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Designing, Implementing and Evaluating Teaching and Learning Modules for Promoting Decision-making Towards STEM Careers

UNIVERSITY OF TARTU
Press

Science Education Centre, Institute of Ecology and Earth Sciences, Faculty of Science and Technology, University of Tartu, Estonia

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LIST OF ABBREVIATIONS

AG	Additional group of students
CAA	Career aspirations and awareness
CG	Control group
EG	Experimental group
EVT	Expectancy-value theory
IRE	Interest, relevance, enjoyment
ISCO-08	International Standard Classification of Occupations 2008
SCA	STEM career awareness
SCCT	Social-cognitive career theory
SDT	Self-determination theory
STEM	Science, technology, engineering, and mathematics
TLM	Teaching and learning module

LIST OF ORIGINAL PUBLICATIONS

The current thesis is based on the following publications, which are referenced in the text by Roman numbers.

I **Kotkas, Tormi**; Holbrook, Jack & Rannikmäe, Miia. (2016). Identifying Characteristics of Science Teaching/Learning Materials Promoting Students' Intrinsic Relevance. *Science Education International*, 27 (2), 194–216.

II **Kotkas, Tormi**; Holbrook, Jack & Rannikmäe, Miia. (2017). A Theory-based Instrument to Evaluate Motivational Triggers Perceived by Students in STEM career-related scenarios. *Journal of Baltic Science Education*, 16 (6), 836–854.

III **Kotkas, Tormi**; Holbrook, Jack & Rannikmäe, Miia. (2019). The Impact of Longitudinal STEM Careers Introducing Intervention on Students' Career Aspirations and on Relating Occupational Images. *EduLearn19 Proceedings*, 1678–1686.

IV **Kotkas, Tormi**; Holbrook, Jack & Rannikmäe, Miia. (2021). Exploring Students' Science-related Career Awareness Changes through Concept Maps. *Education Sciences*, 11(4), 157.

V Soobard, Regina; **Kotkas, Tormi**; Holbrook, Jack & Rannikmäe, Miia. (2020). Students' Perceptions of an Intervention Course Designed to Raise Science-Related Career Awareness. *European Journal of Educational Research*, 9(4), 1539–1555.

The author has contributed to articles I–IV by designing the studies, formulating research questions, developing research instruments, collecting, and analysing data, writing the articles as the first author in co-operation with other authors. In V article, contribution is through participating in instrument development, developing instructional materials for the first module, collecting data, and participating in the article writing.

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1. INTRODUCTION

The current study addresses the problem of students, especially girls, not aspiring to a career in STEM (science, technology, engineering, and mathematics) fields (Organisation for Economic Co-operation and Development [OECD]; 2016, 2019). According to the European Commission (2015), this is alarming due to an overall aging trend among STEM professionals—45.4% of human resources in science and technology are at a senior age (45–65 years old) among European Union countries (Statistical Office of the European Communities, last visited in January 2021). Furthermore, it is problematic that a minority of girls are pursuing STEM careers, which is one of the reasons for a gender imbalance within such STEM fields, as information and communication technology (ICT), engineering and medicine, in a range of countries including Estonia (Dorph et al., 2018; Kukk et al., 2017; Van Griethuijsen et al., 2015). STEM professionals play an important role in helping societies cope with various issues, such as reducing the use of fossil fuels by implementing renewable energy sources and tackling growing human population impact on natural habitats. Therefore, it is important to seek ways to address the problems which are directing school students away from a consideration of a future STEM career path.

Students' lack of STEM career aspirations has been linked with poor pedagogical practices, which are unable to make science and mathematics studies at school relevant and interesting (Krapp & Prenzel, 2011; Osborne & Dillon, 2008; Potvin & Hasni, 2014; Sjøberg & Schreiner, 2010). In addition, several studies have indicated that students have low awareness about the range of STEM careers (Blotnicky et al., 2018; Franz-Odendaal et al., 2016; Salonen et al., 2017; Salonen et al., 2019a). A lack of STEM career awareness among students has been linked to lack of attention paid to raising career awareness in science lessons (Soobard & Rannikmäe, 2014; Vaino et al., 2015). This thesis addresses the problem of students not aspiring to a career in STEM fields by:

a) motivating students to learn science at school and
b) supporting students in developing an awareness of STEM careers.

There have been several European Union (EU) funded research projects such as PARSEL (Rannikmäe et al., 2010), PROFILES (n.d.) and ESTABLISH (n.d.), which have addressed the lack of relevance and interest through developing inquiry-based science teaching and learning modules (TLM) for teachers to use in Estonian schools. These have often included a scenario to present a socio-scientific issue as an initial context (Rannikmäe, 2001; Teppo & Rannikmäe, 2003), but there has been little research on how the TLM developers address relevance in scenarios—the initiating step for following learning activities within the frames of a TLM. Furthermore, there is little research on how relevant, interesting, enjoyable, and motivating students consider the developed TLMs. This raises the need for investigating and evaluating motivational triggers using a theoretically justified instrument, to determine interest, relevance, and enjoyment, perceived by students, when interacting with scenarios and TLMs.

Several commonly used motivation theories in science education research like self-determination theory (Deci & Ryan, 2000), expectancy-value theory (Wigfield & Eccles, 2000), social-cognitive career theory (Lent et al., 1994) include interest, relevance or value and enjoyment as characteristics of a motivated state. Thus, to support motivation to learn science and mathematics, there is a need for teaching and learning module developers to understand the psychological constructs such as interest, relevance, enjoyment (IRE) and how best to support students perceiving IRE in the school science context.

In the context of the current thesis, motivation to learn science and mathematics is important due to its implications on measures undertaken to encourage students to pursue STEM careers. More specifically, a lack of motivational triggers impacts on students' efforts to learn science and mathematics, which in turn, affects students' achievements in science and mathematics (Lent & Brown, 2019). Not succeeding in science and mathematics negatively affects students' ability beliefs, which in turn, impacts on their setting of goals and pursuing STEM careers (ibid.).

Career choices are influenced by the images attached to different careers (Gottfredson, 1981, 2002) and these images partially represent persons' career awareness (Wise et al., 1976). Career awareness is described as a multifaceted term, which includes an individual's knowledge about:

a) occupations within a career path and their characteristics.
b) competence requirements.
c) one's values and interests.
d) self- awareness of one's abilities (Wise et al. 1976).

Students' lack of knowledge about possible careers in STEM fields have been considered to be one of the reasons for not choosing a science field as a career prospect (Maltese & Tai, 2011; Tytler & Osborne, 2012). People working in the STEM career fields are often characterised as being solitary, involved in careers not supporting altruistic goals and not supportive of having a family (Eccles & Wang, 2016). These characteristics point to some of the reasons why girls often decide not to pursue a career in STEM fields (Diekman et al., 2011). In addition, several studies have implicated students' low awareness of the applicability of science and mathematics subjects in STEM careers (Blotnicky et al., 2018) and their low awareness of competences required for such careers (Salonen et al., 2017). In fact, research by Vaino et al. (2015) and Soobard & Rannikmäe (2014) indicate that Estonian high school students tend to have developed little awareness about science- and technology-related careers in school. Plus, a more recent study has linked Estonian students' low STEM career awareness with science teachers' lack of work experience and awareness of the current career options in science-related fields (Kivistik et al., 2019).

Without promoting students' motivation to learn science and mathematics and without supporting the development of students' STEM career awareness, the problem of a lack of specialists is likely to remain (Bybee & McCrae, 2011). As Tytler and Osborne (2012) indicate—how can students aspire to something about which they lack an awareness? This suggests a need for science and mathematics courses at school to provide motivational studies, focusing on the prospect of interesting jobs and careers (Holmegaard et al., 2014). In fact, according to the Michigan Department of Education (2017) incorporating STEM career-related information into motivational and hands-on activities involving TLMs, can possibly solve both problems by raising students' awareness and their motivation to learn science.

