JOURNAL OF BALTIC SCIENCE EDUCATION

ISSN 1648-3898 /Print/
ISSN 2538-7138 /Online/

THE RELEVANCE OF LEARNING OUTCOMES INCLUDED IN ESTONIAN GRADE 7-9 SCIENCE SUBJECT CURRICULA ASSOCIATED WITH THE CONCEPT OF ENERGY

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Abstract. *This study on the Estonian lower secondary (7-9th grade) science curricula, is seen as an important framework for educators preparing students as tomorrow's citizens able to reflect on sustainable energy development. As the curriculum is taken to be the major document allowing insights into Estonian educational standards, this study identifies components within the intended lower secondary science curricula for subjects of biology, chemistry, earth science, physics, and interdisciplinary science. Using document analysis, verbs associated with career-related learning outcomes are detected, allowing the relatedness of the energy conceptualizations and determination of their cognitive level utilizing SOLO (Structure of Observed Learning Outcomes) taxonomy. A team of coders identify a total of 782 learning outcomes across three learning domains: psychomotor (176), affective (32), cognitive (574) at unistructural (33), multistructural (225), relational (276), and extended abstract (40) levels. The majority of energy concept learning outcomes (274) are identified in the source (form) and transfer (transform) categories. Very few career-related learning outcomes are detected with the science education relevance dimensions (individual, societal, career). The suitability of the findings is discussed. The current analyzing method can be applied to other educational disciplines for raising awareness of disciplinary crosscutting concepts.*

Keywords: *energy concept, learning outcomes, relevance in science education, lower secondary science curriculum, SOLO taxonomy*

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Introduction

Energy is a key concept in science education and in our everyday life. At the same time, current everyday energy production is also affecting our everyday life and one of the biggest challenges facing society today is the need for a paradigmatic shift in climate policy (Hall, 2007; Kinley, 2017; Meckling & Allan, 2020; Nepras et al., 2023; United Nations, 2015). According to the European Green Deal (European Commission, 2019), the goal is to enable no net greenhouse gas (mainly CO_2) emissions throughout the European Union by 2050, in order to stop further global warming (European Commission, 2019). In recent years, carbon footprint is considered as a main metric indicator in greenhouse gas emissions (Kanemoto et al., 2016; Schwenkenbecher, 2014; Yue, 2020). Main carbon footprint increasers are fossil fuels, which are currently used in energy production and transportation (Shea et al., 2016). In order to reduce governmental carbon footprint, Estonia's biggest challenge is definitely replacing oil shale electricity production with alternative energy sources (Kama, 2016; Holmgren et al., 2019). In this respect, the Estonian Education Strategy for 2021-2035 (EMER, 2020) indicates that steps are needed to be taken to achieve climate neutrality, by raising awareness related to the state of the environment, sustainable development, and enhancing an energy-efficient infrastructure.

Based on the above, Ocetkiewicz et al. (2017) have raised a concern whether energy conceptualizing and sustainability are sufficiently promoted in education. Multiple authors have indicated that educators need to raise students' awareness of future sustainability concerns on planet Earth (Bilgen & Sarıkaya, 2018; Klein & Coffey, 2016; Murray, 2012; Rieckmann, 2018; Sidiropoulos, 2014; van Ruijven et al., 2019). Given the objectives of the energy sector for the next thirty years (Skea et al., 2011; European Commission, 2019), a key challenge in the field of education is to develop educated workers conceptualizing energy and especially energy transfer and energy transformation in line with labor market expectations (Kandpal & Broman, 2014).

https://doi.org/10.33225/jbse/23.22.653

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

The main framework used by educational institutions for orienting students' learning is the curriculum (McFarlane & Ogazon, 2011). The intended curriculum parameters – referred to as learning outcomes are usually written related to three different domains: cognitive, affective, and psychomotor (Sönmez, 2017). And within the curriculum, the science education provision (in the various science sub-divisions) focuses on energy transfer (Eisenkraft et al., 2014; Fortus et al., 2015; Guven & Cakir, 2019; Next Generation Science Standards, 2012; Park, 2019). Suryana et al. (2019) indicate that students tend to lack cognitive knowledge of the energy learning process. Nevertheless, studies show that teaching related to the concept of energy is problematic (Ben-Zvi e al., 1993; Driver et al., 2014; Herrmann-Abell & DeBoer, 2018; Mamlok-Naaman & Mandler, 2020), both within and across science education subjects, even though issues associated with energy need to be meaningfully developed for preparing future well-educated citizens (Hodson, 2011; Matus & Talburt, 2015; Yacoubian, 2015).

