89$, $p = .002$, $p < .05$). The Mann-Whitney U test as a non-parametric test was applied in order to verify if there was a statistically significant difference in performance between the E and C groups.

Research Results

The basic statistical parameters obtained for E and C groups students' performance on knowledge tests are summarized in Table 1. These parameters include mean scores (*M*), standard deviation (*SD*), minimum and maximum, and range. The mean scores indicated that the E group ($M = 13.34$) achieved slightly higher scores in comparison to the C group ($M = 10.85$), observing students' performance on each task on the knowledge test. The maximum possible score on the knowledge test was 28 points. None of the students in the E and C groups achieved the highest score. It is interesting to mention that the highest score achieved on the knowledge test on Hydrocarbons was 27 in the E group, while it was 23 points in the C group. On the other hand, the lowest score was 2 points in the E group and 1 point in the C group.

Table 1
The Basic Statistical Parameters Obtained from Students' Performance on Knowledge Test

Statistical parameter	**Group**	
	Experimental	Control
M	13.34	10.85
Minimum	2.00	1.00
Maximum	27.00	23.00
Range	25.00	22.00

To determine whether there was a statistically significant difference in the students' performance between the E and C groups, a non-parametric Mann-Whitney U test was applied. A statistically significant difference was found in favor of the E group, since the *p*-value was less than .05 ($p = .035$), for the $U = 3583.50$.

The examination of the knowledge test results was followed according to the test task types: those with and without illustrations integrated into it. Looking at students' performance on the test tasks with illustrations, the non-parametric Mann-Whitney U test showed that there was no statistically significant difference in the performance of the E group ($M = 6.79$, $SD = 2.85$) and C group ($M = 6.36$, $SD = 3.58$), as the *p*-value was greater than .05 ($p = .845$) for the $U = 4289.00$. This might be explained by the fact that the test tasks were provided with illustrations that the students of both groups could have encountered in everyday life, in previous school lessons, or even in their textbooks.

Also, the illustrations were realistic and of a conventional type and not a hybrid type with which E group students were faced during experimental classes.

The data gathered from the knowledge test result on the tasks without illustrations was also statistically analyzed. Non-parametric Mann-Whitney U test showed that there was a statistically significant difference in the performance of the E group (M = 6.54, SD = 3.28) and C group (M = 4.49, SD = 2.75), as obtained p-value was significantly lower than .05 for the U = 2984.50.

Discussion

In this study, the overall results showed a statistically significant difference in the performance of the knowledge test between the two groups. However, the similarity in the E and C groups students' performance on the knowledge test on Hydrocarbons was observed (E group students' average performance was about 46%, and the C group average performance was about 39%). In the previous study by Rončević et al. (2019a), no statistically significant difference in the average students' performance was found between the groups, where the experimental group was using hybrid illustrations as teaching and learning visual tools, and the control group was subjected to traditional chemistry teaching methods (i.e., lecture, laboratory chemistry demonstrations and discussion).

It is important to mention that the knowledge test on Hydrocarbons teaching topic included numerous tasks with illustrations. About 53.5% (15 points) of the maximum possible score on the knowledge test came from tasks with illustrations, while the rest, 46.5% (13 points) were tasks with only text content without illustrations. Therefore, the test results were also examined according to those aspects.

During the analysis of the test results from the perspective of the tasks complemented with illustrations, there was no statistical difference between the groups. The textbook that follows the curriculum related to the Hydrocarbons teaching topic in primary school contains a significant number of conventional illustrations, which were presented in both the E and C groups. The part of the teaching topic dealing with nomenclature and writing formulas of organic compounds was taught to both groups of students by relying on the traditional method and was introduced exclusively with abstract conventional illustrations. During the revision classes in the E group students, the nomenclature, formulas of organic compounds and organic reactions were additionally exemplified with hybrid illustrations, supplemented with realistic images to highlight individual groups of atoms, reagents, or products. In the previous study by Rončević et al. (2019b), it was found that secondary school students possessed difficulties in reading illustrations included in the test of knowledge about dispersed systems. When students' answers about realistic illustrations were analysed, these difficulties came to the forefront. It was concluded that students relied on what they literally saw in realistic illustrations, i.e. photography, and they did not make proper connections with the chemical content of interest (Rončević et al., 2019b). A similar approach to students' interpretation of science textbook illustrations was presented in the study by Ametller and Pinto (2002).

However, it is worth highlighting some differences between the E and C groups observing test tasks with illustrations. In the first task on the test, the goal was to circle a false statement about the structural formula of but-1-ene, i.e. the answer was "the

https://doi.org/10.33225/BalticSTE/2023.210

compound is the fourth member of the homologous series of alkenes". The E group students solved the task with a percentage of 47.19%, while the C group students only achieved a result of 18.75%. In this case, the C group students may have a misconception, as they mistakenly regard 1–butene as the fourth member of the homologous series of alkenes and rule out the correct answer. The almost 30% difference in the results on this test task between the E and C groups indicates that during the lesson "Systematization of contents of hydrocarbons" the E group students effectively mastered the structural features of Hydrocarbons through an interactive game related to nomenclature with hybrid illustrations, sharply separating the homologous series of the alkanes, alkenes, and alkynes.

Another difference in the performance of the E and C groups was found in task 13 of the knowledge test. The task asks for the name of the crude oil fraction used in passenger aircraft, which has a boiling point of 170°C. The task is presented with a picture of an aeroplane. The E group solved the task correctly with 82% success. On the other hand, 66% of the C group students circled the correct option "kerosene". During the "Systematization of contents from hydrocarbons" the E group students placed the fractions produced during the refining of crude oil on a summary hybrid illustration, matched with the appropriate boiling point, used in everyday life, and name of the fraction. This interactive hybrid illustration provided the students with a complete picture of the most important products of crude oil refining, the effectiveness of which is indicated during the testing. Both previous studies showed that including hybrid illustrations as teaching, learning or evaluation tools can provide valuable information about students' misunderstandings and misconceptions (Rončević et al., 2019a, 2019b).

The highest difference in the performance between the E and C groups appeared in test tasks without illustrations. In this test tasks category, E group students outperformed C group students. Among the tasks without illustrations, task 4 showed significant differences between groups E and C. The assignment was a fill-in-the-blank question. The text was about the division of hydrocarbons and the structure of the alkane. Out of the maximum 5 points, the students of group E scored an average of 2.3, while the students of group C scored only 0.9. This can be explained by the fact that the students of group E solved an interactive task during the revision classes in which they had to match the detailed division of hydrocarbons with diagrams of structural features, thus helping them master this abstract concept. Certainly, hybrid illustrations with efficient methodological design could help students to develop conceptual understanding and clarify some important chemical concepts (Rončević et al., 2019a).

Conclusions and Implications

The eighth-grade organic chemistry curriculum serves as the basis for later, more detailed knowledge of this branch of chemistry. Hence, it is important to record the basic concepts and structural features of organic compounds for the students. They get to know how these compounds play an active role in their everyday life, how important they are for industry, and how can be found in the energy sources. By using digital, interactive hybrid illustrations, the teaching process itself can make learning chemistry playful and motivating, as evidenced by the openness experienced by the students in the experimental classes towards this application of the illustrative-graphical teaching method and the use of mobile phones for educational purposes.

https://doi.org/10.33225/BalticSTE/2023.210

In the case of tasks without illustrations, the interactive tasks used during revision classes played a very important role. Through these interactive tasks, the students of group E could not only learn about the properties of hydrocarbons in text form but could also practice them with the help of hybrid illustrations. As a result, they gave correct answers to the questions asked in the test even if they did not contain illustrations. The differences between the results of the groups E and C are shown in the tasks with illustrations on everyday use of hydrocarbons and the representation of their formulas. These tasks brought the students closer to the concept we expected them to know, which was one of the main goals during the revision classes in the E group.

It is important to conclude that the overall test results showed a statistically significant difference in the performance of the E group and C group students, in slight favor of the E group. The E group worked with the illustrative-graphic method (i.e., interactive form of hybrid illustrations) within only 2 school lessons before the performance test on Hydrocarbons. According to our opinion, a more significant difference in the groups' performance requires the continuation of the experimental teaching and learning in the E group of students.

Also, there were differences between the groups' performances in the individual test tasks. In these cases, it would be worthwhile to analyze the sources of possible misconceptions generated by the students. Analyzing the details of the tasks representing the divergence between the E and C groups, it is necessary to continue the research on other topics of organic chemistry with increased attention, focusing on their role in everyday life, their impact on health and their functional groups.

The processing of the topic "Oxygen-containing organic compounds" is currently ongoing in the concerned primary school in Novi Sad, so the lessons for the review classes for this part of the curriculum are also continuously prepared on the Moodle platform. After the end of the topic, another testing will be conducted, in which the performance of E and C groups students will be compared again.

The research on which this paper is based was carried out through the Moodle system, a free educational platform available worldwide and offering a wide range of possibilities. It also provides space for development and expansion based on the suggestions of the users. The application of Moodle platform in this research was limited to the repetition lessons, but it can also provide an opportunity for the interactive processing of new educational materials and even for evaluation. From the point of view of digital education, it is easy to use and can be an excellent teaching aid for all teachers, for which the courses created during our research serve as an example. Also, in the available literature in science education domain, there are a few empirical studies about the usage of hybrid illustrations in the science classroom, and therefore there is a necessity for the new, ongoing studies.

Acknowledgements

The authors gratefully acknowledge the financial support of the Ministry of Science, Technological Development and Innovation of the Republic of Serbia (Grant No. 451-03-47/2023-01/200125). The author gratefully acknowledges the financial support of the Sapientia Hungarie Foundation and the State Secretariat for National Policy of Hungary.

Declaration of Interest

The authors declare no competing interest.

References

Ainsworth, S. (2006). A conceptual framework for considering learning with multiple representations. *Learning and Instruction, 16*(3), 183-198. https://doi.org/10.1016/j.learninstruc.2006.03.001

Ametller, J., & Pintó, R. (2002). Students' reading of innovative images of energy at the secondary school level. *International Journal of Science Education, 24*(3), 285–312. https://doi.org/10.1080/09500690110078914

Bobek, E., & Tversky, B. (2016). Creating visual explanations improves learning. *Cognitive Research: Principles and Implications, 1*(27), 1-14. https://doi.org/10.1186/s41235-016-0031-6

Birbili, M. (2007). Making the case for a conceptually based curriculum in early childhood education. *Early Childhood Education Journal, 35*(2), 141–147. https://doi.org/10.1007/s10643-006-0112-0

Dimopoulos, L., Koulaidis, V., & Sklaveniti, S. (2016). Towards an analysis of visual images in school science textbooks and press articles about science and technology. *Research in Science Education, 33*(2), 189–216. https://doi.org/10.1023/A:1025006310503

Evagorou1, M., Erduran, S., & Mäntylä, T. (2015). The role of visual representations in scientific practices: from conceptual understanding and knowledge generation to 'seeing' how science works. *International Journal of STEM Education, 2*(11), 1-13. https://doi.org/10.1186/s40594-015-0024-x

Mayer, R. E., Steinhoff, K., Bower, G. and Mars, R. (1995). A generative theory of textbook design: Using annotated illustrations for foster meaningful learning of science text. *Educational Technology Research and Development, 43*, 31–41. https://doi.org/10.1007/BF02300480

Raiyn, J. (2016). The role of visual learning in improving students' high-order thinking skills. *Journal of Education and Practice, 7*(24), 115–121.

Rončević, T., Sedlar, A., Rodić, D., & Segedinac, M. (2019a). Hybrid images as part of the primary school chemistry class instruction: Mastering the concepts of amino acids and proteins. *Biochemistry and Molecular Biology Education, 47*(6), 644–655. https://doi.org/10.1002/bmb.21294

Rončević, T., Ćuk, Ž., Rodić, D., Segedinac, M., & Horvat, S. (2019b). An analysis of the high school students' abilities to read realistic, conventional, and hybrid images in general chemistry. *Journal of Baltic Science Education, 18*(6), 943-954. https://doi.org/10.33225/jbse/19.18.943

Salame, I., Pater, S., & Suleman, S. (2019). Examining some of the students' challenges in learning organic chemistry. *International Journal of Chemistry Education Research, 3*(1), 6-14. doi: 10.20885/ijcer.vol3.iss1.art2

Teaching and learning program for the eighth grade of basic education and upbringing (2019). *Official Gazette of the Republic of Serbia, Educational Gazette*, 15. August 2019, 68, 11, 61-189.

Received: *April 05, 2023* Accepted: *May 15, 2023*

Cite as: Sedlar, A. R., Rončević, T. N., & Horvat, S. A. (2023). The application of interactive learning tasks made by using digital hybrid illustrations in the topic "Hydrocarbons" in eighth-grade organic chemistry classes. In V. Lamanauskas (Ed.), *Science and technology education: New developments and Innovations. Proceedings of the 5th International Baltic Symposium on Science and Technology Education (BalticSTE2023)* (pp. 210-222). Scientia Socialis Press. https://doi.org/10.33225/BalticSTE/2023.210

STUDENTS' PERCEPTION OF AN INQUIRY-BASED METAVISUAL ACTIVITY ABOUT CONCEPTS OF CHEMICAL KINETICS

Marcella Seika Shimada , Solange Wagner Locatelli
Federal University of ABC, Brazil
E-mail: marcellashimada@gmail.com, sol.locatelli@gmail.com

Abstract

Students' perceptions of an activity involving visualization are important in assessing their learning of the task. In view of this, this study was developed with undergraduate students from different courses at a public Brazilian university. The research objective was to determine how three students, who are majoring in different courses (chemistry graduation and engineering), perceive their participation in an inquiry-based metavisual activity (IBMA). For this, the students were interviewed and data were categorized according to similarities and differences in the reports. The findings indicate that the IBMA was able to facilitate the reconstruction of concepts with an emphasis at the submicro level, for the students that were majoring in chemistry. The engineering student reported a partial construction of concepts. The student's learning may have been compromised due to the smaller repertoire that he had in chemistry and on models at the submicro level.
Keywords: *chemistry teaching, inquiry-based activity, metavisualization, students' perceptions*

Introduction

Chemistry employs visual representations that aid to understand the phenomena, not only in industry but also in the classroom. According to Johnstone (1993), one of the main difficulties encountered by students is the comprehension and development of the three levels of representation in chemistry: macro, sub-micro, and symbolic levels (Gilbert & Treagust, 2009).

Furthermore, many students perceive chemical diagrams as a mere teaching method that simplifies a particular subject (Fernandes & Locatelli, 2020). Thus, it is necessary to employ approaches that link scientific ideas to the concrete world, with specific phenomena that capture students' interest (Quadros et al., 2018).

