THE DURABILITY OF FORMAL KNOWLEDGE AND ITS RESTRUCTURING DURING LIFELONG LEARNING

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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.

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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

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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.

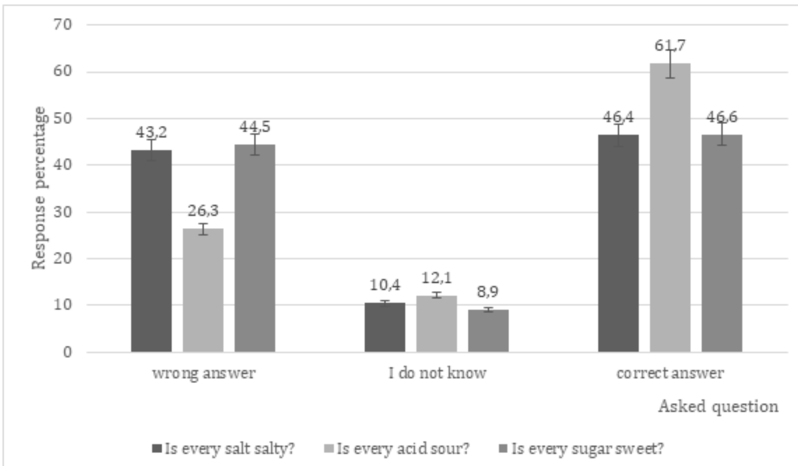
Research Results

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 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.

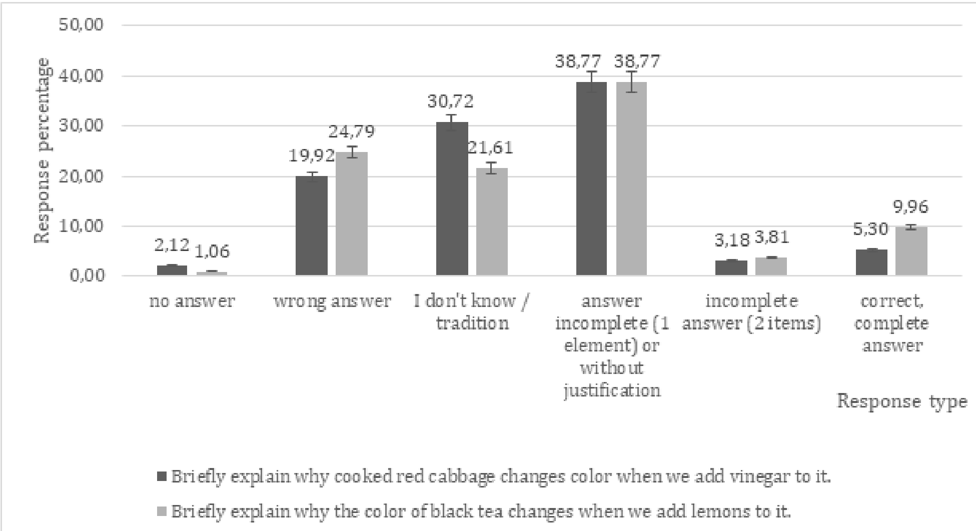
The study compared the knowledge of information on the indicator known to primary school students from formal education (red cabbage) with the knowledge of information on the indicator known from everyday life (tea). The null hypothesis assumed no differences between the answers to the questions regarding 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).

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

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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.

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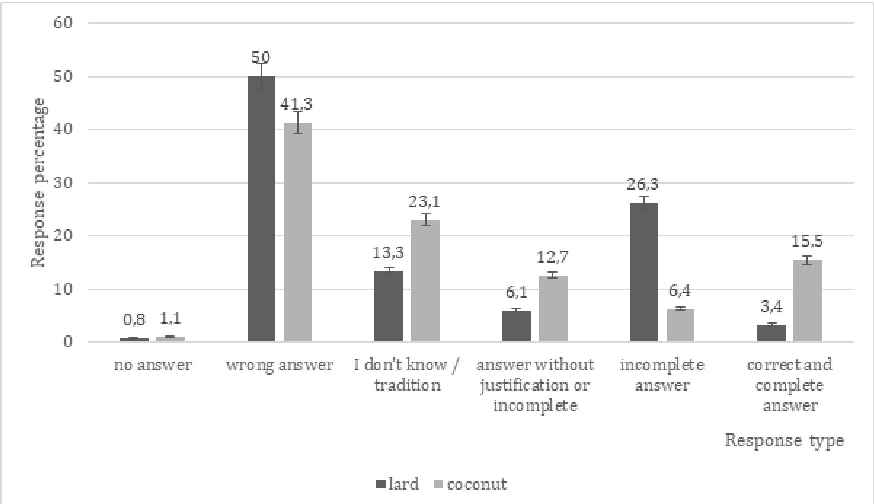
Open responses are broken down into six categories (Figure 3):

- 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

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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.

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