Relevance is one of the key terms in science education and making science education teaching and learning processes and future science-related career relevant needs to be a key goal (Stuckey et al., 2013; Kim & Dionne, 2014; Lamanauskas, 2022) in the development of scientific literacy, seen as going beyond the acquisition of cognitive learning and relating to learning at both societal (linking science to the concerns within the society) and the acquisition of personal attributes such as problem solving and decision making (Holbrook & Rannikmäe, 2009). Thus, in order to determine whether the current provision for energy studies is appropriate in preparing students for future changes in energy developments, there is a need to determine whether (the intended curriculum) meets the expectations for the next generations in terms of relevance and the acquisition of scientific literacy for a future sustainable society.

Literature review

School Science Curriculum and Science Education Relevance

Nowotny et al. (2018) have expected schools to play an important role in preparing a future sustainable society through their curriculum provision. However, for achieving curriculum expectations for a future sustainable society, Østergaard (2017) has pointed out that learning science needs to be mainly based on relevance for everyday life and built on societal situations to enable students' awareness to be promoted through in science education. In fact, Eilks and Hofstein (2014), and Keller et al. (2017) saw sustainability and science education expectations to be strongly characterized through a focus on relevance aspects. Stuckey et al. (2013) have divided relevance within science education into three dimensions:

- Individual dimension – phenomena which support students' interest and curiosity - with necessary information and skills for coping with their everyday life and in the future.
- Societal dimension – focusing interaction between science and society, while promoting a personal contribution to sustainable development and being a responsible citizen.
- Career dimension – preparing for further science-related academic education, or vocational training, and hence preparation for possible science-related careers.

Studies by Akitsu et al. (2017), Halilovic et al. (2021), Hoque et al. (2022), Lay et al. (2013), and Wojuola and Alant (2019) have indicated a gap between science experienced in everyday life and the portrayal of the science education curriculum. For example, Akitsu et al. (2017) have predicted a low awareness between energy-related sustainability relevance dimensions and cognitive knowledge of the concept of energy. A relevance indication study by Murphy et al. (2006) has shown the impact of students' engagement increased in physics lessons if relevance was added to the learning context. Furthermore, Eilks and Hofstein (2015), and Keller et al. (2017) have pointed out that in order to increase the relevance of the curriculum in the 21st century teaching and learning process, it is not just learning the theories and facts in science education that are important, but also the need to relate this to the society and career aspects.

The Energy Concept in Science Education

In science education, energy is usually defined through a dualistic approach:

(i) As a *core concept* – mainly seen as the quantity defined in a system (Duit, 2014), which integrates all science disciplines and which occurs in the literature in several terminological variations, for example:

a) big/core idea (Next Generation Science Standards, 2012; Opitz et al., 2015);

https://doi.org/10.33225/jbse/23.22.653

b) core concept (Aguiar et al., 2018; Park, 2019; Neumann et al., 2013);
c) crosscutting concept (Crissman et al., 2014; Jin & Anderson, 2012; Fortus et al., 2015; Krajcik et al., 2014; Next Generation Science Standards, 2012);
d) concept (Duit, 1984, 2014; Bächtold, 2018; Herrmann-Abell & DeBoer, 2018; Kesidou & Duit, 1993; Lancor, 2014; Liu & McKeough, 2005; Nordine et al., 2010; Solbes et al., 2009; Yao et al., 2017).

(ii) As a *literacy* expectation – This seems to identify energy as an entity of nature and the role of energy as a function of the universe and our lives (DeWaters & Powers, 2013; Martins et al., 2020; USDE, 2017). The Energy Literacy Framework (USDE, 2017), actively seeks to promote connections across subject disciplines, dividing energy as:
- A physical quantity that follows precise natural laws;
- Physical processes on Earth stemming as the result of energy flow through the Earth as a system;
- Biological processes depending on energy flow through the Earth as a system;
- Various sources which can be used to power human activities, often this energy being transferred from source to destination;
- Governed by decisions which are influenced by economic, political, environmental and social factors;
- That required by human society to function depending on many factors;
- Feeding the quality of life of individuals and societies affected by their choices.

Although there is no universal definition of energy in science education, four main characteristics can be identified through which the determination of the teaching and learning content within science education can be determined (Nordine et al., 2010; Herrmann-Abell & DeBoer, 2018; USDE, 2017). These characteristics specify energy as: (i) a source-form, (ii) transferable or undergoing transformation, (iii) degradable or capable of dissipation, and (iv) being conservable.

Research has shown that students have problems understanding the energy concept (Ben-Zvi et al., 1993; Driver et al., 2014; Herrmann-Abell & DeBoer, 2018; Mamlok-Naaman & Mandler, 2020). Furthermore, Cooper and Klymkovsky (2013), and Dreyfus et al. (2012) indicate that the fragmentation of the energy concept between science subjects leads to the possibility that students obtain an incomplete understanding of the energy concept as a whole. Furthermore, Barrow and Morrisey (1989), DeWaters and Powers (2013), and Suryana et al. (2019) have indicated that students tend to lack cognitive knowledge of the learning process, which needs to be overcome to promote energy concept.