According to Zômpero and Laburú (2011), inquiry-based activities foster perspectives go beyond students' inductive reasoning, preparing them to become active thinkers who seek answers and enabling the development of the necessary skills to solve problems. These skills enable the formation of citizens who are better able to face the challenges of modern society, in an active and critical way, by making decisions about scientific issues that affect everyday life (Schnetzler, 2002), through chemical knowledge.

Therefore, constant reflection in the learning process is of paramount importance, which can be achieved through metacognition. According to Schraw (1998), cognitive ability refers to what is necessary to perform a task, whereas metacognitive ability relates to understanding how the activity was performed.

https://doi.org/10.33225/BalticSTE/2023.223

Given the visual nature of chemistry, metavisualization, that is, metacognitive thinking through visualizations (Gilbert, 2005), has proven to be an effective strategy in the process of constructing and reconstructing concepts using visual tools (Locatelli & Davidowitz, 2021), and can be useful to improve students' understanding in scientific modelling (Chang, 2021). Thus, this work had a didactic approach, using an inquiry-based metavisual activity (IBMA), based on the assumptions of inquiry-based teaching, the experimental laboratory practice, and the modelling of chemical representations from the metavisual strategy.

Regarding modelling, Chang (2021) has cited that there are few studies that focus on the process of constructing visualization, asking about: what are students' difficulties in the process of developing representations and the factors that lead to successful visualization? "Research into these issues would provide fundamental insights with regard to how to support students in successfully developing visualizations and representations during the modelling process" (Chang, 2021, p. 451).

Despite the possibilities for learning chemistry concepts that IBMA can promote in students, several factors need to be considered for its implementation, especially related to the high complexity articulation of the three representative levels of chemistry. A study by Chittleborough et al. (2002) has revealed some limitations that students face in developing more in-depth models, such as a lack of prior knowledge of chemistry and mental models, an excessive amount of information, speeds that the content must be assimilated by the student, and lack of motivation.

Therefore, the students' perceptions of the practical experience of IBMA are important to assess the difficulties inherent in the process as well as whether the strategy was effective for learning chemistry. In addition, understanding how students' perceptions of laboratory activities (and in general) can help teachers adjust them to provide a more positive experience for students (Nyutu, et al., 2021).

Given this, this study aims to ascertain the perceptions of students participating in IBMA, the research question was: What do undergraduate students from different courses report about the didactic experience of an inquiry-based metavisual activity (IBMA)?

Research Methodology

General Background

This study presented a preliminary study of larger research in progress being characterized as qualitative research (Stake, 2010), and as a case study (Alves-Mazzotti, 2006). Participated in this research all students enrolled in the subject of Chemistry Teaching Practices II (PEQ II) of a public Brazilian university, who were present on the day that occurred the application of IBMA, being only three students: two students were studying undergraduate chemistry, and one student engineering. The IBMA involved the study of the rate of the nail reaction in an aqueous sulfuric acid solution, wherein the concepts of this phenomenon were deepened through the elaboration and comparison of chemical representations. Six months after the activity, students were interviewed individually considering their perceptions of the lesson. The results were grouped according to the similarity and divergence of reports.

Sample

The participants of this study were three undergraduate students: two chemistry education students, Ariadne and Cecília, and one engineering student, Yohan (fictional names chosen by the participants themselves). These students were enrolled in the course Chemistry Teaching Practices II (PEQ II) at the Federal University of ABC (UFABC), located in São Paulo, Brazil, during the months of September to December 2022.

The choice of a PEQ II class was motivated by the assumption that the students enrolled had seen the content covered in this research activity during elementary school, and/or in the discipline of General Chemistry, which is one of the compulsory subjects for all undergraduates at the university.

The heterogeneity of the participants is due to the university context, which allows students to enrol in any discipline, regardless of their chosen undergraduate course. Yohan chose to take the discipline because he works as a teacher in a technical school and had an interest in theoretical and pedagogical deepening.

In the PEQ II class, four students were enrolled and, on the day of the application for IBMA, which occurred in October 2022, one student was absent. The low enrollment occurred due to the conflict of PEQ II schedules with other compulsory university courses, which were held back until that moment due to the suspension of classes caused by the Covid-19 pandemic.

Due to the small number of participants, this study is characterized as a case study, which for Alves-Mazzotti (2006) is useful for exploring complex and situated relationships, generating in-depth knowledge about a particular phenomenon.

The collected data were obtained during a class of this specific discipline, where participants volunteered to provide the analytical products for the study. They signed an informed consent form, following the ethical parameters for research involving human subjects.

Instrument and Procedures

The research-developed IBMA has two main phases: in the first phase, the students were guided to solve a problem situation that dealt with the reaction rate with the increase of temperature involving metallic iron with an aqueous solution of sulfuric acid. In groups, they elaborated hypotheses of an experimental plan, considering the provided reagents and materials, such as an aqueous solution of 1.0 mol/L H_2SO_4, nails, a heating plate, test tubes, and a water spray bottle. After outlining the work plan, the group, through the experiment proposed by them, tested the hypotheses listed at the beginning of the activity, observing the phenomena that occurred and discussing their preliminary conclusions.

In the second phase, the group continued the IBMA by discussing and creating symbolic and pictorial representations that represented what was done in the experimental procedure, consisting of four items: a) the chemical equation of the reaction, b) an explanatory model at the submicro level before the reaction, c) an explanatory model at the submicro level during the reaction, and d) explanatory models at the submicro level at the end of the reaction.

At the end of the elaboration on each item, the group compared what they had done with the corresponding visual representation presented by the teacher. The aim was for the students to identify, analyze, and to discuss the differences and similarities of the representations, configuring a metavisual approach. The explanatory models, presented to the group of students, involved concepts about: the level of particle agitation, collision theory, the concept of solvation, the behavior of ions in solution, the function of the spectator ion, notions of stoichiometry, and the size of atoms. Throughout the IBMA, both the course instructor and the researcher made the fewest interventions possible so as not to influence the group's discussions.

Six months after the activity took place, that is, in April 2023, the students were individually interviewed by the researcher, considering their experiences, difficulties, and general comments. Minayo (1993) described interviews as "conversations with a purpose," providing reports from a particular point of view for specific objectives (Charmaz, 2006). Therefore, in the research, sensitive listening was sought to understand the participants based on their use of language, considering how they attribute meanings to their experiences, cognitive processes, and themselves.

For this study, 2 questions were selected and asked to the students, as described in Table 1.

Table 1
Questions to Research Participants about the IBMA

Questions
Could you talk about the main difficulties encountered in the development of the IBMA?
Considering that the IBMA aimed to reconstruct concepts, what did help you in terms of your chemistry knowledge? Did anything change for you?

Data Analysis

The interviews lasted an average of 15 minutes, were recorded in audio, and were transcribed. In addition, the questions also delimited the participants' profiles and were used to assist in the analysis of the IBMA report provided by them, as well as the researcher's field notes.

For the analysis of the results, the students' answers were read several times, based on Bardin's (2011) assumptions, following the three main steps: i) pre-analysis, which refers to the organization and systematization of initial ideas, ii) exploration of the material, which involves the decomposition of data and subsequent regrouping based on categories; and iii) treatment of results.

Research Results

Based on the collected data, it was identified that Ariadne and Cecilia, who are chemistry education students, had similar perceptions about the difficulties related to IBMA and chemistry learning, while Yohan, an engineering student, reported different

https://doi.org/10.33225/BalticSTE/2023.223

perceptions. These similarities and differences may be due to the students' context and their mastery of chemistry and are categorized into two subsections, as follows.

Chemistry Education Students (Ariadne and Cecilia)

When asked about the main difficulties involved in the development of IBMA, the following responses were obtained from the students:

> **Ariadne:** "(...) I think basic chemistry because we had a lot of difficulty in determining what reaction was happening. (...) We had trouble understanding the medium as well, what was happening, how to represent it, that was a difficulty from the drawing (explanatory model)."
> **Cecília:** "The equation part and the drawing (...) I always feel very insecure when working with, let's say, the elements and everything else, how it works. (...)."

Regarding learning in chemistry and the reconstruction and construction of concepts that could have occurred during the activity, the students reported the following:

> **Ariadne:** "(...) I remember a lot about your drawing of the collision of atoms. That was something I didn't think of when I did the activity, but then I never forgot about it."
> **Cecília:** "I believe it was more the submicro level part when we had to build a model with the molecules and everything. We started to realize that understanding this part (submicro level) makes it much easier for us to understand the algorithm part (chemical equation), what we saw (in the chemical reaction), and everything else."

Engineering Student (Yohan)

Unlike his group mates, when asked about the difficulties involved in the development of IBMA, Yohan reports that:

> **Yohan**: "(...) I think our biggest difficulty was just visualizing if there was any change, (...) in what didn't have an increase in temperature, because we were looking here, looking there in every way, right? And then what happened when we put it there, we didn't know if the color (of the nail) changed because it was wet (...)."

In addition, for the student, the activity allowed for partial construction of the concepts he had about the activity content, as reported below:

> **Yohan**: "(...) I understood the situation, but then if you gave me, I don't know, other elements that had a different effect, but with the same analogy, maybe I wouldn't arrive at the result, you know? (...). One thing is (to understand), but to prove it is another."

Discussion

Chemistry Education Students (Ariadne and Cecilia)

The reports of the students regarding the difficulties faced in the IBMA refer to the moments when symbolic and pictorial representations (chemical diagrams) were elaborated. They stated that they had difficulty establishing the chemical equation of the reaction performed in the experiment (symbolic level) and how to explain and represent it through models (submicro level). Such levels are abstract, and many students have problems understanding them, as already reported by Gilbert and Treagust (2009) and Michalisková and Prokša (2018).

Difficulties seemed to have been overcome using the metavisual strategy, as the students reported that drawings at the submicro level assisted their comprehension of chemical reactions, such as collisions between atoms and the construction of molecular models.

In other words, for the students, IBMA aided in the process of reviewing and reconstructing concepts regarding how the reaction occurred, citing aspects that involve the submicro level which, for Cecilia, allowed her to understand what was being observed in the experiment and the related chemical equation, i.e., the macroscopic and symbolic levels, respectively. In this discourse, the student gives evidence that there was articulation between the levels of chemistry, which according to Johnstone (1993), confers a better understanding of the phenomenon.

Among the students, Ariadne was the participant who mentioned specific elements of the activity at the submicro level more frequently during the interview, as evidenced in the excerpt where she talks about the effective collision of "atoms". It can be suggested that this occurred because she was the student in charge of drawing the models in the group, which in a way made her reflect more on the elaboration of the representations. In this regard, a possibility for future work is to instruct the group, as far as possible, to alternate positions at this stage.

It is important to highlight the training of these students because, as they are linked to the chemistry teacher education program, they had already taken courses in which the theoretical deepening of representational levels and their importance for the teaching and learning of chemistry was addressed. In addition, the students report that they participated at least twice in activities that involved modelling, both in PEQ II and other disciplines in the program. Therefore, there is an emphasis in their speeches that relates to the submicro level, as they attributed it as an important aspect for understanding and relating to the other levels. In this sense, the factors described by Chittleborough et al. (2002) such as prior knowledge of chemistry and modelling, as well as the motivation of the students to understand the phenomenon more deeply, prove to have been fundamental to more effective learning.

Engineering Student (Yohan)

The engineering student's perception differed from his group mates, particularly when he pointed out that the main difficulties involved in the IBMA were during the observation of phenomena (macro level) in the experimental procedure developed by the group. The adopted method did not allow them to be certain about the visual differences in the solid iron after corrosion. However, it is important to highlight that the students had access to more materials that could be tested so that such questions could be explored.

Results from Michalisková and Prokša (2018) suggested that some students do not know, from the visual perception of a phenomenon, when there is an expression of a chemical reaction, which may result from their inexperience in activities that involve observation of experiments. Yohan stated in an interview that he had not attended classes involving chemistry during his undergraduate studies, and therefore, it can be assumed that he had participated in few or even no experimental chemistry classes, in view of this, there was little prior knowledge of the student related to the activity, which for Carvalho (2013) is fundamental to give conditions for the construction of hypotheses and tests for the resolution of the situation posed.

Moreover, as already presented in the results, for Yohan, the IBMA provided partial construction of the concepts related to the studied content. In his report, he understood the result of the studied phenomenon, the influence of temperature on the rate of the chemical reaction, but he said he would not be able to replicate the same concept in other problematic situations. This data indicates that the learning process at the submicro level, which explains how the reaction occurred, had little significance for him, which may have been due to the student's superficial involvement in this stage of the activity, as when asked about the construction of models, he stated: "I remember it was Ariadne who did it, so I don't remember much of it".

Silva et al. (2021) stated that students do not perceive visual representations in chemistry as necessary for constructing knowledge, instead perceiving them as mere illustrations, "understood as a product that transmits its content by itself" (p.17). Thus, it can be understood that the student understood the representations as a domain necessary only for the context of the activity or even specific to chemistry teachers, i.e., his classmates, and did not perceive them as elements that assist in problem-solving and understanding of the chemical reaction.

In addition, access to and articulation of models at the submicro level is complex and difficult to assimilate (Fernandes & Locatelli, 2020). The lack of significance that this student may have attributed to the representations may be related to the difficulty in understanding them. Unlike Ariadne and Cecília, it was the first time that Yohan had contact with an activity that involved submicro level modeling, as in the days leading up to the IBMA there were tasks of this nature in the PEQ II discipline, but the student was absent.

For Yohan, explanatory models, as well as their elaboration and comparison, probably represent a high intrinsic burden, causing him to select the aspects that are more familiar, such as the visual phenomena at the macro level. Findings by Kelly (2017) indicated that students prefer simpler models that are explicitly linked to the macro, and in addition, Chittleborough and Treagust (2008) stated that graduates who have little chemical knowledge end up demonstrating "poorer" mental models because they have difficulty interpreting diagrams at the submicro level. This suggests that less proficient students in the manipulation of these representations, such as Yohan, should be involved in a gradual process so that they can understand more complex models.

The student also reported that he did not recall the representational levels, even though the topic was frequently discussed throughout the discipline. For Fernandes and

https://doi.org/10.33225/BalticSTE/2023.223

Locatelli (2020), the unfamiliarity with this concept can directly impact these students' understanding of chemistry, as attested by Yohan.

Although the student, based on the interview, did not show evidence of accessing the submicro level, it is believed that the experience was important to initiate the process of constructing and reconstructing mental models, which is a valuable step for learning chemistry.

Overall, this study allowed us to determine the perceptions of this small group of students considering the difficulties that emerged in the activity and the learning of chemistry. It is recognized that the research is limited due to its characterization as a case study, which means that the data collected is applicable only to the sample analyzed within the context of this research and is not suitable for producing generalizations (Alves-Mazzotti, 2006). However, the findings provide exploratory evidence that may be useful for the advancement of international studies involving metavisual strategies (Chang, 2021; Locatelli & Davidowitz, 2021) and may also contribute to international studies related to the approach of chemical representations in the classroom (Chittleborough & Treagust, 2008; Kelly, 2017; Fernandes & Locatelli, 2020) by means of the level of familiarity that the student has with chemistry, models and experimental practice, whether more experienced (chemistry majors) or novices (engineering student).