Vaino et al. (2015) provided support to these suggestions by showing a positive impact on students' aspirations in the field of technology, after implementing design-based science learning (DBSL) modules. Additionally, a recent EU funded Horizon 2020 project, MultiCO (n.d.), sought to address the students' lack of career awareness through developing STEM career awareness promoting TLMs, which were intending to be interesting and relevant and therefore motivating to middle school students. The Finnish partners in the MultiCO project found that although middle school students gained awareness of STEM careers, they did not consider the introduced STEM careers as suitable for themselves and deemed the developed skills not applicable for their chosen careers (Salonen et al., 2018; Tolppanen et al., 2019). Nonetheless, the previously mentioned Finnish studies reported these results after implementing only one teaching and learning module at school. The impact of implementing several TLMs during a 3-year period, from 7^{th} until 9^{th} grade, had yet to be reported. The current thesis aimed to fill this knowledge gap by reporting the longitudinal impacts of implementing STEM career awareness promoting intervention in science lessons at Estonian schools.

1.1. Focus of the study

This thesis aimed to give an overview of the development of an intervention, designed to support students' study motivation through enhancing interest, relevance, and enjoyment (IRE) of learning science by incorporating information about, and work activities of STEM professionals in science teaching. In terms of the current research, the focus on STEM career-related teaching and learning modules (TLM) was taken to be a sequence of study activities, following a 3-stage model proposed by Holbrook and Rannikmäe (2010): a contextualisation stage involving a scenario for inducing motivation to study, followed by a de-contextualisation stage for learning conceptual science through inquiry and/or hands-on activities and a re-contextualisation stage, for undertaking socio-scientific decision making, reflecting on the learning and applying it to the context presented in the first stage.

Starting a TLM with a scenario utilized fundamentals from situated learning theory (Lave & Wenger, 1991) and the idea of situated cognition (Brown et al., 1989) both of which emphasized that meaningful learning took place when learning materials were situated in an original context. Adding information to the modules about work activities of STEM professionals was considered relevant to provide opportunities for students to experience the learning of science and mathematics curriculum topics within the context of 'working life'. Moreover, it was hypothesised that this approach helped students to value science studies, appreciate STEM careers and provided support for the development of students' STEM career awareness. Additionally, the current study focused on assessing the intervention impacts on students' study motivation, STEM career awareness and career aspirations by applying a longitudinal quasi-experimental pretest-posttest design with non-equivalent experimental and control groups.

The following research aims were put forward:

1. To determine scenario characteristics which promote relevance to study science topics.
2. To determine the impact of STEM career-related teaching and learning modules (TLM) on:
   a. Students' motivation to study science topics.
   b. Students' awareness of STEM careers (including awareness of possible occupations and competences needed in STEM careers).
   c. Students' career aspirations.

These aims led to the following research questions:

1. Which scenario characteristics support perception of relevance for studying science topics?
2. How do STEM career-related a) scenarios and b) modules (TLMs) impact on students' motivation (in terms of interest, relevance, enjoyment) to study science topics at middle school level (Grades 7–9)?
3. What impact do STEM career-related teaching and learning modules (TLMs) have on a) students' awareness about possible STEM careers and needed competences, b) students' career aspirations?

The above stated research questions are addressed in the research articles as follows:

Research question (RQ) 1 was explored in Article I. More specifically, article I examined different interpretations of relevance and covered the aspects of intrinsic and extrinsic relevance mediated by science teaching and learning modules (TLMs). This first study determined, which strategies had been previously used to promote relevance in scenarios—the initial and context setting stage of TLMs—developed in the European Commission funded project PROFILES.

The results gave input to the TLMs' and instruments' development, the latter aiming for determining motivational triggers perceived by students when interacting with the STEM career-related scenarios (Article II) and TLMs (Article V)

(RQ 2). The impact of STEM career-related TLMs was explored in Article V through an overview of the whole intervention in the frames of the EU funded project MultiCO.

RQ 3 was addressed in Articles III and IV. More specifically, Article III explored how a 3-year long intervention with five STEM career-related TLMs impacted on students' career aspirations and their STEM career awareness from the perspective of needed competence. Article IV examined the intervention impact on students' STEM career awareness from the perspective of STEM occupations in combination with relevant competences.

2. REVIEW OF THE LITERATURE

The following focuses on how the literature portrays factors which affect students' career aspirations or decisions, either toward or away from science and relating fields like engineering, technology, and mathematics. Initially, the role of social influencers on career choices, including stereotypical images of STEM professionals, is discussed. Secondly, a brief overview is given of prior STEM career awareness-promoting interventions and their findings. This is followed with an overview of selected motivation theories and the roles contributed to interest, relevance or value and enjoyment in these theories, in connection with career aspirations and decisions. The last section provides an overview of the Estonian school context and how students' STEM career awareness development is supported.

2.1. Impact of social factors on career awareness and career decisions

Although the most recent PISA study, conducted in 2018, reports that similar proportions of boys and girls aspired to STEM careers, there are, however, big gender differences in students who aspire to information and communication technology (ICT) and medicine as a future career (OECD, 2019). The same study reports that among Estonian students, ICT is largely favoured by boys and medicine by girls. These results are consistent with PISA 2015 results (OECD, 2016), indicating that little has changed in students' attitudes towards STEM careers within recent years. These tendencies translate into gender segregation between specialities at the tertiary level in Estonia: ICT, engineering and production specialities are mostly chosen by boys, and healthcare and education specialities are mostly chosen by girls (Kukk et al., 2017).

Multiple studies show that social factors impact on a science career track and influence students' career awareness, such as the school environment and pedagogical practices, out-of-school science-related experiences, peers, and family, as well as their self-perceptions of their science identity, made up of personal values, interests and ability beliefs, thus perseverance (Carlone et al., 2014; Lent et al., 1994; Shirazi, 2017; Tan et al., 2013; Wigfield & Eccles, 2000). According to Wise et al. (1976) career awareness includes awareness of work characteristics and awareness of self-related characteristics and more specifically is considered to include four components:

1. Knowledge
   a. about work routines,
   b. benefits gained and
   c. requirements for obtaining that position.

2. Values
   a. of a social group *vs* personal
   b. of working *vs* of some aspects of work (such as good salary, fame, social relevance).

3. Preferences
   a. regarding work activities,
   b. of work characteristics liked or being interested in.

4. Self-concepts
   a. about ones' ability beliefs regarding competence requirements.

These aspects are seen to have either a direct or motivational influence on each other and on career decisions (ibid.). Tai et al. (2006) suggest that the majority of students make decisions about their future career during middle school. According to Gottfredson's theory of circumscription and compromise (1981; 2002), students within the age range 9–14 have reached the stage in their cognitive development where it can be expected that they are able to imagine occupations with their characteristics and through that, deliberate about career paths for themselves. The theory of circumscription and compromise (Gottfredson 1981; 2002) implies that, when students imagine STEM occupations in a way, which do not align with their desired image of themselves, or with the benefits, or with the work activities, or work environment, then STEM careers are excluded from their pool of options. Moreover, students, in this age group, start to eliminate occupational options, based on their self-evaluation of internal factors, such as their abilities, interests and values, as well as external factors, like other people's expectations, the status of occupations and gender-stereotypical images of occupations (ibid.). Thus, Gottfredson's theory of circumscription and compromise provides an explanation as to how different components of career awareness impact on career decisions.

Multiple studies have indicated students' low awareness of STEM careers and their characteristics (ASPIRES, 2013; Blotnicky et. al, 2018; Franz-Odendaal et al., 2016; Salonen et al., 2017; 2019a). More specifically, students' knowledge of STEM careers is often restricted to those of scientists, medical doctors and teachers (ASPIRES, 2013). Franz-Odentaal et al. (2016) have shown that middle school students lack awareness of the work undertaken by engineers and according to Blotnicky et al., (2018) students do not know which careers require mathematics and science competence. Furthermore, middle school students' awareness of relevant competences for STEM careers are dominated by the need for sector specific knowledge over collaboration and creativity (Salonen et al., 2017; 2019a). Related to career values, research has shown, that while valuing working with people and having a creative job (Blotnicky et al., 2018; Lavonen et al., 2008), these are not seen as characteristics of STEM careers by students in middle school (Salonen et al., 2019a). The descriptions by Jang (2016) and ILO (2012) of the most prevalent work activities in STEM career paths indicate the differences between the stereotypical image students often hold and the actual picture presented by the workers in STEM fields. More specifically, competences, such as communication (active listening, presentation skills), collaboration, teamwork, supervision, and creativity, are seen as equally important for STEM occupations as science competences like managing field-specific knowledge, experimenting, problem solving, evidence-based decision making (Jang, 2016).