Structure of Learning Outcomes

Since the turn of the millennium, schools have sought to change the intended curriculum parameters to outcome-based learning (Kennedy, 2006). The intended learning outcomes tend to be written in three different domains: cognitive, affective, and psychomotor (Sönmez, 2017). The cognitive domain is related to thinking (Bloom et al., 1956; Anderson & Krathwohl, 2001; Biggs & Collis, 2014), the psychomotor to hands-on activity (Simpson, 1972) while the affective domain relates to emotions (Klopfer, 1976).

Brooks et al. (2014) and Stalne et al. (2016) have indicated that a learning outcome (LO) is a statement that describes the learning that a student is expected to achieve, while other researchers see LOs as expressing the key learning through the gaining of knowledge, skills, or attitudes (Biggs & Tang, 2011; Elmas et al., 2020; Kennedy, 2006; Popenici & Millar, 2015). According to Elmas et al. (2020), the more detailed the curriculum-stated LOs are, the easier it is to implement, assess and evaluate, plus determine its impact on educational progress.

In stating a LO, the two main components are seen as: (i) a verb and (ii) a noun. While the verb refers to what a student is expected to be able to do (for example *name*, *give examples*) and the noun relates to that expected to be attained (for example – *renewable and non-renewable natural resources*) (Adelman, 2015; Anderson & Krathwohl, 2001; Biggs & Tang, 2014; Krathwohl, 2002).

Researchers have proposed various taxonomies in order to achieve educational goals as expressed through LOs, the two most commonly used for designing curriculum LOs being (i) Bloom et al. (1956) – Taxonomy of Educational Objectives (TEO) and its revision by Anderson and Krathwohl (2001) named as Revision of Bloom's taxonomy (RBT), and (ii) Biggs and Collis (1982) – SOLO (*Structure of observed learning outcome*) taxonomy (Chan et al., 2002; Whalley et al., 2006; Weay et al., 2016).

According to Stanny (2016) the first two RBT levels (*remember* and *understand*) are considered as lower-level

https://doi.org/10.33225/jbse/23.22.653

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

with higher cognitive domain levels as *apply, analyze, evaluate, and create*. On the other hand, Chan et al. (2002) classify *unistructural* and *multistructural* levels, in the SOLO taxonomy, as cognitively lower levels and *relational* and *extended abstract* as cognitively higher levels.

In promoting SOLO, Biggs and Tang (2011) have stated that neither TEO, nor RBT are based on the research of students' learning, but rather on the opinions of educational leaders, and that the taxonomies are not actually hierarchical. The SOLO taxonomy is based on two main theories: constructivism (Piaget, 1954) and phenomenography (Marton, 1981) and the Estonian school teaching approach and the student-centered learning process are based on constructivism (NCBC, 2014), it is seen as appropriate to base further analysis of the NCBCSS (Estonian National Curriculum for Basic School, Natural Science Syllabus) on the SOLO taxonomy.

The Estonian Science Curriculum

The Estonian national curriculum for compulsory school (1-9th grade) is described as competence-based and explicitly states as one objective the need to promote scientific literacy (Soobard et al., 2015). This compulsory component consists of a general part plus through appendices establishes various subject curricula and descriptions of cross-curricular topics (NCBC, 2014). One compulsory learning area at the 7-9th grade level is stated as science, although actually this comprising of five sub-divisions, or subjects: (i) biology; (ii) chemistry; (iii) earth science, (iv) physics, and as a pre-course for future chemistry and physics studies (v) interdisciplinary science (NCBC, 2014).

The weekly number of lessons for compulsory science subjects differ in the 7th grade, the number of science lessons consists of – 1 biology, 1 earth science, and 2 interdisciplinary science lessons, while in the 8th and 9th grade, it is 2 biology, 2 chemistry, 2 earth science, and 2 physics lessons. One lesson at the Estonian basic school level usually lasts 45 minutes (NCBC, 2014).

The science 7-9th grade curricula (NCBCSS, 2014), specify: (i) general principles (e.g., competencies to be achieved through science learning and options for implementing cross-curricular topics), and (ii) the physical learning environment with the stated aim of enhancing scientific and technological literacy by putting forward: (a) learning and educational objectives for each of the 7-9th grade of studies, and (b) a list of topics to be taught for each of the five subjects together with specified learning outcomes.

Within this frame, each subject sub-division identifies: (i) the learning content, (ii) keywords/concepts, (iii) recommended practical work and Information and Communication Technology (ICT) inclusions, plus (iv) intended learning outcomes.

For example, renewable energy within the topic of Estonian Natural Resources in the Earth Science curriculum:
Content:

- "renewable and non-renewable natural resources; natural resources as sources of energy; Estonian minerals, mining and use";
- Keywords/concepts:
- *"renewable and non-renewable natural resources, underground mining, energy"*;
- Practical work and use of ICT:
- *"compiling an overview of the use of natural resources in the student's home area"*;
- Learning outcomes:
- *"name the renewable and non-renewable natural resources in Estonia and give examples of their use; give examples of ways of producing and using renewable energy in your home area"*(NCBCSS, 2014).