In the specific case of students who are less familiar with the strategies used, a gradual introduction and the use of less complex models would be necessary, so that little by little, they can appropriate chemical representations and understand them as important for problem-solving and acquire the ability to use this knowledge for issues in their daily lives.

Furthermore, although there was an assumption that the engineering student had access to chemistry content in high school, this study revealed the gap that this student had in this knowledge, which reinforces the idea that they may perceive chemistry only as a subject in basic education and not as a fundamental training for critical thinking.

Conclusions and Implications

Returning to the question that guided this research: *What do undergraduate students from different courses report about the didactic experience of an inquiry-based metavisual activity*? It can be concluded that the chemistry education students showed evidence of construction and reconstruction of the concepts, as well as possible articulation between the three levels of representation in view of the studied phenomenon. This may have occurred due to the conceptual baggage they already had about chemistry, which allowed them the necessary repertoire for understanding the steps and strategies involved in the IBMA.

The engineering student showed evidence of partial concept construction, limited to the descriptive level, that is, at the macro level. Among the possible reasons for this, the lack of the student's experience with activities involving modelling can be cited, which may have compromised his learning in interpreting models at the submicro level.

It is reiterated that the study has limitations due to the number of participants and the context in which it is set, but the findings may be useful for a more careful approach to chemical models, experimentation, and inquiry-based teaching in the classroom through the students' prior conceptions.

https://doi.org/10.33225/BalticSTE/2023.223

Acknowledgements

The authors would like to thank the Federal University of ABC (UFABC) for funding our research through a scholarship, the São Paulo Research Foundation (FAPESP), process 2022/16395-3, for funding the research project, the students who agreed to participate in this study and to the reviewers for the suggestions for improvement given to this research.

Declaration of Interest

The authors declare no competing interest.

References

Alves-Mazzotti, A. J. (2006). Usos e abusos dos estudos de caso [Uses and abuses of case studies]. *Cadernos de Pesquisa*, *36*(129), 637-651. https://doi.org/10.1590/S0100-15742006000300007

Bardin L. (2011). *Análise do conteúdo* [Content analysis] (5th ed.). Edições 70.

Carvalho, A. M. P. (2013). *Ensino de ciências por investigação: Condições de implementação em sala de aula* [Teaching science by exploration: Conditions for implementation in the classroom]. Cengage Learning.

Chang, H. Y. (2022). Science teachers' and students' metavisualization in scientific modeling. *Science Education*, *106*(2), 448-475. https://doi.org/10.1002/sce.21693

Charmaz K. (2006). *Constructing grounded theory: A practical guide through qualitative analysis*. Sage.

Chittleborough, G., & Treagust, D. (2008). Correct interpretation of chemical diagrams requires transforming from one level of representation to another. *Research in Science Education*, *38*(4), 463–482. https://doi.org/10.1007/s11165-007-9059-4

Chittleborough, G. D., Treagust, D. F., & Mocerino, M. (2002). Constraints to the development of first-year university chemistry students' mental models of chemical phenomena. In A. Bunker & G. Swan (Eds.). *Focusing on the student* (pp. 43–50). Professional Development@Learning Development Services.

Fernandes, B. G., & Locatelli, S. W. (2020). O conhecimento dos níveis representacionais na química pelo levantamento de concepções de estudantes universitários [The knowledge of representational levels in chemistry by surveying university students' conceptions]. *Latin American Journal of Science Education*, *7*, 1-10. Available in: http://www.lajse.org/nov20/2020_22018_2.pdf

Gilbert J. K. (2005). Visualization: A metacognitive skill in science and science education. In Gilbert J. K. (Ed.), *Visualization in science education* (Vol. 1, pp. 9-27). Springer. https://doi.org/10.1007/1-4020-3613-2_2

Gilbert, J.K., & Treagust, D. (2009). Introduction: Macro, submicro and symbolic representations and the relationship between them: Key models in chemical education. In Gilbert, J. K. &Treagust, D. (Eds). *Multiple representations in chemical education* (Vol.4, pp. 1-8). Springer. https://doi.org/10.1007/978-1-4020-8872-8_1

Johnstone, A. H. (1993). The development of chemistry teaching: A changing response to a changing demand. *Journal of Chemical Education*, *70*(9), 701-705. https://doi.org/10.1021/ed070p701

Kelly R. M. (2017). Learning from contrasting molecular animations with a metacognitive monitor activity. *Educación Química*, *28*(3), 181–194.

Locatelli, S. W., & Davidowitz, B. (2021). Using metavisualization to revise an explanatory model regarding a chemical reaction between ions. *Chemistry Education Research and Practice*, *22*(2), 382-395. https://doi.org/10.1039/D0RP00339E
Michalisková, R., & Prokša, M. (2018). The level of mastery of the concept of chemical reaction rate by 9th-grade students. *Chemistry-Didactics-Ecology-Metrology*, *23*, 81-95. https://doi.org/10.1515/cdem-2018-0005
Minayo, M. C. S. (1993). Trabalho de campo: Contexto de observação, interação e descoberta (30th ed.) [Fieldwork: Context of observation, interaction and discovery]. In: MINAYO, Maria Cecília de Souza (Org.), *Pesquisa social: Teoria, método e criatividade* (pp. 61-77). Editora Vozes.
Nyutu, E. N., Cobern, W. W., & Pleasants, B. A-S. (2021). Correlational study of student perceptions of their undergraduate laboratory environment with respect to gender and major. *International Journal of Education in Mathematics, Science, and Technology*, *9*(1), 83-102. https://doi.org/10.46328/ijemst.1182
Quadros, A. L., Silva, A. S. F., & Mortimer, E. F. (2018). Relações pedagógicas em aulas de ciências da educação superior [Pedagogical relations in higher education science classes]. *Química Nova*, *41*(2), 227-235. https://doi.org/10.21577/0100-4042.20170178
Schnetzler, R. P. (2002). A pesquisa em ensino de química no Brasil: Conquistas e perspectivas [Research in teaching chemistry in Brazil: Achievements and Perspectives]. *Química nova*, *25*, 14–24. http://dx.doi.org/10.1590/S0100- 40422002000800004
Schraw G. (1998). Promoting general metacognitive awareness. *Instructional Science*, *26*, 113-125. https://doi.org/10.1023/A:1003044231033
Silva, F. C., Silva, E. P. C., Duarte, D. M., & Dias, F. D. S. (2021). Relação entre as dificuldades e a percepção que os estudantes do ensino médio possuem sobre a função das representações visuais no ensino de química [Relationship between the difficulties and the perception that high school students have about the function of visual representations in chemistry teaching]. *Ciência & Educação (Bauru)*, *27*, 1-21. https://doi.org/10.1590/1516-731320210061
Stake R. E. (2010). *Qualitative research: Studying how things work.* (First ed). Guilford Press.
Zômpero, A. F., & Laburú, C. E. (2011). Atividades investigativas no ensino de ciências: Aspectos históricos e diferentes abordagens [Exploratives activities in science education: Historical aspects and different approaches]. *Ensaio: Pesquisa em Educação em Ciências*, *13*(3), 67-80.

Received: *April 04, 2023* Accepted: *May 17, 2023*

Cite as: Shimada, M. S., & Locatelli, S. W. (2023). Students' perception of an inquiry-based metavisual activity about concepts of chemical kinetics. In V. Lamanauskas (Ed.), *Science and technology education: New developments and Innovations. Proceedings of the 5th International Baltic Symposium on Science and Technology Education (BalticSTE2023)* (pp. 223-232). Scientia Socialis Press. https://doi.org/10.33225/BalticSTE/2023.223

THE INFLUENCE OF A PROJECT-BASED CLUB PROGRAM ON MIDDLE SCHOOL STUDENTS' ACTION COMPETENCY IN RESPONDING TO CLIMATE CHANGE

Young-Joon Shin
Gyeongin National University of Education, Republic of Korea
E-mail: yjshin@ginue.ac.kr

Hyunju Park
The War Memorial of Korea, Republic of Korea
E-mail: libraphj@naver.com

Hae-Ae Seo
Pusan National University, Republic of Korea
E-mail: haseo@pusan.ac.kr

Abstract

Incorporating climate change into education is critical for building a sustainable future and empowering the next generation to take action. This study aims to explore how a project-based club program influences middle school students' action competency in responding to climate change. For this aim, ten students who participated in a project-based club program in a boys' middle school were selected. A pre-test on relevant knowledge was surveyed, students' behaviors during the program were observed, and in-depth interviews were conducted after the program. The results revealed that students showed a better understanding of climate change and carbon neutrality concepts, increased sensitivities to climate change, deepened reflections on climate change activities, improved communication and decision-making abilities, and improved willingness to take action in climate change mitigation activities. It was concluded that the project-based club program has positively influenced students' action competency in responding to climate change.
Keywords: *action competency, climate change, middle school students, project-based club program*

Introduction

Climate change has been recognized as a significant social problem worldwide and now emerged as a newly rising social problem in our lives closely related to local communities. Climate change is no longer a problem that only happens in other countries. To solve such a climate change problem, the international community is responding by organizing the Intergovernmental Council on Climate Change (IPCC). The IPCC recommended that carbon neutrality (net-zero), in which the amount of greenhouse gases

https://doi.org/10.33225/BalticSTE/2023.233

caused by human activities is reduced to zero through carbon dioxide emissions and absorption, should be achieved in order to prevent ecosystem destruction and respond to the crisis facing humanity (IPCC, 2022).

Korea also actively responds to climate change issues by announcing the Korean version of the Green New Deal policy. This newly developed policy declared carbon neutrality by 2050 and established a presidential carbon neutrality committee for the greenhouse gas reduction goals (Kim, 2021). In the field of education, in order to better prepare for future uncertainties such as the climate crisis, climate change education in schools becomes strengthened with the goal of cultivating competencies necessary for the future society (Ministry of Education, 2022).

Students are going to be the most significant stakeholder in climate change of future society. They will take the role of a main agent of problem-solving and become a citizen of decision-making and a leader of society in the future, for future generations to deal with the climate crisis, climate change education needs to be strengthened. It is necessary to involve youth in efforts to solve problems such as climate change (Stephens & Ballard, 2021). It is an important task of the education system to ensure that young people are learning the right facts about the causes, societal impacts, and potential solutions of climate change, and to promote critical and ethical views on this complex issue (Kronlid, 2009; Ojala, 2012; Shin, 2023).

For this reason, students need to learn at school about how to participate in social problems and how to prepare for their roles. Recently, climate change education has stressed developing students' practical capabilities in daily life so that they can deal properly with climate change (Busch et al., 2019; Vaughter, 2016). Due to the urgency of climate change issues, climate change education emphasizes the importance of action competency in everyday life and opportunities for participation so that young people can play a promising role as ecological citizens.

Action competency refers to taking action voluntarily for solving problems and having competency as democratic citizens (Jensen & Schnack, 1997). In other words, action competency means the ability to act in order to solve issues and to become active citizens in a democratic society (Sass et al., 2020). Since action competency has been introduced in the field of environmental and sustainable development education, how to effectively develop students' action competency should have been more importantly recognized in schools (Baek et al., 2021).

In fact, environmental education has been implemented in schools for several decades in Korea. However, the school curriculum has not allocated a reasonable amount for climate change-related content, and its achievement standard remains at the level of knowledge acquisition and not focusing on action competency (Shin, 2017; Shin, 2023). On the other side, there have been relatively few studies conducted on the development of action competency (Baek et al., 2021). Even further, effective teaching methods to develop action competency in climate change have not been specifically introduced and examined.

The project-based learning can be considered as an effective educational method to develop students' action competency in climate change. It is well acknowledged that climate change is not just a scientific phenomenon but also involves a complex socio-scientific issue. It is necessary for climate change education that students are encouraged to find complex and uncertain problems occurring in the real world, define what the

https://doi.org/10.33225/BalticSTE/2023.233

problem is, understand the problem from the perspective of various interest groups, seek solutions based on cause analysis, and find the optimal solution (Blumenfeld et al., 1991; Lee & Hwang, 2019). In this context, project-based learning seems to be suitable for climate change education as it includes a variety of complex activities, such as finding a solution and finding possible alternatives to act (Jonassen, 1997). However, research on how the project-based club program influences on developing students' capability to deal with climate change, has not been conducted extensively in Korea.

Research Problem

The study paid considerable attention to the project-based club program about climate change. The school club programs are part of the creative experiential activities to help students perform practical and voluntary activities, cultivate a healthy mind and body, and develop their abilities of inquiry and problem-solving (Ministry of Education, 2015). The realization of action competency on global issues of climate change can be accessed through the project-based club program. In this study, a project-based club program is developed and applied to middle school students with the goal of cultivating action competency to deal with climate change as being ecological citizenship. Therefore, the research question in this study includes what kind of changes in middle school students' action competency related to climate change occurred after participation in the project-based club program.

Research Methodology

General Background

The aim of this study was to explore how the project-based club program influenced middle school students' action competency related to climate change. To accomplish the aim, a qualitative research design was chosen in taking advantages to reveal students' changes in depth from various aspects. This study was conducted with ten students who participated in a climate change club program at a boys' middle school located in a city with about 30,000 people. The city seems to be characterized by facing unfavorable circumstances of the deepened educational gap between urban and rural areas, poor rural economy, population decline due to low birth rate and intensified decrease in the number of incoming new students. In order to solve these problems, various strategies such as the school's development of a specialized curriculum suitable for local communities are required. In addition, as there are many students from broken families such as single fathers, single mothers, and grandparents' families, scholarship benefits and administrative and financial resources are needed foremost.

Sample

The students in the study participated voluntarily in a climate change club named 'NT2050 Green Center' on the theme of climate change education, ecological transformation education and civic education. These students showed high interest and preference in hands-on activities such as field trips, experiments, and practical training,

https://doi.org/10.33225/BalticSTE/2023.233

as well as science, arts and physical education subjects. The participants in this club were ten male students, and the data collection was conducted with them under the students' and their parents' agreements at the beginning. The ten students consisted of two 7th graders, four 8th graders and four 9th graders.

Development of the Project-Based Club Program of Climate Change

Teacher K, who voluntarily took charge of the climate change club, was an English teacher with six years of teaching experience and has implemented several STEAM projects for various subject matters. The topic of climate change was kind of new to Teacher K. Teacher K studied about climate change on his own to provide students with various experiences. In fact, Teacher K was running a carbon-neutral challenge program for the whole school. Teacher K discussed about the contents and teaching methods for the club with the researcher in advance. The program was developed with STEAM contents by adopting the PDIE (Preparation-Development-Implementation-Evaluation) model (Kim, 2012; see Table 1). After the development of the project-based club program, the team of the researcher and Teacher K reviewed it thoroughly and revised it when needed.