Prior research regarding scientists' personal characteristics has identified that scientists are portrayed mostly as Caucasian, male, working in a lab, wearing a lab coat and glasses, being smart geniuses, working alone and that these characteristics of a scientist have been prevalent among students, grown-ups, minorities, and various nations for more than fifty years (see review by Finson, 2002). A more recent meta-analytical study by Miller et al. (2018) shows that although women's representation in science has risen in United States of America, students still imagine scientists as men more often than women. DeWitt et al. (2013) further mentions, based on interviews with parents and elementary school students, that the image of scientists as "geeky", different from regular people, extremely dedicated, hardworking, persistent, logical, methodical and analytical, and for some parents also creative, form the environment in which students formulate their career aspirations. However, among 10–11 years old students, the image of "peers who are really into science" consider this as normal and not different from the rest of the students (ibid.).

The difference between the stereotypical smart scientists and self-perceptions of not matching the smart image, has been linked with low motivation to pursue STEM careers (ASPIRES, 2013). Students form ability beliefs through social comparisons and through comparing ones' abilities in different subject domains (Guo et al., 2017). Ability beliefs start to influence students early in their educational track. Wigfield and Eccles (2000) have indicated that ability beliefs already affect students' performances in elementary school. Although studies indicate that students' ability beliefs become more critical over time with school progression (review by Murphy et al., 2019) contradictory results are also present (Petersen & Hyde, 2017).

Ability beliefs in mathematics and science are shown to be different among boys and girls. In general, boys having higher competence beliefs in mathematics in comparison to girls indicate gender stereotypical ability beliefs as early as in the 1st grade (Eccles et al., 1993). Although girls tend to perform on a high level in mathematics and science in Grades 4–8, they still hold lower ability beliefs in comparison with boys in these subjects (Kurtz-Costes et al., 2008). Furthermore, these gender stereotypical ability beliefs have been shown to be derived from perceived ability expectations among adults being seen as different for boys and girls (ibid.). Nonetheless, a more recent study conducted by Petersen & Hyde (2017) provide opposing results, showing no gender differences in progression of students' ability beliefs in mathematics among middle school students.

Ability beliefs have also been used to explain career choice and gender differences in career choices. Findings from a study by Van der Vleuten et al. (2016) show that 9th grade students' higher ability beliefs in mathematics support the choice of a science and technology trajectory. Furthermore, to engage in and aspire to a career in science-related fields, students need to have good self-efficacy beliefs in science, in addition to being interested in and being able to perceive the value of science for oneself (Aschbacher et al., 2014; Guo et al., 2017; Potvin & Hasni, 2014).

Stereotypical images of science-related careers such as the scientists' and teachers' career affect career decisions through perceived societal norms (Diekman et al., 2011; Eccles & Wang, 2016; Gottfredson, 1981) and therefore influence the male-to-female ratio in a science-related career trajectory (Van Tuijl & Van der Molen, 2016). McPherson et al. (2018) have empirically researched the discrepancy between the image of self and an image of a typical scientist. Findings show a greater discrepancy between self and a scientist's image predict lower interest in pursuing a STEM career. In addition, the inaccurate image of STEM career pursuers covary with the discrepancy between self and a scientist's image, which decreases interest in STEM careers (McPherson et al., 2018). This emphasizes the importance of educating students on STEM occupations to avoid excluding this career field based on misconceptions and lack of awareness. Thus, a need to pay attention to providing girls equal opportunities to succeed in STEM career fields, have been internationally and nationally emphasized (Kukk et al. 2017; OECD, 2016).

2.2. Interventions aimed to support students' STEM career awareness

As the problem of lacking STEM career awareness (SCA) has been reported in several countries, many projects involving interventions, aiming to raise students' SCA have been introduced e.g. ASPIRES in England (ASPIRES, 2013), Career-Start in the USA (Orthner et al., 2013), MultiCO as a co-operation project between Germany, Estonia, Finland, the United Kingdom and Cyprus. The interventions implemented in these projects, however, differ. For example, they differ in duration lasting only for one learning sequence (Salonen et al. 2018; 2019b; Steinberg & Diekman, 2017; Tolppanen et al., 2019), to longer interventions, which last year(s) (Fouad, 1995; Schütte & Köller, 2015). In addition, while some projects focus on high school students (Schütte & Köller, 2015; Steinberg & Diekman, 2017), others have addressed middle school students (Archer et al., 2014; Fouad, 1995; Salonen et al., 2018; Salonen et al., 2019b; Tolppanen, 2019). All mentioned projects have incorporated activities into their interventions, which enabled students' active involvement through, for example:

- visits or field trips to universities, industries, or places under investigation;
- self-driven and relevant investigations either about socially embedded science topics, careers or topic-related industries;
- inviting STEM professionals to visit schools and encouraging conversations between students and STEM professionals.

These types of activities have been linked with greater interest in learning science and mathematics, which in turn have been shown to support the choice of studies in science or relating fields at the tertiary level (Levrini et al., 2017; Maltese & Tai, 2011; Potvin & Hasni, 2014). Furthermore, indicating the value of learning curriculum topics through the use of career examples, which involve implementation of the knowledge or skill, have been shown to produce positive effects on school engagement and perceived value of schooling among middle school students (Orthner et al., 2013). Overall, findings from these projects tend to indicate that, although students become more aware of different careers, they do not find the introduced STEM careers suitable for themselves nor find the skills related to the introduced careers valuable for their future careers (Archer et al., 2014; Salonen et al., 2018; 2019b; Tolppanen et al., 2019).

2.3. Motivation to study science and mathematics

When motivation to learn, for example, science and mathematics, is the target of research, it is generally guided by motivation theories, which use different terminologies with overlapping descriptions, or, often, no elaborate definition for interest, relevance and motivation is provided (Murphy & Alexander, 2000; Potvin & Hasni, 2014; Stuckey et al., 2013). Motivation as a theoretical construct, according to Maehr & Meyer, (1997), explains besides behaviour initiation, direction, persistence, intensity, and quality, also goal-directedness together with making choices. Thus, when researching motivation, Brophy (2004) suggests an understanding of motivation and its triggers from several motivation theories perspectives is needed for an unbiased evaluation and understanding of others' motivation, which might not be triggered by the same reasons in similar situations.

Article II focused on the distinguishing characteristics of interest, relevance, and enjoyment (IRE) for determining students' reaction when interacting with a scenario. Here it is aimed to deliberate further on these constructs from expectancy-value theory (EVT) (Wigfield & Eccles, 2000), social-cognitive career theory (SCCT) (Lent et al., 1994) and self-determination theory (SDT) (Deci & Ryan, 2000) perspective, to understand the role contributed to them as motivation triggers. However, none of the above-mentioned motivation theories include 'relevance' as a subconstruct. Instead 'value' is used as a subconstruct. 'Value' is defined in the Oxford Lexico dictionary (n.d.) as follows: "*The regard that something is held to deserve; the importance, worth or usefulness of something*". The Oxford Lexico dictionary (n.d.) defines 'relevance' as follows: *"The quality or state of being closely connected or appropriate"*. However, Merriam-Webster dictionary (n.d.) provides three definitions for the word 'relevance':

> *"1: relation to the matter at hand;*
> *2: practical and especially social applicability;*
> *3: the ability (as of an information retrieval system) to retrieve material that satisfies the needs of the user".*

In the context of teaching the meaning of 'relevance' has been described through words importance, relatedness, usefulness, meaningfulness (Levitt, 2002), which are all present in discussed motivation theories under the 'value' construct. In the current thesis both 'value' and 'relevance' are used to follow the original wording of other authors. However, from an intrinsic perspective value and relevance are considered as synonyms. Additionally, in SCCT and SDT interest and value are included separately, whereas in EVT the dividing line between interests and value is unspecified (Deci & Ryan, 2000; Lent et al., 1994; Wigfield & Eccles, 2000).