Research Questions

To determine the relevance of learning outcomes put forward in the various Estonian science curricula, the following research questions are asked:

1) To what extent does the Estonian 7-9th grade science curriculum encompass learning outcomes covering the three learning domains – cognitive, affective and psychomotor?

2) Based on the cognitive process dimension – how are the energy learning outcomes conceptualized and developed within the various subject provisions in the Estonian 7-9th grade science curriculum?

3) To what extent does the Estonian 7-9th grade science curriculum encompass learning outcomes covering the three science education relevance dimensions – individual, societal, career?

https://doi.org/10.33225/jbse/23.22.653

Research Methodology

Document Analysis Method

The document analysis was undertaken by a research group consisting of 2 Tartu University educational science PhD students (1st and 4th year) and one PhD degree lecturer from Tartu University Chemistry Institute (more than 10 years of higher education teaching experience). Document analysis methods are used for studying and analyzing the printed or electronic papers that a researcher has gathered on a certain subject (Bowen, 2009).

Procedure

This study was conducted based on an analysis of the current Estonian 7-9th grade science curriculum electronic document, focusing on the identification of (i) learning outcomes lists and (ii) practical work and use of ICT lists (which are meant to be achieved by students in the learning process) associated with the three domains of learning, namely cognitive, affective, and psychomotor. Using SOLO taxonomy, a list of learning outcomes and practical work and use of ICT (LO) within the cognitive domain for the 7-9th grade science curricula document (in action since 2014 in Estonia) were identified in subjects: chemistry (C), physics (P), biology (B), earth science (ES), interdisciplinary science (IS). In addition, energy concept components (E_1 = a source-form, E_2 = transferable or undergoing transformation, E_3 = degradable or capable of dissipation, E_4 = being conservable) identification based on 3 sources: (i) Herrmann-Abell and DeBoer (2018), (ii) DeWaters and Powers (2013) – a framework for energy literacy, (iii) US Energy Literacy Framework (2017), were taken into account. Also, science education relevance dimensions (R_1 = individual dimension, R_2 = societal dimension, R_3 = career dimension) based on Stuckey et al. (2013) paper, were taken into account for identifying LO relevance relatedness.

The analysis was undertaken, based on the procedure by Näsström (2009), Wei and Ou (2019), and Yaz and Kurnaz (2020) on the Estonian 7-9th grade science curriculum LOs stated in the Estonian national curriculum for basic schools.

Procedure Steps

First, the domain of learning outcomes based on verbal expression was determined. This was undertaken by identifying the verbal expression in LO for example:

"*Associate forms of life with different groups of organisms"* (the cognitive domain – associate).

Based on Hoque (2016), the cognitive domain primarily involves learning abilities which are related to mental or thinking processes.

"Make wet preparations and use a light microscope to study them" (the psychomotor domain – make, use). Based on Hoque (2016), the psychomotor domain targets distinct physical functions, automatic responses, and interpretive motions.

"Value scientific methods when drawing trustworthy conclusions" (the affective domain – value). Based on Hoque (2016), the affective domain is related to our feelings, emotions, and beliefs).

For curriculum cognitive learning outcomes, the analysis used SOLO taxonomy, which classified learning outcomes in terms of their structural quality, which according to (Biggs and Tang, 2011) makes them useful for defining the levels of understanding. Similar to Soobard and Rannikmäe (2015), this study did not utilize the first SOLO taxonomy level, since the research did not assess the item responses.

In order to classify verbs according to the cognitive domain, the noun of within the LO sentence was taken into account identified:

"*Associate forms of life with different groups of organisms"* (associate – the SOLO level 3 – relational).

If several verbs appeared in one noun expression, both verbs were included in the analysis of the LO:

"Compile and analyze schemes of the source material of photosynthesis" – compile, analyze.

If more than one noun expression was related to the verb, this was still taken as a one verb LO:

"Analyze the dependence of the structure of the organs of flowering plants on their tasks, location of growth and the means of reproduction and distribution" – analyze.

https://doi.org/10.33225/jbse/23.22.653

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Analysis

The following six steps were used to perform the analysis: (i) First, the verb(s) in the LO statement were determined; (ii) The placement of the verb in the learning domain was determined; (iii) When LO verb belonged to a cognitive domain, the SOLO taxonomy level was determined; (iv) LO statement relevance dimension was determined; (v) LO statement was compared with energy concept categories; (vi) If LO was related with energy, the association with four energy concept components was determined, and (vii) in order to check the reliability and validity of the coding process the entire 7-9th grade science curriculum was examined first three times within 2-months intervals.

Validity

The validity of the study was established by consulting with the former official Estonian 7-9th grade science curriculum developmental manager who confirmed the theoretical framework of Estonian 7-9th grade science curriculum LO alignment with this study and other 3 educational experts.