The project-based club program was developed as a creative experiential activity program centered on carbon neutrality to cultivate middle school students' action competency. In particular, the program was developed with an emphasis on practical actions to change individual behaviors in order to develop action competency related to climate change and ecological citizenship. Through this program, first, participating middle school students are able to find examples of practical uses in real life and develop action competency in climate change in daily lives. Second, the students are able to integrate knowledge from various subject matters such as social studies, Korean language, and English as well as science into the program. Third, the program will allow students to participate in activities on their own initiative and to develop action competency to deal with climate change and ecological citizenship through cooperation with members.

Table 1

Procedures to Develop the Project-Based Club Program by Adopting the PDIE Model

Phase		Procedures	Contents
Preparation	1	Needs assessment	– literature review
	2	Analyze STEAM curriculum	– analyze 2015 and 2022 revised curricula
	3	Select learning standard	– problem contexts, creative design, emotional experiences
	4	Select integrated topic	– topic-centered, integrated with two or more subjects
Development	5	Select activity topics	– climate change (carbon neutrality)
	6	Set learning objectives	– action competency to deal with climate change
	7	Clarify performance expectation	– varied strategies to improve students' action competency
	8	Set contents of the topics	– ACT NOW! Campaign, choose one rule to follow daily carbon neutrality, the definition of climate change, and more
	9	Organize contents	– Introduction - Development - Summary
	10	Select STEAM contents	– NT2050 Green Center ACT NOW!
Implementation	11	Implement the STEAM program	– Implement a total of 8 class periods
Evaluation	12	Evaluate the STEAM program	– Administer tests and in-depth interview
	13	Revise and finalize the program	– Revise and improve the program

Table 2
Overview of the Project-Based Club Program in Climate Change to Develop Action Competency

Step		Topics	Activities of Teaching and Learning
Introduction to Problem Contexts	1	Understand climate change	– Discuss examples of climate change experienced near – Changes in suitable areas for apple cultivation – Examine concepts and causes of climate change
	2	Understand carbon neutrality	– Investigate NET ZERO carbon neutrality – Do the board game of carbon footprint, – Share opinions about carbon neutrality
Creative Design	3	Global efforts on climate change	– Investigate global efforts on climate change – Share opinions about individual efforts on climate change – Make a picket to promote actions to deal with climate change
	4	Individual efforts and actions on climate change	– Introduce ACT NOW! by UN – Interpret 10 living rules in English into Korean – Each student selects one rule out of 10 living rules – Plan how to act accordingly, and take into action
	5	Practice ACT NOW!	– ACT NOW! Among the rules, practice SPEAK UP! – Explain climate change and picket at the Apple Festival – Summarize results of participation in the Apple Festival
Emotional Experiences	6	Find ACT NOW from neighborhood	– Understand the elements of producing a newspaper in English – Introduce a project to make ECO-TIMES newspaper in English – Group as teams to play different roles
	7	The ACT NOW what I found	– Present and share what each team developed – Design the layout of articles and photos – Produce articles in English
	8	Produce ECO-TIMES	– Finalize and present the ECO-TIMES newspapers – Publicize the newspapers within and out of schools via SNS – Write the report about the program

The project-based club program consists of three steps (see Table 2). The first step is about introduction to the contextual background of problem situations and the causes and effects of climate change are presented with two lesson themes. The second step is about creative design to explore climate change problem situations. In the second step, three themes are presented. The third step includes the development of action plans to implement solutions. It is structured so that people can plan and participate in social practices to deal with climate change issues through emotional experiences.

This project-based club program maintains the overall framework according to teaching and learning directions for the school club programs recommended by the Ministry of Education (2022) but allows students to choose on the operation and direction of detailed activities.

https://doi.org/10.33225/BalticSTE/2023.233

Data Collection and Analysis

Data were collected in three ways. First, Teacher K administered the pre and post-tests about students' understanding of knowledge of climate change. The data provided changes before and after the program. Second, Teacher K took the observation journal during the program. Teacher K observed each student's distinct behaviors, participation, and interaction among peers and recorded them in the observation journal. Through the observation journal, individual students' thoughts and conceptual changes for each class activity were examined, and how and how much they contributed to the production of activity outputs were confirmed.

After all activities were completed, the researcher conducted in-depth interviews with participants about climate change focusing on seven perspectives, 1) climate change-related issues, 2) timeliness of climate change, 3) ability to reflect, 4) integrated thinking, 5) communication ability, 6) decision-making ability, and 7) willingness to take into action. In-depth interviews were conducted about 20-30 minutes individually with seven out of ten students who participated in all activities of the program. Seven students interviewed are four 8th graders (A3, A4, A5, and A6) and three 9th graders (A7, A8, and A10). While participating in all processes of the project activities, these students are well aware of the intentions and themes of each stage of the program. Their thoughts and opinions were well reflected in their project outputs.

The entire process of the interview was recorded, and it was converted into text using a recording management service, using artificial intelligence voice recognition technology, and errors were corrected by confirming it with the actual voice. In-depth data were analyzed in relation to how the project-based club program influenced students' changes to deal with climate change and the results were drawn.

Research Results

Knowledge Related to Climate Change

Knowledge related to climate change is about climate change itself, such as the main causes of climate change (natural and artificial) and various consequences of climate change (social, environmental, economic, etc.), and knowledge of how to deal with climate change. Students answered about what climate change is before starting the project-based club program as a pre-test. Most students did not recognize what climate change meant as they described it vaguely. They answered the question with short answers such as garbage, air conditioners, global warming, storms, showers, and so on. The results from interviews after the program with students are as follows.

Teacher K: Did you learn anything new about climate change or carbon neutrality through the club activities?

Student 7: Before the club activities, I did not take climate change seriously, but after the club activities, I became to know that climate change is serious.

Student 4: While studying and working on climate change and carbon neutrality, I realized that climate change requires more attention from us than I originally knew and that we can solve it only when we take action.

Student 8: Originally, I did not know about carbon neutrality, but through this club activity, I learned about carbon neutrality itself, and now I know that carbon neutrality is important for us to prevent climate change.

After the program, students were able to elaborate on their knowledge about climate change. Student A7 replied that he learned how serious climate change can be while participating in club activities. Student A4 also replied that the climate change problem could be solved when the members of society showed concern and willingness to take action. Through these answers, it was confirmed that their prior knowledge was improved. In addition, student A8 said that he was able to obtain a clear concept of carbon neutrality, which was very vaguely conceptualized before the program.

Sensitivities to Climate Change

Sensitivity to climate change implies that individuals recognize the values of the natural environment and the earth system, respond sensitively to climate change, and have a concern about targets (people, environment, and society) damaged by climate change. It also implies that individuals understand targets and feel empathy for them. When students were asked about how climate change affects them, their answers appeared as ‘food becomes scarce, ‘arctic glaciers are melting’, and ‘four seasons are disappearing.’ It was revealed that students perceive climate change as a problem in general but not directly influencing on their daily lives. Some students’ sensitivities about climate change drawn from interviews are as follows.

Teacher K: How did you feel when you discussed and predicted drastic changes in locations suitable for growing apples?

Student A7: I felt sad when I predicted that my parents are no longer able to grow apples after just a few years. The sad feelings remain in my mind.

Student A4: Looking at the map to show suitable locations for growing six major fruits, there are fruits that I can’t eat any more after a little while. Now that I feel that these things are no one else's business, they are coming soon to me as well. I have been able to act with awareness as much as possible, and I have tried to make people aware of this fact by addressing people at the Apple Festival. I tried to tell the truth.

Student A6: It helped me to know how much damage climate change is doing to our daily lives. I think these activities have helped raise awareness about climate change.

Shin and Shin (2021) argue that developing sensitivity to the environment is the beginning of change, and the first step in environmental education is to start by knowing that one is related to the environment. For this, it was said that it was necessary to enhance the sensitivity to accept the change in the environment as one’s own. When environmental ecological sensitivity is the basis, we can respond sensitively to changes in the natural environment, and we can think about the seriousness of climate and environmental problems. The increase in sensitivity to climate change through this process would have been the basic driving force to lead the cultivation of action competency in dealing with climate change.

https://doi.org/10.33225/BalticSTE/2023.233

Reflections on Climate Change Activities

Reflecting on climate change can be an important first step towards taking action to address the issues. Reflection is a process of thinking about and evaluating experiences, events, or information in order to gain a deeper understanding or insight. For the question, 'Have you ever done anything that worsens climate change and what have you done?' in the pre-test, students answered 'no' or with simple words such as 'just throwing garbage,' or 'leaving food behind.' However, their levels of ability to reflect on climate change after the program became articulated. Students' changes in reflections on climate change drawn from the interview after the program are as follows.

Teacher K: You said that you learned about environmental activist Greta Thunberg through the club activities. What kind of person do you think this person is?
Student A5: I think it's great that Greta Thunberg walked the path of an environmental activist at such a young age. And if I get a chance, I want to be an environmental activist like Greta Thunberg.
Teacher K: What kind of behavior did you change through the campaign and if you do another campaign, what kind of campaign would you like to try?
Student A8: I learned about various alternative energies to reduce energy. I want to do a picketing activity with the theme of using alternative energies in the city. I will do this at the busiest spots where many people come and go.

It was confirmed that student A5 learned about behaviors of teenagers in responding to climate change through the case of environmental activist Greta Thunberg. Even further he explored careers related to the environment. He seemed to be motivated by knowing an example of the participation of the peer group in climate change activities. In the case of student A8, he responded that he was able to change individual behaviors by conducting a climate change campaign. Through this, it was possible to see that students were exploring their own ways for a sustainable future while looking back and observing individual behaviors through club activities.

Communication Abilities

In resolving climate change, communication ability is necessary to respect and accept the opinions of various topics in society and to effectively communicate one's own and others' thoughts and feelings. Students' changes in reflections on climate change drawn from the interview after the program are as follows. From the pre-test data in relation to this communication ability, most students were exposed to news related to climate change mainly through media such as news (broadcasting, articles), YouTube, and SNS. It was difficult to see cases where topics such as climate change were discussed in everyday life outside of the media. After the program, students' changes in climate change at interviews were revealed as follows.

Teacher K: It was said that taking into action in a group had a greater influence on climate change than acting alone. What part do you think had an impact?
Student A6: If I had done it alone, I wouldn't have actually practiced it, and even if I had done it, I wouldn't have done it properly. But since I did it with my friends and high graders, I

became more confident and the range of activities I could do broadened and grew. I was able to realize it better and I think it helped me when I decided to act on climate change.

Teacher K: Did you meet people who are interested in the environment at the Apple Festival and have your thoughts changed? Please tell me if there is.

Student A6: At the apple festival, a grandmother came, and we were explaining about climate change. Because I thought people were only thinking about it and not many people were actually interested in it, but I was very surprised that there were people like that, contrary to what I thought.

At the interview, student A6 replied that he was able to gain confidence while communicating with seniors and classmates, which he could not have done alone. It was also confirmed that the scope of activities was expanded than he thought in the process of collaboration. In particular, students carried out the project output to perfection while actively sharing and communicating with each other through activities such as data research, article coverage, and article composition for the production of ECO-TIMES. In addition, through conversations with people who expressed interest in the environment at the Apple Festival during the SPEAK UP activity, students improved their degree of interest in climate change and were determined to change their behaviors. They improved action competency with such thoughts.

Decision-Making Abilities

Decision-making ability refers to the ability to the skill of evaluating options and selecting the best way to achieve a specific goal to adapt and mitigate climate change. In this regard, the data from the pre-test, students responded that it was possible to solve climate change, particularly, students mainly answered that ‘it can be solved in the direction of changing individual behavior.’ After the participation in the club program, students’ responses at the interview are as follows.

Teacher K: You said that the climate change problem should be solved globally, is there a reason you think so? Then, please tell us what efforts can be made to solve this problem globally.

Student A3: Since climate change is now a global issue, not just one region or one country, I think we should do it together globally. In addition, in these days, the Internet media is well developed, so it would be good to publicize it through the Internet media and act as a stimulus to inform the seriousness of climate change.

Teacher K: Shall we talk about how to promote carbon neutrality to those who have not yet practiced it?

Student A4: I would like to show people who are not practicing carbon neutrality a climate crisis-related video about what happens if they do not practice carbon neutrality, so that they realize its seriousness.

Student A3: I think I can play a role in promoting and informing people about ACT NOW’s living rules on saving energy at home by writing an article or something like that on the Internet.

Student A6: First of all, I think we should convey exactly what kind of damage has occurred due to climate change. Because, honestly, I didn't think there would be such a big damage, and thanks to the NT2050 activity. I have an idea to practice more carbon neutrality. In particular, it would be nice to approach the younger generation through SNS.

https://doi.org/10.33225/BalticSTE/2023.233

In the case of Student A3, it can be confirmed that he recognizes the climate change problem as a global problem as well as an individual one. In order to solve this problem, a decision should be made to use the Internet as a medium to share and inform the seriousness of the climate change problem. It was also confirmed that the problem of climate change is thought to be a problem that can be overcome with global efforts. For the case of Student A4, he suggested using climate crisis-related videos as a way to promote carbon neutrality. Moreover, Student A6 also suggested that clear facts be conveyed about the damage caused by climate change. He was convinced that the cases of damage caused by climate change are bigger than he thought, and he learned about this information through club activities and developed a willingness to share it with teenagers of his age through SNS.

Willingness to Act Climate Change Mitigation Activities

The willingness to take action refers to a person investing time, money, and energy in individual and social practices to solve climate change problems with critical thinking about climate change. For the pre-test data in relation to this willingness to practice mitigation activities, students were able to identify responses that actions were mostly temporary, non-continuous, and cost-free. Their willingness to deal with climate change problems was not so great before the program. After the program, students' changes in terms of willingness at the interview are as follows.

Teacher K: Do you think individual action is important to respond to climate change? If so, can you explain why?

Student A4: The reason why I thought that individual action is important to respond to climate change is that each of us must take action to change, not just one person acting. It's not just me, I think everyone should practice individually now.

Student A5: In order to respond to climate change, I think it is important that if we start as individuals, we can become the whole. What I did at school lunches was to eat but nothing left or eat more vegetables to reduce the use of food resources. And what I felt through what I practiced was that I felt proud that I had contributed a little more to this carbon-neutral challenge.

Student A8: I think individual practice is important. The reason is that individual actions can save the earth, and individuals can come together to change the world.