The common aspect among these three motivation theories is their recognised effect of prior experiences and social environment on developing values and interests (Deci & Ryan, 2000; Lent et al., 1994; Wigfield & Eccles, 2000). Yet the way values and interests are expressed, varies. Table 1 indicates, how EVT, SCCT, SDT define or interpret 'value', 'interest' and 'enjoyment'.

In EVT (Wigfield & Eccles, 2000) five separate constructs are put forward under the umbrella term 'achievement value'. For SCCT (Lent et al., 1994) the construct of 'values' is a quiescent part of the 'outcome expectations' construct. SDT (Deci & Ryan, 2000) is special in terms of providing an explanation on how values or importance or meaningfulness of an activity affects the perception of control over the situation, hence motivation. When values, which are socially and experientially formed, become a part of one's identity, then actions are taken due to an internal drive (Deci & Ryan, 2000). Nonetheless, by separating intrinsic and extrinsic motivation, a distinction between interests and values as motivational state characteristics has also been made (Deci & Ryan, 2000).

'Interest' in EVT is described under the constructs 'interest value' and 'intrinsic value' (Wigfield & Eccles, 2000), drawing parallels with intrinsic motivation characteristics from SDT (Deci & Ryan, 2000) by referring to intrinsically motivated activities as enjoyable and undertaken purely out of interest. Nonetheless, values are seen as a source of extrinsic motivation, although closest to intrinsic motivation in the SDT context (Deci & Ryan, 2000). In SCCT two constructs are indicated with regard to interest, specifically 'interests' and 'vocational/academic/career interests'. Lent et al. (1994) consider interests as having a role in setting goals and acting towards the goals, whereas for describing 'vocational/academic/career interests', Lent et al. (1994) refer to liking, disliking, or feeling indifference towards career-related activities. Nonetheless 'like' is a construct that is only used in this theory, the SCCT (Lent et al., 1994) and SDT (Deci & Ryan, 2000) refer to enjoyment, when feeling (intrinsically) motivated.

Science (or separately as chemistry, physics, biology, geography) and mathematics are school subjects, in which students tend to lose interest and relevance with progression through schoolyears (Petersen & Hyde, 2017; Potvin & Hasni, 2014), although differences have been shown with respect to gender, subjects and even topics level (Wang et al., 2017; Wigfield & Eccles, 2000).

Table 1. Interpretations of interest, relevance (value) and enjoyment in selected motivation theories

Motivation Theory	I/R/E inclusivity	Definitions/interpretations
Expectancy-value theory (Wigfield & Eccles, 2000)	Achievement values	'Attainment value': importance of doing well on a given task. 'Intrinsic value': enjoyment gained from doing a task. 'Utility value': Congruence with future plans. 'Cost': restrictions (access to other activities, effort, emotional cost) which come with the decision to engage in an activity. Wigfield and Eccles (2000) compare 'interest value' with intrinsic motivation from self-determination theory, because it entails doing a task out of interest and enjoyment.
Social-cognitive career theory (Lent et al., 1994)	Interests	Interests are forms of cognized goal reflections like self-efficacy, outcome expectations and self-regulators of motivation. Interests are formed together with self-efficacy and outcome expectations. Interests lead to setting goals and availing oneself for actions, which in turn shape self-efficacy and outcome expectancies and crystallisation of interests.
	Vocational interests, also academic and career interests	Patterns of likes, dislikes, and indifferences in regard to career-relevant activities and occupations. Interests promote career-related actions and acquiring skills.
	Values	In a definition for 'value' Lent et al. (1994) refer to Dawis and Lofquist (1984): "*preference of reinforcers in a work or academic environment, are acquired by children and adolescents through basic social learning process* […]". Value concept is part of outcome expectations. *"[…] interests in a particular academic or a career-relevant activity depends, in part, on the outcomes that are anticipated to result from an activity, along with the relative value or the importance of these outcomes to the individual."* pp 91.
Self-determination theory (Deci & Ryan, 2000)	Interest	Interest is a characteristic of intrinsically motivated behaviour, which is influenced by prior experiences of need satisfaction for competence, relatedness, and autonomy.
	Value / importance of an activity	Value or perception of importance of an activity, is a characteristic of external motivation. Authors have recognised the social aspect of value formation and the potential to be internalized thus becoming part of oneself.
	Enjoyment	Enjoyment is the perceived consequence of need (belonging, competence, autonomy) satisfaction. In the context of research regarding SDT, the more self-determined and internally valued the activity, the more enjoyment is reported for an activity.

The tendencies to lose interest and relevance are, in turn, affecting students' motivation to study, resulting in putting less effort into learning, affecting achievements, and giving input to reducing students' ability beliefs (Lazarides et al., 2020; Wigfield & Eccles, 2000). Based on several meta-analytical studies, Lent & Brown (2019) conclude that ability beliefs and outcome expectations drive educational and occupational interests, which in turn affects career goals. Furthermore, the goal of pursuing a science and technology degree has been shown to be rooted in perceived value of, and interest in, STEM careers at middle school level (Maltese & Tai, 2011). Based on Articles I and II, table 2 is developed with specific relevance and interest promoting suggestions to be considered when TLMs are developed for the intervention highlighted in this thesis.

Table 2. *Characteristics of relevance and interest promotion in TLMs (Articles I and II)*

	Subcategory	How to support?
Relevance	Useful	Applicability of gained knowledge and skills for the future (near or distant): school studies, tertiary level, future career (both science-related and not) (Keller, 1983). Indicating which outcomes (salary, prestige, work environments) can be expected when knowledge, experiences and/or skills are applied in careers.
	Meaningful	Content linked with prior knowledge: in line with constructivism (Frymier & Shulman, 1995); arouse curiosity; familiar context; active collaborative inquiry-based learning; attainable.
	Important	Socio-scientific issue implementation (Sadler, 2009); problem-solving; science as a medium for managing societal issues; student as future responsible citizen; acute topics in the media (Kember & McNaught, 2011; importance of science practices and knowledge; "education through science" mentality (Holbrook & Rannikmäe, 2007).
	Relatable	Choosing context, which students can relate with (Aikenhead, 2006; Broman et al., 2011; Broman & Simon, 2015): close relationships (friends, family); everyday problems experienced by students; able to put oneself in the position of others at different levels (local, global). Provide experience through role play.
Interest	Individual	Determining students' interests. Choosing a topic, in which students are interested. Fitting study content into a context in which students indicate an interest. Showing the potential for knowing more about specific interests (Kintsch, 1980).
	Situational	Incorporating hands-on activities; inducing cognitive conflict (Berlyne, 1960; Loewenstein, 1994); novelty (new routines, visitors, field trips); involve food (making, eating, connecting study content with food); enable social interactions (group work); teacher modelling; include games/puzzles; interactions with other forms of life (biophilia); fantasy, humour, narratives and stories (Bergin, 1999); showing potential of interesting things to learn.

Table 2 utilises Levitt's (2002) description of relevance and Krapp et al. (2014) description of interest. Krapp et al. (2014) distinguish individual interest and situational interest, the first being specific to individuals and the latter induced by situation-specific conditions similarly among people. Although interest and relevance have distinguishing characteristics, they are often present together (Article II). This is recognised in the interest development model by Hidi and Renniger (2006), whereby their model implies that the situational interest can develop into individual interest and with this process perception of relevance grows. Other studies have shown that by supporting perception of relevance, interest towards learning science or mathematics has also been supported (Gaspard et al., 2015; Orthner et al., 2013).

This thesis is driven by the theory-based model represented in Article II, which recognises the role of interest, relevance, and enjoyment mediated by prior knowledge, as motivation triggers when acquainted with a scenario (Figure 1). However, the same theoretical considerations are applicable when learning science topics through teaching and learning modules. Thus, it suggests that when relevance, interest and enjoyment supportive measures are implemented in TLMs, motivation to learn science topics is also supported.