Reliability

To check reliability, active science teachers were used as the outside coders (one in each discipline: chemistry, physics, biology, earth science, interdisciplinary science). The results between the coders were similar. The outside coder results were not considered as agreement if at least one dissonance appeared between any of four coding categories: a) learning domain, b) SOLO taxonomy level, c) energy concept component, and d) relevance domain. Coder inter-rater agreement percentages reliability was determined with a summative value .88 (interdisciplinary science = .75, biology = .86, earth science = .89, physics = .93, and chemistry = .95).

Research Results

An analysis of the current Estonian national 7-9th grade science curriculum identified, in total, 782 LOs. The learning outcomes related to the cognitive domain (73.4%), followed by the psychomotor (22.5%) and the affective domains (4.1%). The distribution of LOs within three learning domains is presented in Table 1.

Table 1
The NCBCSS Learning Outcome Overall and the Energy Concept Learning Outcome Distribution, Based on the Three Domains of Learning

Learning Domain	Science Curriculum LO Distribution						Energy Concept LOs					
	IS_1	B_2	ES_3	P_4	C_5	T_6	IS_1	B_2	ES_3	P_4	C_5	T_6
Cognitive	32	158	137	142	105	574	13	26	47	95	27	208
Psychomotor	35	12	41	39	49	176	20	1	7	18	16	62
Affective	2	23	5	-	2	32	-	-	3	-	1	4
Number of LOs per Subject	69	193	183	181	156	782	33	27	57	113	44	274
Number of Lessons in 7-9th Grade	70	175	175	140	140							
Average LOs per One Lesson	1.0	1.1	1.0	1.3	1.1							

Note. IS_1 = interdisciplinary science; B_2 = biology; ES_3 = earth science; P_4 = physics; C_5 = chemistry; T_6 = total

As shown in Table 1, the greatest number, and the percentage of cognitive domain LOs were stated in the subject biology (158; 81.9%), while the largest number of LOs per lesson appeared in physics (1.3). The current analyzing method did not identify any affective domain LO for physics.

With the exception of interdisciplinary science, all other science subjects (biology, earth science, physics, and chemistry) had more than 67% of stated LOs in the cognitive domain.

From the entire 782 LOs within the NCBCSS, the analysis revealed:

https://doi.org/10.33225/jbse/23.22.653

- 274 (35.0%) related to the energy concept LOs (Table 1), which were divided between the three learning domains,
- Similar to the analysis of the entire curriculum, LOs related to energy concepts, for all subjects except interdisciplinary science, appeared mostly in the cognitive domain,
- For interdisciplinary science, more than half of the LOs were categorized in the psychomotor domain,
- As it appeared in the general analysis of LOs, biology had the largest number of energy concept LOs in the affective domain,
- The comparison with the total curriculum LO and the energy concept LOs showed the highest percentage of energy concept LOs in interdisciplinary science.

Table 2
The NCBCSS Subject Cognitive Domain LO Distribution Based on the SOLO Taxonomy Levels

SOLO taxonomy level	Cognitive LO Distribution						Energy Concept LOs					
	IS_1	B_2	ES_3	P_4	C_5	T_6	IS_1	B_2	ES_3	P_4	C_5	T_6
Unistructural	3	1	8	14	7	33	-	-	5	7	1	13
Multistructural	10	43	55	82	35	225	3	1	21	56	11	92
Relational	11	107	63	38	57	276	7	24	14	26	11	82
Extended Abstract	8	7	11	8	6	40	3	1	7	6	4	21
Number of Subject LOs	32	158	137	142	105	574	13	26	47	95	27	208

Note. IS_1 = interdisciplinary science; B_2 = biology; ES_3 = earth science; P_4 = physics; C_5 = chemistry; T_6 = total

Table 2 shows that out of 574 cognitive domain LOs, the majority (87.3%) of the LOs were identified at the multi-structural and relational SOLO taxonomy levels. On the lower unistructural level, 33 LOs were identified while on the extended abstract level, 40 LOs were identified. Furthermore, for the first two SOLO taxonomy levels (unistructural and multi-structural – taken as lower cognitive process levels), table 2 reveals the following proportion of the entire curriculum - 258 LOs (44.9%) and at the higher levels – relational and the extended abstract – 316 LOs (55.1%). The current LO analyzing method was able to determine only one LOs in biology at the unistructural level in the NCBCSS.

The study indicated 208 (39%) energy concept LOs (see Table 2) out of a total of 534 cognitive LOs. The majority of the energy concept LOs appeared in physics (95; 45.7%), followed by earth science, chemistry, biology and interdisciplinary science. This study was not able to detect any SOLO taxonomy unistructural level energy concept LOs within interdisciplinary science and biology. The largest number of SOLO taxonomy extended abstract level energy concept, cognitive LOs appeared, compared with other subjects, in earth science (7).