Students responded positively that climate change can be solved through practice in club activities. In particular, in the way that A4, A5, and A8 students all answered that the theme of solving climate change is not only the individual but also the world, it was confirmed that the scope of the theme to solve the problem of climate change is expanding. Through this, it was confirmed that the club activities are effective for middle school students in having the perception of building governance as an action competency to solve the climate change problem.

https://doi.org/10.33225/BalticSTE/2023.233

Discussion

This study is to explore how a project-based club program influences middle school students' action competency in responding to climate change. For this purpose, changes in students' thoughts on action competency were analyzed through a pre-test on their prior knowledge, a teacher's observation journal recorded and collected during teaching and learning activities, project outputs, and in-depth interviews at the end of the project-based club program. The main research results in this study are summarised and discussed as follows.

Most students in this study were able to articulate concepts and knowledge about climate change and carbon neutrality after participating in club activities. Their sensitivity to climate change was improved and in turn, led to nurturing their action competency to respond to climate change. Further, students were able to search for their own way while observing and reflecting on individual behaviors. Students also gained confidence by communicating with their seniors and classmates. The process of these project-based club activities played a positive role in respecting and accepting various opinions and effectively communicating thoughts and feelings with others in resolving climate change. Such results were in line with the previous research in Korea that students' changes in awareness, sensitivity, and involvement in environmental issues resulted from project-based environmental education (Hwang et al., 2014).

Students recognized the climate change problem not only as an individual but also as a local and global problem. This was helpful in improving decision-making ability on how our society should act in terms of adapting and mitigating climate change. Students represented a willingness to accept that climate change can be solved through practice through club activities. They further explained that it was not only individuals but also the world that must solve the climate change problems. Similar results and discussions about changes in behaviors also appeared in a study of community-based SSI programs in domestic (Kim & Lee, 2017) and in a study about everyday activities abroad (Gould et al., 2019).

Conclusions and Implications

This study attempts to approach the issue of climate change in an educational way. It is necessary for students as future citizens to feel personal awareness of global environmental issues and responsibility as global citizens. Action competency in climate change implies an individual or organization's ability to effectively take action to mitigate the impacts of climate change. It involves not only having the knowledge and awareness of the issue, but also the skills and resources necessary to create and implement solutions. The study with the goal to nurture middle school students' action competency in climate change developed a project-based club program and implemented it for ten middle school students. The students in this study were able effectively to make changes with better understandings of knowledge in climate change and carbon neutrality, improved sensitivities to climate changes, enhanced reflection, communication, and decision-making abilities and a strong willingness to take into action for solving climate change problems.

https://doi.org/10.33225/BalticSTE/2023.233

Although the project-based club program in climate change developed in this study could not be a model that represents all the project-based programs, but it can be a guide for student-directed project programs, especially for developing action competency in climate change. In order to promote project-based educational activities in climate change education, teacher education and training programs should be continuously provided. Furthermore, other effective teaching approaches in climate change education should be developed and diffused.

Declaration of Interest

The authors declare no competing interest.

References

Baek, S., Shin, H., & Kim, C-J. (2021). A theoretical inquiry on the environmental action competence. *Korean Journal of Environmental Education, 34*(2), 136-150. https://doi.org/10.17965/kjee.2021.34.2.136

Blumenfeld, P. C., Soloway, E., Marx, R. W., Krajcik, J. S., Guzdial, M., & Palincsar, A. (1991). Motivating project- based learning: Sustaining the doing, supporting the learning. *Educational Psychologist, 26*(3 & 4), 369-398. https://doi.org/10.1080/00461520.1991.9653139

Busch, J., Engelmann, J., Cook-Patton, S., Griscom, B., Kroeger, T., Possingham, H., & Shyamsundar, P. (2019). Potential for low-cost carbon dioxide removal through tropical reforestation. *Nature Climate Change, 9*, 463–466. https://www.nature.com/articles/s41558-019-0485-x

Gould, R. K., Ardoin, N. M., Thomsen, J. M., & Wyman, R. N. (2019). Exploring connections between environmental learning and behavior through four everyday-life case studies. *Environmental Education Research, 25*(3), 314-340. https://doi.org/10.1080/13504622.2018.1510903

Hwang, Y., Choi, D-H., & Kim, C. (2014). The changes in high school students' creativity through environmental project-based learning activities. *Korean Journal of Environmental Education, 27*(4), 534- 548.

IPCC. (2022). *Climate change 2022: Mitigation of climate change*. Working Group III Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. https://www.ipcc.ch/report/ar6/wg3/downloads/report/IPCC_AR6_WGIII_FullReport.pdf

Jensen, B. B., & Schnack, K. (1997). The action competence approach in environmental education. *Environmental Education Research, 3*(2), 163-178. https://doi.org/10.1080/1350462970030205

Jonassen, D. H. (1997). Instructional design models for well-structured and ill-structured problem-solving learning outcomes. *Educational Technology Research and Development, 45*(1), 65-94. https://link.springer.com/content/pdf/10.1007/BF02299613.pdf

Kim, G., & Lee, H. (2017). Effects of community-based SSI programs on promoting middle school students' understanding of issues and character and values as citizens: Focused on fine dust issues. *Journal of the Korean Association for Science Education, 37*(6), 911-920. http://dx.doi.org/10.14697/jkase.2017.37.6.911

Kim, H-W. (2021). *What the 2050 carbon neutrality scenario should contain*. Labor N Issue, No. 2021-05. Korea Trade Union Central Research Institute.

Kim, J-S. (2012). *Theory in STEAM education*. Yangseowon Publishing.

Kronlid, D. (2009). Sigtuna think piece 2. Climate capabilities and climate change education research. *Southern African Journal of Environmental Education, 26*, 27-37. https://www.ajol.info/index.php/sajee/article/view/122788

Lee, Y-H., & Hwang, Y. (2019). Suggestion of RI (IR) - DCA project model and investigation about teachers' awareness about activating the student-centered project. *Journal of Education & Culture, 25*(2), 175-202. https://doi.org/10.24159/joec.2019.25.2.175

Ministry of Education. (2015). *General overview of the 2015 revised curriculum*. Ministry of Education Notice No. 2017-74 [Annex 1].

Ministry of Education. (2022). *General overview of the 2022 revised curriculum*. Ministry of Education Notice No. 2022-33 [Annex 1].

Ojala, M. (2012). Regulating worry, promoting hope: How do children, adolescents, and young adults cope with climate change? *International Journal of Environmental and Science Education, 7*(4), 537-561. https://files.eric.ed.gov/fulltext/EJ997146.pdf

Sass, W., Boeve-de Pauw, J., Olsson, D., Gericke, N., De Maeyer, S., & Van Petegem, P. (2020). Redefining action competence: The case of sustainable development. *The Journal of Environmental Education, 51*(4), 292-305. https://doi.org/10.1080/00958964.2020.1765132

Shin, W., & Shin, D. (2021). A study on climate change attitudes, inquiry, and knowledge of elementary and middle school students. *Journal of Energy and Climate Change Education, 11*(2), 95-107. https://doi.org/10.22368/ksecce.2021.11.2.95

Shin, Y-J. (2017). Analysis on contents related to appropriate technology, sustainable development, climate change and energy of the 2015 revised national curriculum. *Journal of Energy and Climate Change Education, 7*(1), 15-23. https://doi.org/10.22368/ksecce.2017.7.1.15

Shin, Y-J. (2023). Contents analysis of the 2022 revised curriculum related to the climate change education. *Journal of Energy and Climate Change Education, 13*(1), 23-34. https://doi.org/10.22368/ksecce.2023.13.1.23

Stephens, A. K., & Ballard, H. L. (2021). Developing environmental action competence in an urban high school agriculture and environmental program. In *Research approaches in urban agriculture and community contexts* (pp. 117-142). Springer. https://doi.org/10.1007/978-3-030-70030-0_7

Vaughter, P. (2016). Climate change education: From critical thinking to critical action. *Policy Brief, 4*, 1-4. http://collections.unu.edu/eserv/UNU:3372/UNUIAS_PB_4.pdf

Received: *April 12, 2023* Accepted: *May 16, 2023*

Cite as: Shin, Y.-J., Park, H., & Seo, H.-A. (2023). The influence of a project-based club program on middle school students' action competency in responding to climate change. In V. Lamanauskas (Ed.), *Science and technology education: New developments and Innovations. Proceedings of the 5th International Baltic Symposium on Science and Technology Education (BalticSTE2023)* (pp. 233-245). Scientia Socialis Press. https://doi.org/10.33225/BalticSTE/2023.233

MENDELEEV EPONYMS IN THE EPOCH OF EDUCATIONAL ETHNOCENTRISM

Uladzimir Slabin
University of Oregon, United States of America
E-mail: uslabin2@uoregon.edu

Abstract

Eponymous terms play an important role in STEM education. This research focuses on the current state of Mendeleev eponyms in the context of education and ethnocentrism, addressing their usage in various languages, their educational value, cases of questioned priority and copyright violation in Mendeleev major eponyms–periodic table and periodic system. 106 chemistry textbooks in 4 languages including Soviet-time and current Russian textbooks were perused to identify and trace Mendeleev eponyms over 1924-2016. Advanced Google Search with queries in Belarusian, English, Latvian, Polish, Russian, and Ukrainian was conducted to evaluate online presence of eponyms "Mendeleev periodic table" and "Mendeleev periodic system." It was found that while Mendeleev eponyms occur generously on the Internet, periodic table and system with Mendeleev's name attached are seldom used on non-Russian webpages. Most Mendeleev eponyms were made up in the USSR and remain popular and Russia, which can be explained within the framework of ethnocentrism as a ruling tendency. Recognizing Mendeleev's priority, Flinn and Ross's periodic systems can be considered plagiarized; a few factors might favor their emergence, but ethnocentrism is unlikely to be one of them. Mendeleev eponyms remain valuable assets for science education, acting as shortcuts to the history of science and actualizing interdisciplinary connections.
Keywords: *chemical education, eponym, ethnocentrism, Mendeleev, periodic table, periodic system*

Introduction

Eponymous terms (Copernican system, Brownian movement, Faraday the father of electrotechnics, Priestley the father of pneumatic chemistry, Beschamp reaction, Cahn-Ingold-Prelog rules, ampere, hertz, etc.) play an important role in STEM education (Slabin, 2007; Slabin, 2017b) both didactics and axiology wise. In the classroom, eponymous terms act as amazing shortcuts that allow teachers to naturally transition from explaining the subject content to telling engaging stories about scholars, thus implementing principles of humanization and historicism in education (Slabin & Krasitski, 2017; Slabin, 2017a; Slabin, 2019b).

Metonymic transfer of meaning made the words "eponymous term" and "eponym" synonymous. Eponymy as a practice of attaching the scholar's or inventor's name to their discovery or creation is one of the most effective forms of recognition in Western scholarship. This recognition, however, has never happened smoothly. According to Merton (1957), "the gradations of eponymy have the character of a Guttman scale in which those men assigned highest rank are also assigned lesser degrees of honorific recognition" (p. 643). Stigler's law of eponymy (1980) claims that no scientific discovery is named after its original discoverer.

https://doi.org/10.33225/BalticSTE/2023.246

Eponymous terms can arise both in an organized way and unplanned. In some countries such as the former Soviet Union an inventor had the right to assign their name to the invention (law "On inventions in the USSR," 1991). The author of this article utilized that opportunity to patent his own invention, Slabin's necktie (1992). In many fields, especially medicine, eponymous terms arise spontaneously and in large amounts, which prompted the World Health Organization (2013) to actively discourage the use of eponymous terms in medicine. Many factors influence formation and use of eponyms, one of them being ethnocentrism—the leading trend in world education after the universalism of the Renaissance (Slabin, 2017c).

Perhaps, the most frequently used eponymous term in Soviet and post-Soviet school chemistry has been Mendeleev periodic table. Considering the periodic law history, Russian teachers surely heard of the Newlands octaves and the Döbereiner triads, but no one there doubts that the law was "discovered by D. I. Mendeleev in 1969" (the words under the scholar's portrait in a common school version of the periodic table). The professional jargonic acronym "PSM", popular among teachers and students, unambiguously stands for "periodic system of Mendeleev."

Research Problem

Although not always the case, it is a general expectation that a great scholar leaves multiple eponymous terms. Over 154 years that passed after Mendeleev had discovered the periodic law, his biography and scholarly heritage have been exhaustively investigated. However, Mendeleev eponymous terms have not been a particular research object in education. As his heritage extends beyond the periodic law, one can expect more linguistic derivatives associated with Mendeleev. Research on eponymous terms of his name, on their origin and usage, would uncover interesting facts, valuable for chemical and science education.

Research Aim and Research Questions

This research aimed at the current state of Mendeleev eponymous terms in the context of education and ethnocentrism, addressing the following questions:

1. What Mendeleev eponymous terms have ever been made up, which of them are in educational use today and in what countries?
2. Are there any cases of challenged priority or violated copyright with Mendeleev discoveries and Mendeleev eponymous terms?
3. What is the role of ethnocentrism in this situation?
4. What is the value of Mendeleev eponymous terms in science education?

Research Methodology

To find Mendeleev eponymous terms, various texts in print and on the Internet were used. Reviewing literature for a dictionary of chemical eponyms, 106 chemistry textbooks for secondary schools and universities in Belarusian, English, Latvian, and Russian languages were perused and 1642 eponyms were identified including named acids, adapters, apparatus, bases, catalysts, condensers, constants, elements, equations,

https://doi.org/10.33225/BalticSTE/2023.246

filters, flasks, formulas, funnels, intermediates, laws, principles, projections, pumps, reactions, rearrangements, salts, stoppers, theorems, theories, vessels, asf. These data collection started in 1995; the data were used for similar research focusing on Verkhovsky eponymous terms (Slabin, 2017c).

Available Soviet-time (1924-1972) and current Russian chemistry textbooks (2016) were looked through with attention to Mendeleev eponymous terms, Mendeleev's priority emphasized, history of the periodic law covered, Mendeleev's competitors mentioned, and Mendeleev's portrait and biography included.

Advanced Google Search was used to find more Mendeleev eponymous terms and to compare their presence in six languages of the Internet: (a) English as one of the most frequently used in science, (b) Russian as the language of the country for which Mendeleev worked, (c) Belarusian, (d) Ukrainian, (e) Latvian as languages in the former USSR where Mendeleev's scientific achievements were popularized, and (f) Polish as the language of a country of former Soviet bloc where Russian and Soviet scholarship was popularized, too, but with lesser pressure. Table 1 lists concurrent search queries for versions of the four most popular eponyms—"Mendeleev periodic table", "Mendeleev periodic system", "Periodic table/system", and "Mendeleev the father of the periodic system."