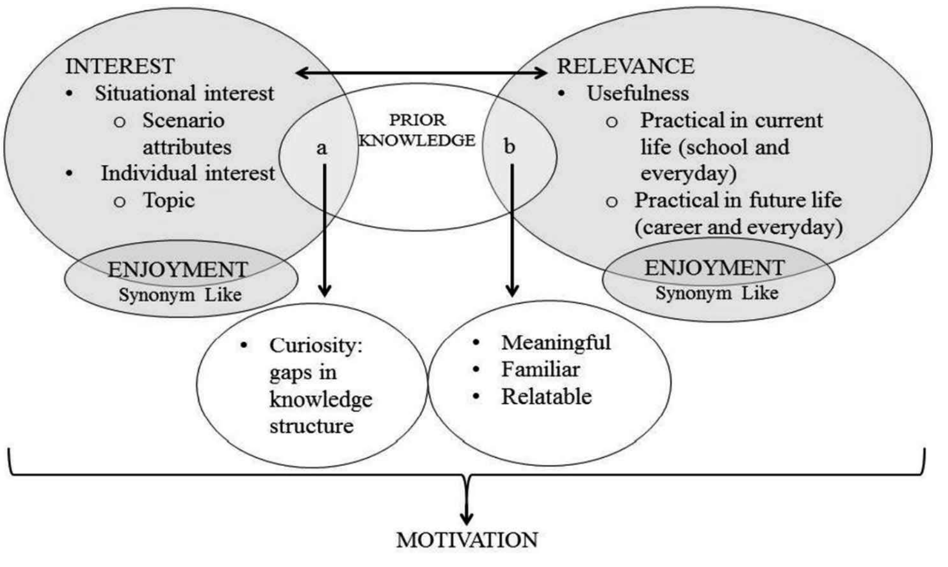

Figure 1. Theory-based model of possible motivational triggers perceived when acquainted with a scenario (Article II).

2.4. General background of Estonian science teaching and support for students' career awareness development

Science teaching in Estonia is divided between five science subjects: overall science until the end of 7th grade (13 years old) and biology, chemistry, physics, and geography starting either in the 7th or 8th grade, which continue until the end of the 12th grade in either nationally set number of classes per week, or in a nationally set number of courses accordingly (Estonian Government, 2011a, b).

Students make their first choices regarding their future studies, which lead to future career opportunities, at the end of 9th grade, when they choose either vocational, or high school. The majority of high schools include different varieties of study directions like humanities, medicine, or economics for which elective courses in addition to compulsory courses, set in the National Curricula (Estonian Government, 2011b), are provided.

'Career education', as a subject, is available as an elective course, both at the basic and high school level, but each school develops their own strategies for providing career education both in terms of career-related information and career counselling, neither of which necessarily include the elective course called 'Career education'.

Nonetheless, it is expected that students' SCA is developed in science studies, within overall science until the end of 7th grade and continued within separate science disciplines until the end of both basic and high school. In fact, the Estonian National Curricula (Estonian Government, 2011a, b) states that students should be aware of biology, chemistry, geography, and physics related occupations and study opportunities added with the acknowledgement of the usability of gained discipline-specific knowledge and skills in various work fields by the end of both basic and high school.

Thus, while science teachers have the expectation to raise students' awareness of STEM careers and take steps to build students' career awareness in science or related fields, teachers' awareness of STEM occupations and requirements is often lacking (Cohen & Patterson, 2012). Estonian science teachers' awareness of STEM careers has been estimated to be insufficient (Kivistik et al., 2019) and according to Estonian high school students, they have not been made aware of STEM careers during science lessons (Soobard & Rannikmäe, 2014).

3. METHODOLOGY

3.1. Overall design of the research

The current research was undertaken in three stages: the pre-intervention stage, the intervention stage and post-intervention stage.

The pre-intervention stage (Article I and IV)

The pre-intervention stage aimed to find an answer to the first research question: which scenario characteristics support perception of relevance for studying science topics? In addition, input for answering the third research question was gathered. The following steps were taken:

1. Determination of the characteristics to support relevance in the scenarios (Article I).
2. Determination of the 7th grade students' STEM career awareness and career aspirations prior to the intervention (Article IV).

The intervention stage (Article V)

This stage involved the development of six and the implementation of five TLMs, promoting STEM career awareness during a 3-year period as shown in Figure 2:

1. "Electricity in the air" (in 7th grade, 5*45 min)
2. "Should there be a sugar tax?" (in 8th grade, 4*45 min)
3. "Crime scene" / "Houses where we live" (in 8th grade, 3*45 min, schools could choose which TLM to implement)
4. "Oil—the king of the World" (in 9th grade, 3*45 min)
5. "CITES" (in 9th grade, 3*45 min)

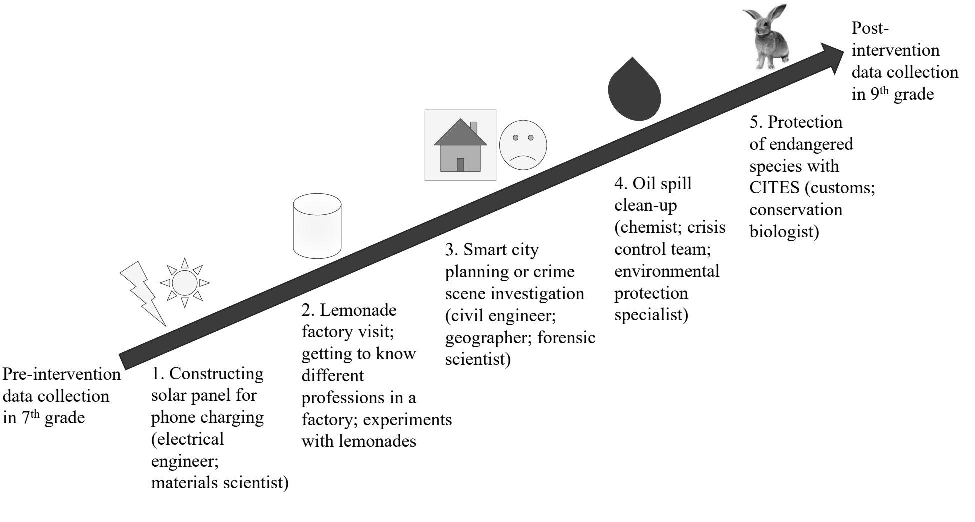

Figure 2. Overview of the intervention TLMs and introduced careers

In order to answer the second research question (How do STEM career-related a) scenarios and b) modules (TLMs) impact on students' motivation (in terms of interest, relevance, enjoyment) to study science topics at middle school level (Grades 7–9)?), students' feedback on the TLMs were determined through a scenario and a module evaluation questionnaire (Articles II and V).

The post-intervention stage (Articles III and IV)

In order to find answers to the third research question (What impact do STEM career-related teaching and learning modules (TLMs) have on a) students' awareness about possible STEM careers and needed competences, b) students' career aspirations?) the research involved in the post-intervention stage included:

1. Determination of students' STEM career awareness and career aspirations after the end of the intervention.
2. Determination of changes in students' STEM career awareness and career aspirations.

3.2. Ethical considerations

Research conducted in the frames of the current thesis followed the guidelines, values and principles of actions described in Estonian Code of Conduct for Research Integrity (2017). Prior to the beginning of the data collections and an intervention, the Research Ethics Committee of the University of Tartu was consulted. As the research activities supported the achievement of the goals set in the Estonian National Curriculum for Basic Schools (2011a), no ethics committee approval was considered necessary.

Schools, parents, and students were informed about the research aims, how students' and schools' anonymity was to be protected, how participation was voluntary for students, how the data would be stored and who had access to collected data.

Students' anonymity was protected by replacing their names with codenames, which were kept separately from the data files. Data analysis was conducted with codenamed data. All collected data were kept in one password protected computer and data files were accessible only to the author of this thesis, or for other involved researchers upon request.

Research data obtained in the frames of the current thesis were analysed and interpreted both critically and as objectively as known possible to the author. Specific validity and reliability supporting measures were taken into consideration for each stage of the research.