Table 3
The NCBCSS Energy Concept Learning Outcome Distribution Based on the Four Energy Categories

Science Subject	Four Energy Categories														
	E_1	E_2	E_3	E_4	$E_{1,2}$	$E_{1,3}$	$E_{1,4}$	$E_{2,3}$	$E_{2,4}$	$E_{3,4}$	$E_{1,2,3}$	$E_{1,2,4}$	$E_{1,3,4}$	$E_{2,3,4}$	$E_{1,2,3,4}$
Interdisciplinary Science	4	16	1	10	2	-	-	-	-	-	-	-	-	-	-
Biology	-	22	-	-	-	-	-	2	-	-	-	-	-	3	-
Earth Science	12	24	4	3	4	-	-	1	1	2	-	-	-	-	6
Physics	10	51	3	-	15	-	-	10	-	-	9	-	3	1	11
Chemistry	7	10	1	1	11	-	-	3	2	1	-	6	-	-	2
Total	33	123	9	14	32	-	-	16	3	3	9	6	3	4	19

Note. E_1=Energy source/form; E_2=Energy transfer/transformation; E_3=Energy degradation/dissipation, E_4=Energy conservation

https://doi.org/10.33225/jbse/23.22.653

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Table 3 shows the NCBCSS energy concept learning distribution, based on the four energy categories: (i) energy source/form, (ii) energy transfer/transformation, (iii) energy degradation/dissipation, and (iv) energy conservation. In total, 95 energy concept LOs (34.7%) were overlapping at least in two different energy concept categories. For example, the LO statement – *'know ways of saving energy and value sustainable use of energy'* – was categorized in both a) energy degradation/dissipation, and b) energy conservation categories.

The highest percentage of energy section LOs were identified in the energy transfer/transformation category (123; 44.9%). Table 3 further showed that energy source/form and transfer/transform categories, including their overlapping (table 3, $E_1 + E_2 + E_{1,2}$), made up 68.6% (188) of the total energy concept LO distribution.

Table 4

The NCBCSS Energy Concept Learning Outcome Distribution Based on the Three Science Education Relevance Dimensions Put Forward by Stuckey et al. (2013)

Subject	Curriculum LO relevance distribution							Energy concept LO relevance distribution						
	R_1	R_2	R_3	$R_{1,2}$	$R_{1,3}$	$R_{2,3}$	$R_{1,2,3}$	R_1	R_2	R_3	$R_{1,2}$	$R_{1,3}$	$R_{2,3}$	$R_{1,2,3}$
Interdisciplinary Science	46	1	-	13	-	-	9	15	1	-	9	-	-	8
Biology	152	30	3	6	-	2	-	24	2	-	-	1	-	-
Earth Science	123	41	4	9	-	4	2	23	23	2	6	-	2	1
Physics	166	3	1	11	-	-	-	91	12	1	9	-	-	-
Chemistry	123	16	-	3	-	6	7	24	13	-	1	-	3	3
Total	610	91	8	42	1	12	18	177	51	3	25	1	5	12

Note. R_1 = Individual dimension; R_2 = Societal dimension; R_3 = Career dimension

Table 4 gives an overview of the Estonian 7-9th grade science curriculum and energy concept LO distribution, based on science education relevance dimensions (Stuckey et al., 2013).

The table shows mainly science curriculum LO were identified in the individual dimension (R_1=610, 78.0%) although, in the same dimension, the proportion appearing in the energy concept was 177 (64.6%). Compared with the entire 7-9th grade science curriculum relevance distribution, the LOs in the societal dimension (R_2) are appearing with a higher percentage in the energy concept LO relevance distribution.

Similarly, to energy concept categories distribution, also in the science education relevance dimension appeared to have an overlapping effect between three dimensions. For example, the LO statement – *'understand the importance of natural sciences and technology in everyday life'* – was categorized in all three dimensions.

Taking into consideration a single distribution and overlapping appearing in science education career dimension (table 4, $R_3 + R_{1,3} + R_{,2,3} + R_{1,2,3}$) leads to the result for the entire science curriculum with 39 LOs (5.0%) and in the energy concept 21 LOs (7.6%). A similar calculation procedure in the societal dimension gives for the entire curriculum LOs distribution a result of 20.8% and for the energy concept LOs 33.9%.

Discussion

The purpose of this study was to determine: a) the distribution of learning outcomes (LOs) in the NCBCSS, based on three domains of learning, namely, cognitive, psychomotor, and affective domains, b) how the crosscutting energy concept is emphasized in comparison with the entire science curriculum, and c) identifying the common relevance dimension of the energy concept LOs.