"Google results" is a common and loosely used term but actually, without manipulation and interpretation it means "data", not "results." Because the number of those so-called results is known to be a complex function, Google Search was completed on one computer within two hours. The initially obtained numbers were then adjusted by dividing by respective numbers of language speakers (https://en.wikipedia.org/wiki/List_of_languages_by_total_number_of_ speakers) and multiplying by 10000–i.e., recalculated to webpages per 10,000 language speakers ("per capita" numbers were quite minute, 10^{-2}-10^{-4}). These results were used for building charts, comparison, and analysis.

https://doi.org/10.33225/BalticSTE/2023.246

Table 1
Basic Queries in Various Languages for Mendeleev Eponyms in Advanced Google Search

English[a]	"Table of Mendeleev", "Mendeleev table", "Mendeleev periodic table"
	"System of Mendeleev", "Mendeleev system", "Mendeleev periodic system"
	"Periodic table", "Periodic system" (without "Mendeleev"–no eponym)
	"Mendeleev", "father of the periodic table", "father of the periodic system"
Russian[b]	"Таблица Менделеева", "Периодическая таблица Менделеева", *"Периодическая таблица элементов Менделеева", "Периодическая таблица химических элементов Менделеева"*
	"Система Менделеева", "Периодическая система Менделеева", *"Периодическая система элементов Менделеева"*, *"Периодическая система химических элементов Менделеева"*
	"Периодическая система", "Периодическая таблица" (without "Менделеева"–no eponym)
	"Менделеев", *"отец периодической таблицы", "отец периодической системы"*
Belarusian	"*Табліца Мендзялеева*", "*Перыядычная табліца Мендзялеева*", "*Перыядычная табліца элементаў Мендзялеева*", "*Перыядычная табліца хімічных элементаў Мендзялеева*"
	"*Сістэма Мендзялеева*", "*Перыядычная сістэма Мендзялеева*", "*Перыядычная сістэма элементаў Мендзялеева*", "*Перыядычная сістэма хімічных элементаў Мендзялеева*"
	"*Перыядычная табліца*", "*Перыядычная сістэма*" (without "*Мендзялеева*"–no eponym)
	"*Мендзялееў*", "*бацька перыядычнай табліцы*", "*бацька перыядычнай сістэмы*"
Ukrainian	"*Таблиця Менделєєва*", "*Періодична таблиця Менделєєва*", *Періодична таблиця елементів Менделєєва*", "*Періодична таблиця хімічних елементів Менделєєва*"
	"Система Менделєєва", "Періодична система Менделєєва", *"Періодична система елементів Менделєєва", "Періодична система хімічних елементів Менделєєва"*
	"Періодична таблиця", "Періодична система" (without *"Менделєєва"*–no eponym)
	"Менделєєв", "батько періодичної таблиці", "*батько періодичної системи"*
Latvian	"Mendeļejeva tabula", "Mendeļejeva periodiskā tabula", "Mendeļejeva elementu periodiskā tabula", "Mendeļejeva *ķīmisko* elementu periodiskā tabula"
	"Mendeļejeva sistēma", "Mendeļejeva periodiskā sistēma", "Mendeļejeva elementu periodiskā sistēma", "Mendeļejeva *ķīmisko* elementu periodiskā sistēma"
	"Periodiskā tabula", "Periodiskā sistēma" (without "Mendeļejeva"–no eponym)
	"Mendeļejevs", "periodiskās tabulas tēvs", " periodiskās sistēmas tēvs"
Polish[c]	"Tablica Mendelejewa", "Tablica okresowa Mendelejewa", "Tablica okresowa pierwiastków Mendelejewa", "Tablica okresowa pierwiastków chemicznych Mendelejewa"
	"Układ Mendelejewa", "Układ okresowy Mendelejewa", "Układ okresowy pierwiastków Mendelejewa", "Układ okresowy pierwiastków chemicznych Mendelejewa"
	"Tablica okresowa", "Układ okresowy" (without "Mendelejewa"–no eponym)
	"Mendelejew", "ojciec tablicy okresowej", "ojciec układu okresowego"

Note: [a]The author agrees with Jana et al. (2013) that eponymous terms should be used in non-possessive form. However, because both forms occur, the queries with apostrophe ("Mendeleev's") were also included in Google Search for English.

https://doi.org/10.33225/BalticSTE/2023.246

[b]Google Search with and without Mendeleev's initials (D. I.) was done for Russian, Belarusian, Polish, and Ukrainian but not English and Latvian, which is explained by difference in word order in these languages.

[c]Synonyms "tablica" and "tabela" were included in Google Search for Polish.

Research Results

Chemistry Textbook Findings

Of the preliminary found 1642 chemical eponyms, the following 11 related to Mendeleev:

1. Mendeleev periodic table
   [of the chemical elements].
2. Mendeleev periodic system
   [of the chemical elements].
3. Mendeleev [periodic] law.
4. Mendelevium, a chemical element.
5. Mendeleev weighing method.
6. Mendeleev hydration theory.
7. Mendeleev pycnometer.
8. Mendeleev scales.
9. Mendeleev altimeter (differential barometer).
10. Mendeleevian lute.
11. Mendeleev-Clapeyron equation.

The new search added 12. "Mendeleev-Geissler (Geißler) pycnometer" and 13. "Mendeleev the father of the periodic table" to the list.

The findings obtained from looking through Soviet and current Russian chemistry textbooks are shown in Table 2.

Table 2
Mendeleev Eponyms in Soviet and Current Russian Chemistry Textbooks

Year the textbook was published	Eponymous terms present	Portrait	Biogra-phy	Competitors mentioned
Kablukov, 1924	Mendeleev table[a] of the elements, Mendeleev periodic system of the elements	—	—	Meyer
Pavlov & Se-menchenko, 1934	Mendeleev system	—	—	Döbereiner triads, Newlands octaves, Tomsen periodic system of the chemical elements
Verkhovsky, 1940	Mendeleev table, Mendeleev system, Mendeleev periodic system of the elements, Mendeleev law	⅙ page	—	Moseley
Levchenko et al., 1953	Mendeleev table, Mende-leev periodic system of the elements, Mendeleev law, Mendeleev periodic law	½ page	2 pages	—
Khodakov et al., 1960	Mendeleev periodic system	full-page	2 pages	—
Khodakov et al., 1979	Mendeleev periodic law, Mendeleev periodic system of the chemical elements	full-page	1½ page	—
Rudzitis & Feld-man, 2016[b]	Mendeleev periodic law, Mendeleev periodic table, Mendeleev periodic table of the chemical elements	—	½ page	Döbereiner triads, Newlands octaves, Chancourtois, Odling

Note: [a]The eponyms (translated from Russian) are shown in non-possessive form as advised in (Jana et al., 2013).

[b]As the latest edition of this textbook was published in 2022, this table spans almost one century (1924-2022).

As follows from the table, eponymous terms "Mendeleev [periodic] table [of the chemical elements]" and "Mendeleev [periodic] system [of the chemical elements]" (the optional terms are indicated in brackets) have been present in Soviet and current Russian's textbooks for decades.

Mendeleev's portrait first appeared in the textbooks shortly before WW2. In the next 13 years its size increased thrice, and in the next 7 years it did twice: from ⅙ page bust view in 1934 to full-page full-length in 1960. Triple enlargement of the portrait coincided with the appearance of Mendeleev's biography and the disappearance of his scientific competitors from the textbooks in 1953.

One more found self-invented Mendeleev eponymous term is "the Mendeleev of biology." Aronova (2021, p.65) used it to characterize academician N. I. Vavilov, an outstanding Soviet agronomist and geneticist. The contemporaries wrote about Vavilov's

https://doi.org/10.33225/BalticSTE/2023.246

discovery, “the remarkable repeatability and periodicity [of plant forms] are opening the possibility to predict the existence of not-yet-known forms, just as the periodic table of Mendeleev allowed [chemists] to predict the existence of unknown elements” (Esakov, 1981, as cited in Aronova, 2021, p.68).

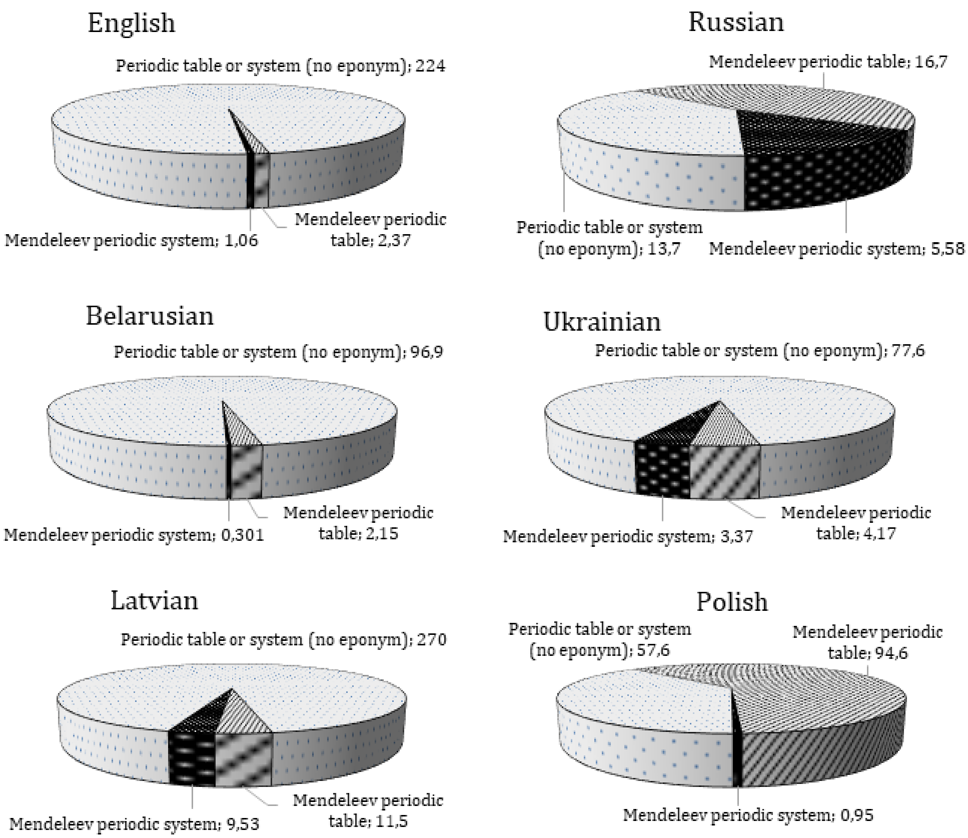
Advanced Google Search

The search revealed that Mendeleev eponyms exist in significant amounts. There are toponyms: astionym *Mendeleevsk* (a town), komonym *Mendeleevo* (a village), metro station *Mendeleevskaya* (in Moscow), ergonym–airport named after Mendeleev, some odonyms. All those objects are found in Russia. Further toponyms include *Mendeleev glaciers* (in Kyrgyzstan and Antarctica), oceanonym *Mendeleev ridge* (on the Arctic Sea bottom), oronyms *Mendeleeva volcano* and *Mendeleev crater* (on the Moon) also known as *Catena Mendeleev*, cosmonym *2769 Mendeleev asteroid*, etc. Machinonyms are represented by the Airbus A321 *Dmitri Mendeleev* (Aeroflot, Russian Airlines) and research ship with the same name. Furthermore, there are university, institute, academy, college, library, oil refinery, Russian Chemical Society named after *Mendeleev*, scholarly journal *Mendeleev Communications*, and a few conferences titled *Mendeleevian Readings* held in Russia, Ukraine, and Belarus.

The search confirmed that major Mendeleev eponymous terms occur unevenly in various languages, which Figure 1 illustrates.

Figure 1

Presence of Mendeleev Eponymous Terms on the Webpages in the Six Languages



Note: The figure shows the numbers of webpages per 10000 language speakers.

As follows from the figure, “Mendeleev periodic table” and “Mendeleev periodic system” prevail only on webpages in Russian and Polish languages, whereas webpages in Belarusian, English, Latvian, and Ukrainian prefer non-eponymous “Periodic table” and “Periodic system”.

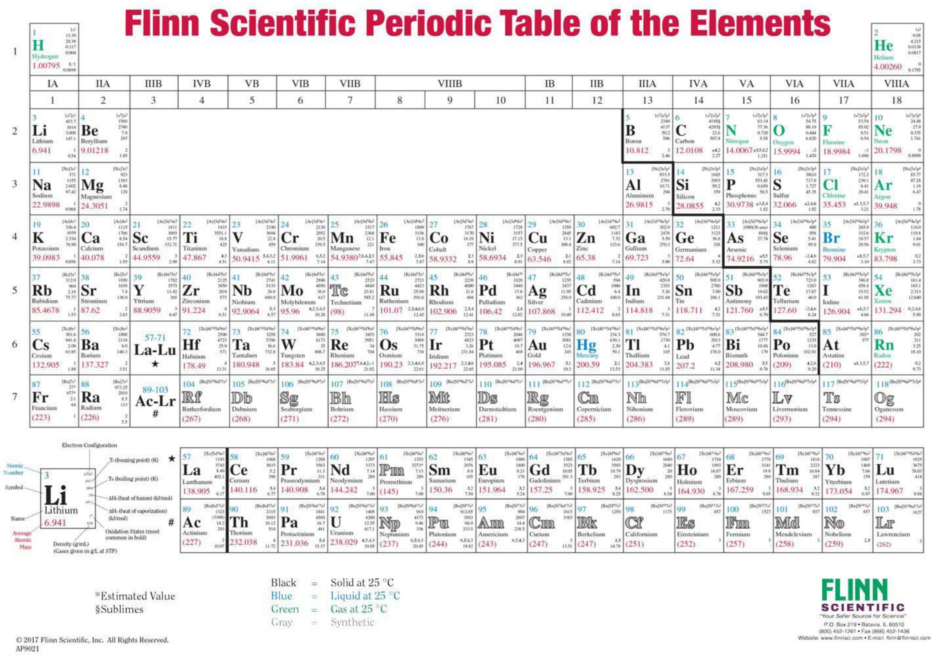
Vice versa, Mendeleev as “the father of the periodic system” occurs predominantly on English pages: English (30.0 webpages per 1 million language speakers) > Latvian (4.00) > Ukrainian (2.95) > Polish (1.26) > Russian (0.941) > Belarusian (0.143).