The author has shared the results obtained from the current study with participating teachers and schools. Career awareness promoting teaching and learning modules or scenarios are publicly available on MultiCO project website for teachers to use, so the local community can benefit from the outcomes of the MultiCO project.

3.3. Stage 1: Pre-intervention

Prior to any intervention, scenarios from the EU FP7 project PROFILES (Professional Reflection Oriented Focus on Inquiry-based Learning and Education through Science) were analysed. The PROFILES project was seen as a meaningful base because it aimed to promote motivation through student-centred approaches such as inquiry-based learning and great emphasis was put on supporting perception of relevance through providing meaningful and valuable learning experiences (Bolte et al., 2014). The project used modules which were following a 3-stage model (Holbrook & Rannikmäe, 2010) to achieve this aim. The scenarios were developed as the first stage of each module, where relevance and motivation were expected to be induced and the context for the follow-up learning steps was set (Bolte et al., 2012).

3.3.1. Source of data

Altogether 88 TLMs written in English were retrieved from the PROFILES project website (n.d.). These modules were developed by project partners in 21 different countries (Germany was represented with two regions) involving 124 science educators, who were aiming towards making science studies more meaningful to students (Bolte et al., 2014). An elimination of repeating modules resulted in 77 scenario titles and 66 scenario texts being analysed. The differences in the number of scenario titles and texts were determined by the fact that some modules began with investigative activities and lacked an introductory scenario.

3.3.2. Data analysis

Conventional content analysis, with inductive category formation, was used to determine which characteristics of relevance emerge from scenarios, presented in the form of short text passages. This qualitative method was implemented, due to its suitability for situations where existing theory, or phenomena description is limited (Hsieh & Shannon, 2005). The specific analysis procedure was as described further in Article I.

3.3.3. Reliability and validity

The initial coding and formation of categories with their description was undertaken by the first author of Article I. The secondary categorisation of scenario titles, using developed categories and descriptions, was carried out by the other two authors. Inter-rater reliability was calculated, resulting with conformity of 90% (an average between two categories). Total conformity of categorisation was established through discussion. To provide additional reliability of the results, intra-rater reliability was determined with re-categorisation of scenarios two months after the initial categorisation. The conformity of the two categorisations was 95.5%.

An avoidance of researcher bias was undertaken by the first author, who was not connected to the PROFILES project at any stage and who, therefore, was not biased by the need to meet the project aims, conducting the initial coding and category development. The validity of the study was supported by constant debriefing among co-authors of Article I during the later stages of the study.

3.4. Stage 2: The Intervention

3.4.1. Description of the intervention

Within the frames of the project MultiCO, the scenarios and the following study activities were designed to support students in:

(a) becoming interested in topics like renewable energy, health and aging, responsible use of resources, including agricultural land etc., which were named as societal challenges and thus European Union strategic development priorities (European Commission, 2010),
(b) seeing the relevance in studying science and,
(c) making the study process enjoyable to students.

To determine the effects of the intervention on students' science-related career awareness and career aspirations, a quasi-experimental pretest-posttest design with non-equivalent experimental and control groups was used.

The intervention was longitudinal in nature, starting at the end of 7th grade (spring 2016) and continued until the end of 9th grade (spring, 2018). During the intervention, six different TLMs were developed for schools (Figure 1 above). Schools could choose which TLM they wished to implement as the third module, either "Crime scene" or "Houses where we live". Thus, in total, five modules were used for teaching different science curriculum topics incorporating STEM career awareness promoting information and activities.

The developed TLMs share some characteristics but differ in others. Table 3 provides an overview of these characteristics. Detailed information regarding each individual TLM is provided in Article V.

Table 3. Commonalities and differences among TLMs

Common characteristics	Different characteristics
• Started with context building (a scenario, field trip etc.). • Followed a three-stage model (1. context building, 2. curriculum-related science teaching with hands-on activities (investigative or design-based), 3. decision-making/reflection on what had been learned, which skills used/developed). • Teachers participated in an in-service course before implementing each TLM. • Introduced STEM careers. • Were collaborative.	• TLMs focused on one science subject. • TLMs were initiated with different activities (to provide novelty). • Implementation of the TLMs were by different teachers, depending on the module specifics.

3.4.2. Participants of the intervention

The intervention activities were carried out in three Estonian-speaking schools from two Estonian towns. Table 4 gives an overview of participating students and their teachers. Altogether five classes of students from Grades 7 until 9 (N = 104; 45% girls) were involved in the intervention activities (experimental group, EG). The activities were carried out by the teachers, who received in-service guidance prior to every module implementation. All the participating teachers had acquired teaching experience for five years or more by the beginning of the intervention.

The control group (CG) was made up of one class of students (N = 24; 64% girls) from another Estonian speaking school (School 4 in Table 4) from a different town. However, the control group was similarly to the experimental group from one of the biggest Estonia's towns. All teachers from the control group had more than ten years of teaching experience, thus the teaching experience among EG and CG teachers was similar, although not the same. The control group was taught according to the Estonian National Curriculum for Basic School (Estonian Government, 2011a). The control group students were tested at similar times as the experimental groups, both in Grades 7 and 9.

Table 4. Participants of the intervention

		No. of students	Gender distribution	Science teachers' profiles
School 1	Class 1	27	13 boys 14 girls	Biology (female; > 10 years of experience); Chemistry (female; > 10 years of experience); Geography (female; > 10 years of experience); Physics (male; > 10 years of experience)
	Class 2	26	12 boys 14 girls	
School 2	Class 1	18	10 boys 8 girls	Biology (female; > 10 years of experience); Chemistry (male; > 5 years of experience); Geography (female; > 10 years of experience); Physics and Mathematics (male; 5 years of experience)
	Class 2	18	13 boys 5 girls	
School 3	Class 1	15	9 boys 6 girls	Biology (female; 5 years of experience); Chemistry (female; 5 years of experience); Geography (female; > 10 years of experience); Physics (female; 5 years of experience)
School 4 Control group	Class 1	24	9 boys 15 girls	Biology (female; >10 years of experience); Chemistry (male; > 10 years of experience); Geography (female; > 10 years of experience); Physics (male; > 10 years of experience)

3.4.3. Scenario evaluation

To determine students' motivational outcomes from the developed scenarios, a specially developed instrument was used. The scenario evaluation instrument was developed with the presumption that when students were interacting with the scenario, relevance, interest, and enjoyment, mediated by prior knowledge, acted as motivation triggers for further science studies (Figure 1). The instrument contained altogether 26 rating scale items (for items 1–22 the rating scale was defined as 1— 'totally disagree' to 4— 'totally agree', and for items 25–28, a 3-point rating scale defined as 'do not agree', 'cannot make up my mind', 'agree') which were initially categorized into four theoretical categories:

1. Role of knowledge (5 items)
2. Perception of relevance with 3 subcategories:
    a. Usefulness (7 items)
    b. Impact level (5 items)
    c. Relatedness (3 items)
3. Scenario attributes (4 items)
4. Affective reaction (2 items)

The instrument contained an additional two items to determine students' prior knowledge related to the scenario topic and the introduced STEM careers, based on self-evaluation (items 23, 24). To determine why students felt or lacked interest, enjoyment, relevance, and motivation after seeing the scenario, reasoning was asked in items 25–28.

Scenario introduction

The first scenario, which students evaluated, was called 'Electricity in the air'. The scenario contained a story of a family, whose monthly electricity bill had significantly risen. The father blamed his teenage siblings, because they were constantly on their smart devices (iPad and smartphone), which thus needed constant charging. During the scenario, an electrical engineer's, an environmental specialist's, and a materials scientist's careers were introduced. The scenario ended with the suggestion for students to construct a small solar panel for charging teenagers' smart devices. The scenario was presented as a video and lasted 11 minutes.

Data collection and the sample

After watching the "Electricity in the air" scenario video, students (N = 143, 50% girls, median age 14 years) were presented with the scenario evaluation instrument on paper, which took 13 minutes on average to complete.