Research Question 1

This research identified 782 LOs (Table 1) in the NCBCSS and LOs were distributed across 3 domains (cognitive, psychomotor and affective), which is to be expected. In general, the current Estonian 7-9th grade science curriculum is strongly biased to the cognitive domain side and the excessive proportion of cognitive domain LOs (73.4%) in the curriculum may give, according to Elmas et al. (2020), a potential focus for a teacher-centered learning ap-

https://doi.org/10.33225/jbse/23.22.653

proach. In contrast to the study by Kácovský et al. (2021), which stated that no major differences existed between subjects in the Czech, Polish, Estonian, and Slovenian science curricula, this research confirmed that major cognitive LO differences existed between different science subjects, also in the LO distribution and between the three LO domains. The difference between this study and the one by Kácovský et al. (2021) could be explained by the use of slightly different methodologies used for the analysis. However, several studies (Elmas et al., 2020; Lee et al., 2015; Wei & Ou, 2019) have found that there is no strict guidance material on how many LOs and in which learning domain they need to be stated in a science curriculum. Roblin et al. (2018) point out that from one side a detailed curriculum with a large number of LOs allows better assessment and has a higher potential to be implemented in schools. But at the same time, Nodding (2013) notes that a long and detailed list of LOs can affect teachers and students' negative promotion to be creative.

The results in Table 1 show in physics zero LOs in the affective domain. This might be possibly due to the specifics of the subject physics which emphasizes a large number of cognitive learning outcomes, which do not allow the incorporation of values in the physics teaching process (Keller et al., 2017). This is seen as a matter of concern worth further discussion, especially since Holbrook and Rannikmäe (2009) point out that values are important factors in shaping scientific literacy and the Estonian Education Strategy for 2021–2035 (EMER, 2020) indicates a need to increase learner's values through science education and has also stated the challenge for current subject-centered learning in general education, which would further support students' development for a future sustainable society.

Results in Table 1 indicate an almost 2:1 LO ratio between the cognitive and psychomotor domains in chemistry, pointing to the importance of the teacher involving students in carrying out laboratory and practical assignments, thereby supporting the cognitive domain (Seery, 2019). Nevertheless, situations can arise whereby it is less plausible to perform a given laboratory or practical activity perhaps because of teachers' beliefs (Vaino et al., 2013). In such cases, the cognitive domains LOs become more relevant, even though the diversity of teaching methods and activities are critical components for enhancing scientific literacy (Millar, 2006; Dragos & Mih, 2015). In fact, diversity can be a critical factor to take into account, since unvaried chemistry learning processes can cause a decline in student interest for the subject (Ferrell & Barbera, 2015; Vaino et al., 2013). This is seen as a matter of concern of worthy further discussion and research to determine the actual reality of chemistry lessons in the Estonian school context.

Table 2 shows an almost equal cognitive LO distribution between low- and high-level SOLO taxonomy levels within 5 science subjects. However, there are anomalies e.g. subject physics compared with chemistry and biology. Table 2 shows that the subjects, physics and chemistry have the same number of study lessons in the 8th and 9th grades. At the same time, there are more LOs in physics and the cognitive percentage of LO in physics is greater at the lower SOLO levels, while in biology only one SOLO taxonomy lower level LO. Elmas et al. (2020) have indicated that lower level LOs in the curriculum may be embedded within the higher level LOs. Westbury (2016) has stated that the unequal cognitive LO distribution between science subjects can be explained due to the curriculum development process when the specialists do not interrelate with the work of others, which can cause developing differences between variables in the curriculum. However, Biggs and Tang (2011) have pointed out the importance of LO quality, rather than quantity, since a large number of low-level LOs can be set seeking equivalence with a low number of high-level LOs and this can lead to the high average LO numbers per lesson – 1.3 (Table 1) – in the Estonian 8-9th grade physics lessons. The results from this study suggest the need to pay more attention to the distribution of LOs especially in physics, biology, and chemistry so that the cognitive demand is more evenly distributed across the subjects.

Research Question 2

35% of all LOs in the science curriculum were classified as related to the energy concept LOs (table 2). Hence this study confirms that energy is an important concept in science education. The current study showed similarities with Duit (2014) finding, which stated that more energy topics are discussed in the subject of physics. This is explained by the multiple conceptual topics covered in physics education, for example, kinetic and potential energy, heat, mechanical work, electrical energy, and power (Duit, 2014).

This study revealed that 7th-grade curriculum subject interdisciplinary science is portrayed as an important starting point for understanding energy concepts since nearly 50% of the LOs in this subject were identified as relating to the concept of energy (table 2). This result may give science teachers a possible indicator for restructuring the planned activities in the teaching process and science teachers may build a new teaching strategy through the energy concept.

https://doi.org/10.33225/jbse/23.22.653

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Studies indicated that energy fragmentation across science subjects can lead to poor conceptualization of the energy concept (Eisenkraft et al., 2014; Stubbs, 1985). This suggests curriculum designers can consider the creation of a separate subject thus avoiding energy concept fragmentation. An integrated approach to the understanding of the energy concept may also help to achieve better scientific literacy (Duit, 2014). Of course, the current process can be also undertaken by science subject teachers, since current Estonian educational legislation does not restrict schools from integrating subjects independently, if the LOs in the curricula are covered by the end of the 9th grade. Based on the results of this study, further research is needed to determine to what extent students have achieved the energy concept LOs and whether or not fragmentation between subjects limits success in understanding the energy concept.