Plagiarized Periodic Tables

Lagerkvist (2012) describes Mendeleev’s nomination for Nobel Prize, “Today it goes without saying that the periodic law is perhaps the most decisive progress ever made in theoretical chemistry” (p. 112). If Mendeleev’s priority in discovery of the periodic law and building the periodic table has been established and recognized, then the found Flinn Scientific Periodic Table of the Elements (Figure 2) and the Ross Periodic Table

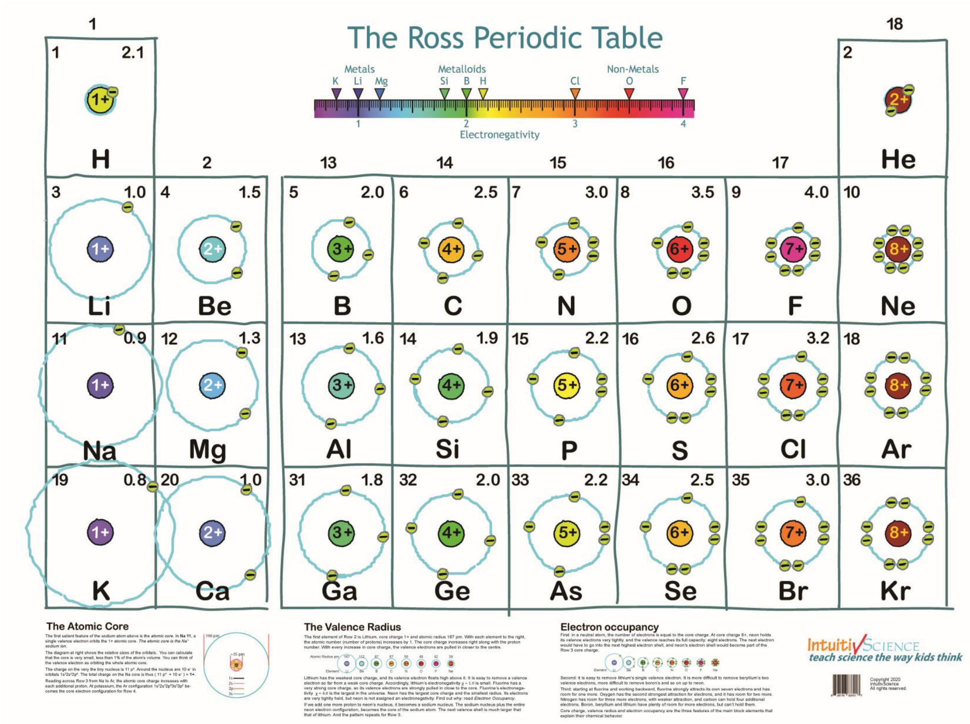
(Figure 3) can be considered a plagiarism. Both tables are produced by Flinn Scientific, they can be ordered on the company's website. Teachers, instructors, and students of U.S. schools, colleges and universities work with these tables, they can be found in classrooms, auditoriums, and laboratories as a visual aid and a handout.

Figure 2
Flinn Periodic Table



Note: From https://www.flinnsci.com/products/chemistry/charts--posters/flinn-periodic-table-charts (May 2023, Flinn Scientific). The company offers other items (mugs, magnets, etc.) labelled "Flinn periodic table."

Figure 3
Ross Periodic Table



Note: From https://www.flinnsci.com/ross-periodic-table/ap11075 (May 2023, Flinn Scientific).

Discussion

The state of Mendeleev eponymous terms resembles that of Verkhovsky (Slabin, 2017c): most of them are either forgotten by now or used predominantly in Russian texts, authored and promoted by Russian chemists (chemistry educators). It is true for both famous eponyms “Mendeleev periodic system” and “Mendeleev periodic table” and less famous. The latter seldom occurs on non-Russian webpages; e.g., Google results for Mendeleev pycnometer show Russian/English webpage ratio 6290:62, for Mendeleev-Clapeyron equation 32500:68 (without “per capita” adjustment). One reason for it can be natural falling out of date; it seems to have happened with the Mendeleevian lute, for which Google returns merely 84 results in original Russian, not to mention other languages. Another reason is common ethnocentrism (Russian in this case), the human tendency to view own group (nation) as centrally important and, in some respect, superior. Eponym “Mendeleev the father of the periodic system” is an exception: such an expression is quite typical in English but sounds not so usual in Russian and the five other languages.

Changing presence of Mendeleev eponyms in chemistry textbooks reminds that over 154 years since the discovery of the periodic law, ethnocentric influence in the case of Mendeleev has not always been consistent. “Many colleagues in Russia had criticized Mendeleev for being inclined to unsupported speculations" (Lagerkvist, 2012, p. 112). His colleagues had never elected him to the Russian Academy of Sciences and, expectedly, never nominated for Nobel Prize (foreign colleagues did it thrice but unsuccessfully). It might have taken time for Russian chemists of the first half of the 20th century to realize the paramount importance of Mendeleev's discovery, to feel their fault of underestimate the scholar and the compatriot, and to do their best to compensate the loss. This is why chemistry textbooks of 1924 and 1934 mention, along with Mendeleev periodic table, his foreign competitors, and include neither his biography nor portrait. In the textbook of 1940, Mendeleev's portrait appears, in the 1953 his biography adds, and in 1960, the portrait reaches full page. Also, in this evolution, Mendeleev's scientific competitors disappear from the textbooks. In the textbook of 2016, Mendeleev's portrait is missing, his biography is reduced down to half a page and, unlike in previous decades, reads more scientific than personal. Mendeleev's competitors in the textbook are back again, as in 1934. It can mean that by now Russian authors have got rid of the guilt, and ethnocentrism is no longer urgent.

The history of Flinn and Ross periodic tables is shorter and, perhaps, less interesting (Slabin, 2019a). Lawrence Flinn is an American entrepreneur, whose firm is a leading supplier of equipment and visual aids for auditoriums and laboratories in the USA. According to a Texas teacher on the firm's website (www.flinnsci.com), "Flinn alone has done more for safety in the science classrooms of America than legislators and educators combined." What relation, however, does Flinn have to the discovery of the periodic law? It probably doesn't matter. The important thing is that Flinn designed the table with this layout. There is a copyright sign (©) in the lower left corner of his table.

How was it possible? Well, eponyms "Mendeleev periodic system" and "Mendeleev periodic table" are neither registered anywhere as a trademark nor universally accepted. In US chemistry textbooks, the periodic system is presented without the Mendeleev's name. For these reasons, American chemists, teachers, students are neither indignant nor surprised by Flinn and Ross's periodic tables (Ross is a designer). The firm smartly calls its product a periodic table, not a periodic system: Flinn does not claim to be the author of the system (scientific concept), he only offers his own design. The trick hides in ambiguity: "Flinn Scientific Periodic Table of the Elements" can be understood both as "manufactured by Flinn Scientific, a firm" and "scientific table invented by Lawrence Flinn, a person."

If those periodic tables were given the name of an American chemist (say, Pauling), it could be attributed to ethnocentrism. However, it is unlikely that Flinn Scientific marketers were influenced that way. Rather, they were just driven by business strategies. Taking advantage of the market situation, playing on the intricacies of the language and patent law, the firm presented to the American teaching community an interesting new/old visual product.

Mendeleev eponymous terms and their ethnocentrism-influenced history are valuable for science education because they humanize it. Uncovering the history of just one eponym—Mendeleev periodic table of the chemical elements—figuratively invites to classroom a company of committed, intellectual, inquisitive people: Meyer, Döbereiner, Newlands, Moseley, Rutherford, and many others. Educational principles of humanization and historicism get effectively implemented. Another valuable impact of Mendeleev eponymous terms is actualized, by the good will of teachers, interdisciplinary connections. Studying the periodic law, chemistry teacher can switch from Mendeleev table to the town of Mendeleevsk and show it on the map (chemistry ⇆ Mendeleev ⇆ geography). Likewise, a language teacher can use *odonym* Mendeleevslaya street as a starting point to Mendeleev himself and then talk for a minute about the periodic law (language ⇆ Mendeleev ⇆ chemistry). Training their students on the Mendeleev periodic system, a chemistry teacher can mention Mendeleev pycnometer and say some words about the property of substances to expand at higher temperatures, the reason pycnometer works (chemistry ⇆ Mendeleev ⇆ physics). Eponymous expression "the Mendeleev of biology" (Aronova, 2021) is complex and requires decent knowledge for understanding but it establishes a strong and essential connection: Mendeleev ⇆ chemistry ⇆ biology ⇆ Vavilov.

Conclusions

As a result of this research, new Mendeleev eponymous terms have been found. Their popularity in print and online sources has been evaluated with the perusal of chemistry textbooks and advanced Google Search. Today, usage of Mendeleev eponyms in English texts is decreasing; some become naturally obsolete because the material objects they signify get out of date, others deserve more attention. The popularity of Mendeleev eponymous terms in the original Russian scholarly environment may be due to ethnocentrism, which has been changing over 154 years since the discovery of the periodic law and can be traced and analyzed by chemistry textbooks. With respect to their potential for implementation of principles of humanization and historicism as well as for making interdisciplinary connections, Mendeleev eponymous terms should be kept and creatively applied in chemistry classrooms.

References

Aronova, E. A. (2021). *Scientific history: Experiments in history and politics from the Bolshevik revolution to the end of the Cold War.* University of Chicago Press. https://doi.org/10.7208/chicago/9780226761411.001.0001

Jana, N., Barik, S., & Arora, N. (2009). Current use of medical eponyms – a need for global uniformity in scientific publications. *BMC Medical Research Methodology*, *9*, Article 18. https://doi.org/10.1186/1471-2288-9-18

Kablukov, I. A. (1924). *Osnovnye nachala neorganicheskoy himii* [Basic principles of inorganic chemistry] (8th ed.). Gosizdat.

Khodakov, Yu. V., Cvetkov, L. A., Shapovalenko, S. G., & Epshtein, D. A. (1960). *Himija* [Chemistry] (S. G. Shapovalenko, Ed.). Textbook for VIII-IX grades of secondary school (6th ed.). Uchpedgiz.

Khodakov, Yu. V., Epstein, D. A., & Gloriozov, P. A. (1979). *Himija* [Chemistry]. Textbook for 7-8 grades (11th ed.). Prosveshchenie. http://fremus.narod.ru/java/h01/him7879.html

Lagerkvist, U. (2012). *The Periodic Table and a Missed Nobel Prize* (E. Norrby, Ed.). World Scientific. https://doi.org/10.1142/9789814295963_0003

Levchenko, V. V., Ivantsova, M. A., Solovjov, N. G., & Feldt, V. V. (1953). *Himija* [Chemistry] (S. A. Balezin, Ed.). Textbook for VIII-IX grades of secondary school (6th ed). Uchpedgiz.

Merton, R. K. (1957). Priorities in scientific discovery: A chapter in the sociology of science. *American Sociological Review*, *22*(6), 635–659. https://doi.org/10.2307/2089193

Pavlov, B. P., & Semenchenko, V. K. (1934). *Uchebnik himii* [Chemistry textbook] (S. A. Balezin, Ed.). (6th rev. ed.). Goskhimtekhizdat. http://fremus.narod.ru/java/h02/him7b34.html

Rudzitis, G. J., & Feldman, F. G. (2016). *Himija* [Chemistry]. Textbook for institutions of general education (4th ed.). Prosveshchenie. https://archive.org/details/Uchebnik-himiya-8-klass-Rudzitis/page/n1/mode/2up

Slabin, U. K. (1992). Galstuk V. K. Slabina [U. K. Slabin's necktie] (Patent No. RU1777785C). Rospatent. https://elibrary.ru/item.asp?id=40833540

Slabin, U. K. (1995). Prablemy asimiliatsyi prozvishchau zamiezhnyh vuchonyh-himikau u bielaruskai movie [Problems of transcription of foreign chemists' names in Belarusian language]. In *Prablemy bielaruskai navukovai terminalohii* (pp. 225-233). Minsk: Tavarystva Bielaruskai Movy.

Slabin, U. (2007). Science education as problematic area in modern education. *Journal of Baltic Science Education*, *6*(3), 4. http://oaji.net/articles/2014/987-1404288398.pdf

Slabin, U. (2017a). Chemical eponyms as recognized and perceived by Belarusian and American students. In *Euro-American Scientific Cooperation* (Vol. 15, pp. 51–57). Accent Graphics Communication.

Slabin, U. (2017b). Scientific eponym in educational universe. *Journal of Baltic Science Education*, *16*(2), 144–147. https://doi.org/10.33225/jbse/17.16.144

Slabin, U. (2017c). Verkhovsky eponyms in the epoch of educational ethnocentrism. In V. Lamanauskas (Ed.), *Science and technology education: Engaging the new generation. Proceedings of the 2nd International Baltic Symposium on Science and Technology Education (BalticSTE2017)* (pp. 122-124). Scientia Socialis Press. https://doi.org/10.33225/BalticSTE/2017.122

Slabin, U. K. (2019a). Amerikanskiy biznesmen protiv rossiyskogo uchionogo [American entrepreneur vs. Russian scholar]. *Khimiya v Shkole*, 2, 66–69. https://elibrary.ru/item.asp?id=37351127

Slabin, U. K. (2019b). Knowledge and perception of eponyms in chemistry by university students in Belarus and the United States. *The Education and Science Journal*, *21*(7), 113-142. https://doi.org/10.17853/1994-5639-2019-7-113-142

Slabin, U., & Krasitski, V. (2017). For humanization and historicism: How well university students know and what they think about chemical eponyms. *Journal of Baltic Science Education*, *16*(2), 250–265. https://doi.org/10.33225/jbse/17.16.250

Stigler, S. M. (1980). Stigler's Law of Eponymy. *Transactions of the New York Academy of Sciences*, 39(1 Series II), 147–157. https://doi.org/10.1111/j.2164-0947.1980.tb02775.x

USSR Supreme Council. (1991, May 31). Law N2213-1 "On inventions in the USSR." http://www.consultant.ru/document/cons_doc_LAW_18406/44e0e082aca4e12ad88f706f84d5732c6263bcb6

Verkhovsky, V. N. (1940). *Neorganicheskaya khimiya* [Inorganic chemistry]. Part II. Textbook for 8-10 grades (8th ed.). Uchpedgiz.

World Health Organization. (2013). *WHO Style Guide* (2nd ed.). https://www.unaids.org/sites/default/files/sg13_web_v4 pdf - adobe reader.pdf

Received: *April 15, 2023* Accepted: *May 15, 2023*

Cite as: Slabin, U. (2023). Mendeleev eponyms in the epoch of educational ethnocentrism. In V. Lamanauskas (Ed.), *Science and technology education: New developments and innovations. Proceedings of the 5th International Baltic Symposium on Science and Technology Education (BalticSTE2023)* (pp. 246-258). Scientia Socialis Press. https://doi.org/10.33225/BalticSTE/2023.246

KEYNOTE SPEAKERS

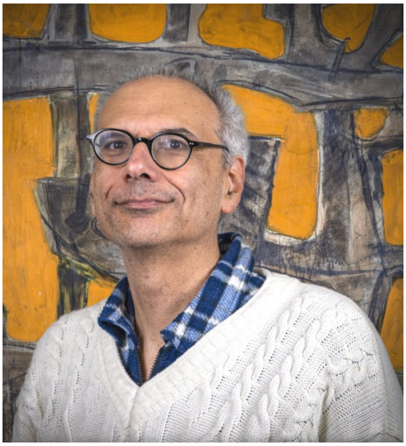
Prof. Dr. **Andris Broks**
University of Latvia, Latvia

Title: HUMAN, LIFE, UNIVERSE: HUMAN'S LIFE WITHIN THE UNIVERSE

Dr. Andris Broks is a Professor Emeritus at the Faculty of Physics, Mathematics and Optometry, University of Latvia in Riga. He completed his PhD in the field of solid state physics and he currently works in the field of physics education and teaches across a wide range of general education topics. His principal research interests today are: systems thinking and systemic approach in physics education, the philosophical and psychological basis of Science education. He has been working on Education Law of Latvia as well as participated in education innovation projects at the national and international level. From 2002 he serves as a Deputy Editor-in-Chief of the Journal of Baltic Science Education and is a member of the Editorial Board of the journal „Problems of Education in the 21st Century“.