Data analysis

Data was analysed using different statistical methods, as shown in table 5. CFA results showed that the theoretical categorisation of items was not performing at the expected level. Exploratory factor analysis produced a 6-factor solution, which shuffled items into different factors, in comparison to the theoretical model. The new factors were named:

- Learning value (8 items)
- Vocational value (6 items)
- Scenario attributes (4 items)
- Career awareness (2 items)
- Like and interest (2 items)
- Social value (4 items)

Further analysis of means and standard deviations was conducted following acquisition of EFA results. Students' explanations for feeling enjoyment, relevance, interest, and motivation, were analysed through qualitative content analysis with a summative approach (Hsieh & Shannon, 2005). Codes and categories were inductively derived.

Table 5. Scenario evaluation data analysis methods with aims and outcomes

Aim	Analysis	Expected outcome	Gained outcome
Confirm or reject the theoretical model	Confirmatory factor analysis (CFA) with Amos software	CFI index > .95; RMSEA < .08; X^2/df = 1.0–3.0	CFI = .72; RMSEA = .10; X^2/df = 2.42
Exploring the underlying model	Exploratory factor analysis (EFA) with principal axis factoring and Promax rotation conducted with IBM SPSS ver. 22	Kaiser-Guttman rule of standard eigenvalue > 1 for determined factors	6-factor solution
Checking the internal consistency	Cronbach's α	α > .80— 'very good'; α = .70–.80— 'respectable'; α =.60–.79— 'undesirable to minimally acceptable'	α (overall instrument) = .90; α (separate factors) = .66–.85

3.4.4. Validity and reliability regarding scenario evaluation

The content validity of the scenario evaluation instrument was addressed by gaining feedback from international science education researchers, who were partners of the MultiCO project. The expert group suggested to add requests for students' explanations. This was considered appropriate to provide qualitative input to data collection, which supported overall validity through triangulation.

To evaluate the construct validity of the instruments' theoretical structure, CFA was used with three different fit indices (CFI, RMSEA, X^2/df). As this did not support the initial structure, EFA was implemented. To check data suitability for EFA, the KMO test of sampling adequacy and Bartlett's test was performed, resulting in support for further analysis (accordingly, KMO = .80; $X^2 = 1560.41$, $p<.001$). Internal consistency was firstly determined for all items, followed with separate category consistency analyses with Cronbach's α (see results in table 5).

Inter-coder reliability was checked by letting another researcher categorise 10% of every response (14 of each—relevance, enjoyment, interest, and motivation), concurrence % was calculated to be 86%. Discrepancies were discussed until total agreement was achieved among researchers.

3.4.5. Evaluation of the modules

The initial scenario evaluation instrument was modified for module evaluation (Article V). Table 1, in Appendix 1, gave an overview of the commonalities and differences between the scenario and module evaluation questionnaire. Most items implemented in the scenario evaluation instrument were also used in the module evaluation instrument. The biggest difference related to determining what students had learned about the topic and about the careers introduced, plus which skills they had developed through the modules. As the teachers' role in guiding the module activities within the school was seen as having a greater influence, in comparison to the scenario presentation, items regarding the teaching process were added.

As the 2nd module ("Should there be a sugar tax?") started with an industry visit, three items were replaced with items addressing the occupations students' saw in the industry, plus items regarding the teacher's role in combining the visit with follow-up activities at school. Students' feedback about the effort and their suggestions for improving the modules, were also asked in the module evaluation instrument.

Data collection and the sample

The module evaluation instrument was implemented after the end of every module, thus detecting various inputs to the overall study motivation. Although 104 students (45% girls) from the 3 schools were included in the intervention, not all of them participated in every lesson. The data analysis undertaken incorporated feedback from only those students, who had taken part in every module lesson.

Data analysis

The Mann-Whitney U-test was used to determine, whether boys' and girls' responses differed in a meaningful way. Both statistical significance ($p < .05$) and differences in means were examined. As statistically significant difference ($p < .05$) in girls' and boys' responses showed similar tendencies (both means either < 2.5 or > 2.5), it was considered justified to analyse both groups together. Further quantitative analysis included descriptive statistics (mean, standard deviations) whereby responses were interpreted as follows: on 4-point scale < 2.5 as a negative tendency and > 2.5 as positive tendency. For items detecting overall affect, value, and motivation, a 3-point scale was used (defined as -1—disagree, 0—cannot make up my mind, 1—agree) and interpreted as < 0 as negative tendency and > 0 as positive tendency.

Students' explanations for (not) perceiving interest, motivation, enjoyment (like), and value, were analysed using qualitative content analysis with inductive coding. A summative approach was used to give an overview of the results (Article V).

For open-ended tasks, which asked students to a) list skills they had developed and b) careers where these would be applicable, students' responses were counted and ranked based on frequency.

3.4.6. Validity and reliability regarding the evaluation of modules

Cronbach's α was used to determine internal consistency of the instrument with every module. Further statistical analyses to determine construct validity, like confirmatory factor analysis (CFA) and exploratory factor analysis (EFA) were not applied due to small sample sizes. Both the CFA and EFA are analysis methods which require large sample sizes to produce fit and stable results (Costello & Osborne, 2005; Wolf et al., 2013). Thus, it was decided to use theoretical categories (see Article II) to simplify the discussion about module evaluation results.

Reliability for the results from analysing open-ended responses was supported by the first author of Article V developing the codes, then themes and their descriptions, which were later used by four MultiCO project members for coding the items. The division between the themes of the responses were discussed until consensus was reached (ibid.).

3.5. Stage 3: Post-intervention

To determine the impact of the MultiCO intervention on Estonian students' career aspirations and STEM career awareness, a 3-part questionnaire (career aspirations and awareness (CAA) questionnaire), plus a concept mapping technique were implemented post-intervention and comparative data analysis between pre-intervention and post-intervention data was undertaken.

3.5.1. Career aspirations and awareness questionnaire

The CAA questionnaire contained three parts:

1. Students' career aspirations
2. Relevance of competences for their aspired career(s)
3. Relevance of competences for STEM careers.

In the questionnaire, students were given a list of possible occupations. However, an option 'other' was included so that students could write their aspired career if they were unable to pick from the given list (see table 6).

Table 6. Examples of students' 'other' choices distributed among the ISCO-08 six professionals' groups

Professionals' group	Examples
Science and engineering	Geneticist, geologist, climatologist, construction worker, engineer, architect
Health and medicine	Anaesthesiologist, veterinary doctor
Teaching	Kindergarten teacher, PE teacher, dance trainer
Business and administration	Politician, administrative worker
Information and communication technology	Computer programmer, "Youtuber", e-sports player
Law, sociology, culture	Economist, psychologist, animal shelter worker, photographer, worker in tourism, sportsman

In the second and third part of the questionnaire, students were presented with a list of 27 competences, as shown in table 7, and asked to evaluate, the degree of importance, in their opinion, on a scale of 1 to 4 (scale defined as 'not important at all' and 'very important' accordingly). The competences were drawn from descriptions of science and engineering professionals' group provided in ISCO-08 by the International Labour office (ILO, 2012) and supported with results from Jang (2016).

Table 7. List of competences used in CAA questionnaire parts 2 and 3

Imagination, technological skills (product design and production), oral presentation skills, written presentation skills, activity planning, foreign language, doing scientific experiments, open-mindedness, creativity, initiative, logical thinking, analysis skills, problem solving, scientific knowledge, independent work, leadership, evidence based decisions, reasoning, computer skills, fast adaptation, precision and accuracy, collaboration, communication skills, persistence, taking responsibility, lifelong learning*, directing and teaching others*.

Note: * only used in the post-questionnaire

Data collection

The instrument was piloted with a separate group of 7th grade students (N = 40). It was found that all the items were understood by students (except administrative work, thus oral explanation was provided to students while they were filling in the questionnaire). It took students 12 minutes, on average, to complete the questionnaire.

Data collection using the CAA questionnaire took place before and after the intervention in Spring 2016 (7th grade) and in Spring 2018 (9th grade). Comparative data was collected from 77 students (43% girls) from the experimental group (EG) and 21 students (62% girls) from the control group (CG).