Research Question 3

The majority of the energy concept LOs were tilted in the source/form and transfer/transform category direction (table 3). These current results need further research since studies made abroad – Ben-Zvi et al. (1993), Driver et al. (2014), Herrmann-Abell and DeBoer (2018) have shown high satisfactory results on energy source-form and transfer-transform categories. At the same time, in the previously mentioned studies dissipation-degradation and conservation categories had an increased proportion of energy concept misconceptions. It might be possible that the Estonian 7-9th grade science curriculum's overwhelming focus on one energy category can be a hindering factor for fully understanding the energy concept. Overall, in the energy production scale, energy conservation and dissipation-degradation are the main causes of global warming (Bilgen & Sarıkaya, 2018).

The lack of similar studies doesn't allow high-level argumentation about the emphasis on energy conceptualizations in science education seen as relevant at individual and social dimensions. At the same time, it is also important to indicate that without relevant conceptualizations of energy or science education in general, it is difficult to make conclusions about interactions between humans and society, and hence the place of science education (Stuckey et al., 2013).

The results from Table 4 indicate a low number of LOs in the science subjects, which do not relate well to promoting career orientations in the Estonian science curriculum, which forces the promotion of the science career process mainly to rest on Estonian science teachers' personal contribution. Similar results appeared also in research by Akitsu et al. (2017), which indicated a gap between energy education needs and curriculum possibilities. The study by Kotkas et al. (2021) in the Estonian context has already revealed both teachers and students' low experiences in the science career field, although a deeper analysis with the NCBCSS was not made. This topic needs also to be considered by curriculum designers since Orthner et al. (2013) and Shin et al. (2015) have shown through their research a positive effect on students' values of science-related professions if career-related topics are addressed in science lessons.

Conclusion and Implications

The current study indicated that in the Estonian 7-9th grade science curriculum LOs are stated in all three learning domains (cognitive, psychomotor, and affective) but mainly identified in the cognitive domain. Nevertheless, learning domain distribution between the different science subjects is seen as uneven and no affective domain LOs are given in the physics curriculum for grades 8-9th.

Within the Estonian 7-9th grade science curriculum cognitive LOs process dimension there is an almost equal distribution between low- and high-level cognitive learning outcomes. The majority of LOs in the entire 7-9th grade science curriculum and also in energy concepts relate to SOLO taxonomy at multistructural and relational levels.

The energy concept transfer and transform category dominance among four energy categories in the Estonian 7-9th grade science curriculum can give science teachers a first indicator of how to start solving energy concept fragmentation between different science subjects. The results showed that in the Estonian 7-9th grade science curriculum LOs distribution appeared a lack in dealing with important aspects of the energy concept (such as energy conservation and dissipation/degradation) and LOs in the science subjects do not relate well to promoting careers in the science field.

The above-stated conclusions can be the base for raising awareness, opening discussions in applicable countries where 7-9th grade science education is taught as a separate discipline. This analysis of the Estonian lower secondary (7-9th grade) science curriculum, has extended our knowledge of the importance of crosscutting concepts in the curriculum, so as to establish a constant focus in the teaching/learning process in science education relevance perspective. Moreover, the value of the method used for energy concept analysis in the current study can be applied internationally to other educational disciplines for curriculum development.

https://doi.org/10.33225/jbse/23.22.653

Limitations

One of the current study limitations is the lack of an analysis of the 1-6th science curriculum, which may impact LOs for 7-9th grade study. Also, a limitation is the verb-centered approach to identify LOs, which can affect the results and with that in mind, the list of nouns defined in this study with one single verb, which can underestimate the extent of the learning outcome content, and at the same time, overestimate the LO statement quality, when two or more verbs appear in one learning outcome statement. Also, in the Estonian 7-9th grade science curriculum, there can be unclassified energy concept LOs, which are not explicitly linked to the energy concept LOs, e.g., gravitational forces addressed as pressure.

Declaration of Interest

The authors declare no competing interest.

Acknowledgements

This research is supported by a) the European Union Horizon 2020 (L 347 - 2013-12-11) programme 'Addressing Attractiveness of Science Career Awareness' (ID: 952470), b) European Union Regional Development Fund through the Estonian Dora Plus Sub-Activity 1.1 Short-term mobility scholarship.

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Received: *May 21, 2023* Revised: *July 01, 2023* Accepted: *July 15, 2023*

Cite as: Kõlamets, L., Kasuk, H., Holbrook, J., & Mamlok-Naaman, R. (2023). The relevance of learning outcomes included in Estonian grade 7-9 science subject curricula associated with the concept of energy. *Journal of Baltic Science Education*, *22*(4), 653-667. https://doi.org/10.33225/jbse/23.22.653

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