Website: https://www.researchgate.net/profile/Andris-Broks
ORCID: https://orcid.org/0009-0007-9196-2801

Assoc. Prof. Dr. **Paolo Bussotti**
University of Udine, Italy



Title: INTRODUCING THE CONCEPT OF ENERGY: EDUCATIONAL AND CONCEPTUAL CONSIDERATIONS

Dr Bussotti graduated with first-class honours in History of Science and Technology from the Faculty of Humanities (degree course in History) of University of **Pisa** on 25th November, 1991. In July 1996 he received a Ph.D. in Historical Sciences at the University of **San Marino**, with a thesis on the foundations of mathematics, wherein he analysed four authors in particular, namely **Bolzano**, **Cantor**, **Frege** and **Husserl**. In 2005 he was appointed with a Humboldt fellowship at the LMU, Munich.
Currently, Dr. Paolo Bussotti is Assistant Professor in History of Science and Technology, at the DIUM.

Website: https://dium.uniud.it/en/dium/persone/docenti-e-ricercatori/paolo-bussotti/
ORCID: https://orcid.org/0000-0002-7883-8618

MSc. **Ilva Cinite**
University of Latvia, Latvia

MSc. Ilva Cinite works at the University of Latvia. Currently, both a lecturer and teaching assistant for several general physics courses, putting into practice elements of the student-centred approach to physics at university. Has many years of experience in physics education and always enjoys new challenges based on research in education and human brain studies of how students learn.

Title: STUDENT-CENTERED EDUCATION IMPLEMENTATION IN UNDERGRADUATE PHYSICS COURSES OF NATURAL SCIENCES AT THE UNIVERSITY OF LATVIA: SUCCESSES AND CHALLENGES

Website: https://www.facebook.com/ilva.cinite/
ORCID: https://orcid.org/0000-0001-6684-1943

Prof. Dr. **Ching-Ching Cheng**
National Chiayi University, Taiwan

Title: IMPLEMENTING A NATIONAL DATABASE ON YOUNG CHILDREN'S LEARNING: A LONGITUDINAL STUDY TO EVALUATE THE QUALITY OF PRESCHOOLS

Dr. Ching-Ching Cheng is a Professor and Department Head at National Chiayi University in Taiwan. Her main professional interests are curriculum in early childhood education, preschool teacher education and professional development, application of digital technology in the professional development of teachers.

Website: https://www.researchgate.net/profile/Ching-Ching-Cheng-2
ORCID: https://orcid.org/0000-0002-1090-771X

Prof. Dr. **Gabriel Gorghiu**
Valahia University Targoviste, Romania

Title: PROMOTING SCIENCE ACTIONS IN NOWADAYS EDUCATION: AN IMPORTANT ISSUE RELATED TO OPEN SCHOOLING

Dr. Gabriel Gorghiu graduated from the Polytechnic University of Bucharest, Faculty of Engineering and Management of Technological Systems, and the Valahia University of Targoviste, Faculty of Sciences and Arts, specialization: Mathematics-Informatics. He has two Master's Degrees: in Project Management and Mathematics-Didactics. He is Professor at Teacher Training Department, Valahia University Targoviste. The area of interest is oriented on: educational technologies - e-learning, interaction, and virtual communication, web-based learning platforms, using ICT for educational purposes.
He is the author/co-author of over 30 books and book chapters, and over 300 scientific papers in scientific journals indexed in Web of Science / international databases, proceedings of national and international conferences, in the areas of ICT in education, Science education, Modelling and Simulation.

Website: https://www.researchgate.net/profile/Gabriel-Gorghiu
ORCID: https://orcid.org/0000-0002-4026-345X

Prof. Dr. **Jari Lavonen**
University of Helsinki, Finland

Title: LEARNING SCIENCE THROUGH PROJECT-BASED LEARNING: US-FINNISH PARTNERSHIPS FOR INTERNATIONAL RESEARCH AND EDUCATION (PIRE)

Dr. Jari Lavonen is a *Professor of Physics and Chemistry Education* at the University of Helsinki, Finland. He is a director of National Teacher Education Forum and the chair of the Finnish Matriculation Examination Board. He is a visiting professor at the University of Johannesburg. He has been researching science and technology education and teacher education for the last 31 years and his main research interests are science and technology teaching and learning, curriculum development, teacher education and use of ICT in education. He has published altogether 170 refereed scientific papers in journals and books, 140 other articles and 160 books for either science teacher education or for science education. He has been active in international consulting, for example, involving the renewal of teacher education for example in Norway, Peru and South Africa.

Website: https://researchportal.helsinki.fi/en/persons/jari-lavonen
ORCID: https://orcid.org/0000-0003-2781-7953

Assoc. Prof. Dr. **Predrag Pale**
University of Zagreb, Croatia

Title: WHICH TEACHERS NEED TO BE REPLACED BY AI

Predrag Pale earned his dipl. ing. (B.Sc.), mr. sc. (M.S.) and dr.sc. (PhD) degrees from Zagreb University, Faculty of Electrical Engineering and Computing.
His current scientific interest and activity are in the fields of ICT in education, user and man-machine interfaces and ICT security.
He is a consultant and designer, educator and lecturer in the fields of information systems and education.
He is one of the main architects of Croatian Academic and Research Network – CARNet at the beginning of the nineties as well as the first national broadband computer network, based on ATM technology at the speeds of 155 and 622 Mbps via optical cables, which connected 12 cities in 1996. He is the co-founder of Central and Eastern European Networking Association – CEENet, the regional association of national academic and research networking organizations.

Website: https://www.researchgate.net/profile/Predrag-Pale
ORCID: https://orcid.org/0000-0003-2171-7302

Assoc. Prof. Dr. **Tiia Rüütmann**
Tallinn University of Technology, Estonia

Title: ENGINEERING PEDAGOGY AND TEACHERS' COMPETENCIES FOR EFFECTIVE TEACHING STE

Tiia Rüütmann is Associate Professor and Head of Estonian Centre for Engineering Pedagogy at the Department of Mechanical and Industrial Engineering, School of Engineering, Tallinn University of Technology (TalTech), Estonia. She graduated TalTech as Diploma Engineer in the field of Chemical Engineering and Cybernetics in 1982, and received her second MSc in chemical engineering at TalTech in 1992. She defended her PhD in education (with specialization in Engineering Pedagogy) at University of Hradec Králové, Czech Republic in 2007.
She has written several book chapters and published a Handbook on Engineering Pedagogy Science and STEM didactics in 2019.

Website: https://taltech.ee/en/contacts/tiia-ruutmann
ORCID: https://orcid.org/0000-0001-8944-0149

Baltic STE

5th INTERNATIONAL BALTIC SYMPOSIUM ON SCIENCE AND TECHNOLOGY EDUCATION

https://balticste.com

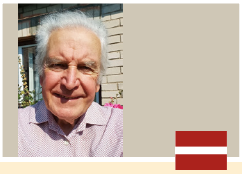
SCIENCE AND TECHNOLOGY EDUCATION:
NEW DEVELOPMENTS AND INNOVATIONS

12-15 June 2023, Siauliai, Lithuania

KEYNOTE SPEAKERS

"IMPLEMENTING A NATIONAL DATABASE ON YOUNG CHILDREN'S LEARNING: A LONGITUDINAL STUDY TO EVALUATE THE QUALITY OF PRESCHOOLS"

Prof. dr. Ching-Ching Cheng
National Chiayi University, Taiwan



"HUMAN, LIFE, UNIVERSE: HUMAN'S LIFE WITHIN THE UNIVERSE"

Prof. dr. Andris Broks
University of Latvia, Latvia

"PROMOTING SCIENCE ACTIONS IN NOWADAYS EDUCATION: AN IMPORTANT ISSUE RELATED TO OPEN SCHOOLING"

Prof. dr. Gabriel Gorghiu
Valahia University Targoviste, Romania

"STUDENT-CENTERED EDUCATION IMPLEMENTATION IN UNDERGRADUATE PHYSICS COURSES OF NATURAL SCIENCES AT THE UNIVERSITY OF LATVIA: SUCCESSES AND CHALLENGES"

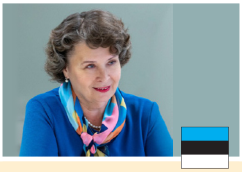
Mg. phys. Ilva Cinite
University of Latvia, Latvia

"LEARNING SCIENCE THROUGH PROJECT-BASED LEARNING: US-FINNISH PARTNERSHIPS FOR INTERNATIONAL RESEARCH AND EDUCATION (PIRE)"

Prof. dr. Jari Lavonen
University of Helsinki, Finland

Topic"INTRODUCING THE CONCEPT OF ENERGY: EDUCATIONAL AND CONCEPTUAL CONSIDERATIONS"

Assoc. prof. dr. Paolo Bussotti
University of Udine, Italy



"ENGINEERING PEDAGOGY AND TEACHERS' COMPETENCIES FOR EFFECTIVE TEACHING STE"

Assoc. prof. dr. Tiia Rüütmann
Tallinn University of Technology, Estonia

"WHICH TEACHERS NEED TO BE REPLACED BY AI"

Assoc. prof. dr. Predrag Pale
University of Zagreb, Croatia

Symposium Website:
http://balticste.com/
Contact Info
E-mail: balticste@gmail.com
Phone: +370 687 95668
Scientia Socialis, Ltd.

Symposium Organizers:

Symposium Partners:
Šiauliai County Povilas Višinskis Public Library
ŠIAULIŲ TECHNOLOGIJŲ MOKYMO CENTRAS
žaliasis PASAULIS

GAMTAMOKSLINIS UGDYMAS
NATURAL SCIENCE EDUCATION

ISSN 1648-939X /Print/, ISSN 2669-1140 /Online/

Dear colleagues,

GAMTAMOKSLINIS UGDYMAS / NATURAL SCIENCE EDUCATION – is a periodical, peer reviewed, scientific-methodical journal, issued by the SMC „Scientia Educologica“ in cooperation with Scientia Socialis Ltd. It is an international journal, wherein the scientific and methodical/applied articles published in Lithuanian and English languages. This journal is intended for the teachers of general education schools, the lecturers of higher educational institutions and all, who are interested in the problems of natural science education.

The GU/NSE journal welcomes the submission of manuscripts that meet the general criteria of scientific and methodical (practical/applied) papers.

GAMTAMOKSLINIS UGDYMAS / NATURAL SCIENCE EDUCATION
ISSN 1648-939X /Print/, ISSN 2669-1140 /Online/

http://gu.puslapiai.lt/gu/
http://gu.puslapiai.lt/gu/jr-online_article_submission/
http://oaji.net/journal-detail.html?number=514

Fast Publication
Peer Reviewed
Open Access

This journal is abstracted / listed / indexed / cited in: COPERNICUS INDEX , LIST OF SCIENCE EDUCATION JOURNALS, JOURNALS OF INTEREST TO CHEMICAL EDUCATORS, SKYLIGHT, OAJI, WebQualis (QUALIS/CAPES), MIAR, EuroPub, QOAM, ESJI, Crossref, DOI, Internet Archive.

Applied research/practical/methodical work. This type of submission is best suited for practical/didactical work and reports, as well as position papers raising original and provocative theoretical or practical discourses and questions (small-scale research, applied research, didactical/methodical papers, case studies, best educational practices etc.). Each submission is carefully reviewed by two independent reviewers and ranked based on: quality of preparation, relevance to the educational community, didactical quality, originality, and importance of the contribution.

Instruction for authors and other details are available on the journal`s website at:

http://gu.puslapiai.lt/gu/aut-info/

GU/NSE is an Open Access journal accessible for free on the Internet. Papers must be submitted on the understanding that they have not been published elsewhere and are not currently under consideration by another publisher. Optimal paper`s size: 8/12 pages. Partial article processing charges are: 5-8 EUR per one A4 page.

For contacts, questions and papers submission: gu@gu.puslapiai.lt

Sincerely yours, Editorial Board

6th INTERNATIONAL BALTIC SYMPOSIUM ON SCIENCE AND TECHNOLOGY EDUCATION (BalticSTE2025)

„SCIENCE AND TECHNOLOGY EDUCATION: EXPECTATIONS AND EXPERIENCES“

Dear Colleagues,

On behalf of the organizing committee, we are delighted to welcome you to Šiauliai, Lithuania, for the V International Baltic Symposium on Science and Technology Education, BalticSTE 2025. The Symposium will be held in **Šiauliai (Lithuania)** in **June 2025** during days **16-19**.
We cordially encourage you to attend and contribute to one of the major events of 2025 on the field of science and technology education. We are confident that you will appreciate the scientific program and the city of Šiauliai. We look forward to seeing you in **2025** in Lithuania.

Website: https://www.balticste.com/

E-mail: balticste@gmail.com

Kind regards,
Symposium committee

Šiauliai, Lithuania

Lamanauskas, V. (Ed.) (2021). *Science and technology education: Developing a global perspective. Proceedings of the 5th International Baltic Symposium on Science and Technology Education (BalticSTE2023)*. Scientia Socialis Press.
ISBN 978-609-96384-0-9 /Print/, ISBN 978-609-96384-1-6 /Online/

Compiler	Vincentas Lamanauskas
Designer & Paste-up artist	Loreta Šimutytė-Balčiūnienė
English language proofreader	Ilona Ratkevičienė

12 June 2023. Publishing in Quires 16,625. Edition 90.

Publisher Scientia Socialis, Ltd.
29 K. Donelaičio Street,
LT-78115 Šiauliai, Lithuania
E-mail: scientia@scientiasocialis.lt
Website: http://www.scientiasocialis.lt/

Printing Joint-stock company „Šiaulių spaustuvė“
9A P. Lukšio Street
LT-76207 Šiauliai, Lithuania
Phone: +370 41 500 333.
Fax: +370 41 500 336
E-mail: info@dailu.lt

ISBN 978-609-96384-0-9 /Print/,
ISBN 978-609-96384-1-6 /Online/

ISBN 609-96384-0-7
ISBN 978-609-96384-0-9 (Print)
ISBN 978-609-96384-1-6 (Online)