Students were asked to provide their name, to detect changes. Students' names were later replaced with codenames and analysis was conducted without any names.

Data analysis

Students' career aspirations were categorised according to the ISCO-08 six professionals' groups (science and engineering; health; teaching; business and administration; information and communication technology; legal, social, and cultural). Students could choose more than one option, if needed. The Mann-Whitney U-test with Bonferroni corrections was used to determine, whether career aspirations' distribution was similar among the CG and EG in 7th grade and for determining changes in Grade 7 and 9 students' opinions about relevance of the competences, either for their career aspirations, or for STEM careers. To determine changes in students' career aspirations, the IBM SPSS McNemar test was used, this being appropriate because of the dichotomous nature of the data.

3.5.2. Concept mapping

A concept mapping technique (Novak, 1995) was used to gather visual data about students' STEM career awareness. Concept mapping was used for data collection because several questionnaires were implemented during the MultiCO project and students were showing resentment to answering to "yet another questionnaire". Concept maps enabled 'to visualise' and thus evaluate students' knowledge structure (Novak, 1995; Ruiz-Primo & Shavelson, 1996). Students were presented with pre-inserted 22 occupation concepts and 18 (20 in 9th grade) competence concepts (Table 8) in the IHMC *Cmap Cloud* application, where each student had their own private folder. The list of occupations was based on careers being introduced in the TLMs (Article IV, V), plus the separate teaching of biology, chemistry, physics and geography in the Estonian education system. The list aimed to include some occupations from each science field (see Article IV). The list on competences was like the CAA questionnaire and drawn from descriptions of science and engineering professionals' group provided in ISCO-08 by the International Labour office (ILO, 2012) and supported with results from Jang (2016).

Table 8. Occupations and competences concepts provided to students for potential use in concept maps

Occupations	Competences
Drug representative, sales manager, secretary, environmental specialist, journalist, school principal, materials scientist, electrical engineer, product designer, factory manager, laboratory manager, brewer, construction engineer, geologist, cell biologist, biochemist, construction worker, baker, miner, microbiologist, food technologist	Collaboration, leadership, technological skills (design and production), communication, evidence-based decisions, reasoning, analysis skill, creative thinking, logical thinking, scientific problem solving, scientific knowledge, scientific experiments, independent work, foreign language, presentation skills (oral and in writing), activity planning, initiative, computer skills (text editing, data management, graphical skills), lifelong learning*, directing and teaching others*

Note: * only used in the post-intervention data collection. Concepts "lifelong learning" and "directing and teaching others" were removed when comparative analyses between pre- and post-intervention data were undertaken.

Data collection

The concept mapping technique, with pre-inserted concepts, was piloted with a group of 7th grade students (33, 75% girls), providing input about the time it took to complete concept maps and whether the concepts were understandable for students. It was found that, for most students, 45 minutes was suitable to complete their concept maps and that students were familiar with the provided concepts.

Data collection with concept mapping took place prior and after the intervention in Grade 7 and Grade 9 by using the IHMC *Cmap Cloud* application on desktop computers at schools. Prior to data collections on both occasions, a short demonstration was given on how to construct concept maps, how the application works and how to use the linking of words. The demonstration lasted 5–10 minutes, depending on whether students had questions. The data collection procedure was overseen by the author, to secure a constant procedure. Students constructed their CMs within one school lesson (45 minutes), guided by the following two focus questions:

1. Which occupations, in your opinion, relate to a science-related career path?

2. Which competences (skills and knowledge) are needed for occupations within a science-related career path?

Comparable concept maps were collected from 64 students, out of which 47 (62% boys) students were from EG and 17 (47% boys) from CG.

Data analysis

The concepts (occupations and competences) used by students were inserted into an Excel file and dummy coded (1—present, 0—absent). Three determinants were calculated: 'overall concepts used', 'occupation concepts used' and 'competence concepts used'.

The Wilcoxon signed rank test with Monte Carlo correction (2-tailed) was used to determine changes in the use of concepts. The Mann-Whitney U-test with asymptotic significance was used to determine differences among groups (boys and girls, EG and CG).

3.5.3. Additional data collection with concept mapping and semi-structured focus group interviews

An additional data collection, involving both CMs and interviews, took place one year after the intervention had ended, in one of the MultiCO partner schools. This was considered necessary for two reasons:

1. To understand the thinking process behind constructing CMs.
2. To determine, how students' STEM career awareness progressed without a STEM career awareness promoting intervention.

The concept mapping and data collection procedure were the same as described for the post-intervention data collection. Altogether, two sets of 7th grade and 9th grade students constructed concept maps (N = 91). After the initial analysis of CMs and semi-structured interviews, 37 (54% boys) concept maps were further analysed, using the same methods as described for analysing the post-intervention data. In order to ensure comparability of the additional dataset (later referred to as AG) with the EG data, the Mann-Whitney U-test was used, resulting in insignificant differences among 7th grade students ($p > .05$). This provided support for further comparative analysis.

Semi-structured focus group interviews

Interviews with the AG students were conducted in groups of 3–5 students, each lasting 15 minutes on average. Students were asked about:

1. the difficulty of concept mapping,
2. the understandability of the provided concepts,
3. their self-evaluation of STEM career awareness,
4. their opinions about how well CMs represented their career awareness,
5. how they interpreted the term 'STEM careers' and what made these different from other careers,
6. how they chose the competence concepts to use,
7. whether they would like to change something in their CMs (c.f. Article IV).

All interviews were conducted by the author and voice recorded. The voice recordings were transcribed, analysed with inductive coding and overall themes were developed based on the codes. A summative approach was undertaken to show the prevalence of emerging themes (Article IV).

3.5.4. Validity and reliability

Translation validity

To provide translation validity, a STEM career awareness definition was developed, based on the definition of career awareness by Wise et al. (1976) and modified to fit for different STEM fields. The definition proposed was as follows:

STEM career awareness is proposed to be an individual's knowledge about:

a) Occupations within a STEM career path and their characteristics.
b) Competence requirements.
c) Knowledge about one's values and interests.
d) Self- awareness of one's abilities.

The CAA questionnaire and concept mapping were aiming to address the first two components of STEM career awareness, namely students' awareness of various occupations and competence requirements. The need to address these two aspects was derived from the Estonian National Curriculum for Basic Schools (Estonian Government, 2011), which states that:

> "By the end of basic school students should be (a) aware of various science related occupations and (b) be able to apply skills and knowledge developed in science classes in various work fields."

Construct validity

To develop a list of competences, the ISCO-08 (ILO, 2012) description of science and engineering professional groups' description was used. In addition, competences were taken from Jang (2016), who analysed competences needed by STEM workers. The list of occupations related to occupations covered in the interventions and aimed to include occupations from each science discipline.

Expert method was applied to determine used concepts compliance with internationally accepted trends regarding relevant competences for adult life and working life. Additionally, the expert concluded that used occupations were typical science-related occupations (Article IV).

Internal consistency

To provide internal consistency for CAA questionnaire parts, McDonalds' ordinal Ω with R software, was calculated for the questionnaire parts 2 and 3. This gave values of .91 and .93 accordingly, supporting the internal consistency of the instrument.

Interpretive validity

Validity with respect to how well the concept maps represented students' STEM career awareness, was established by congruency between the focus group interviews and concept mapping analysis results. In addition, the interviews enabled addressing students' values, interests, and abilities, thus supporting the translation validity of the STEM career awareness definition.

Reliability

To exclude the possible maturation effect on students' STEM career awareness, which in turn could jeopardize identifying the true impact of the intervention, additional data collection with concept mapping and semi-structured focus-group interviews was conducted in one of the MultiCO intervention schools. This step enabled the determination of, how students' STEM career awareness developed, without special intervention, thus provide reliability to the results.

4. FINDINGS

4.1. Relevance supporting scenario characteristics

The pre-intervention stage (amplified in Article I), focused on answering research question 1: ‘Which scenario characteristics support perception of relevance for studying science topics?’

Findings from analysing scenario titles

The analysis of the titles resulted with three categories:

1. ‘Format of the title’ (a statement, a question or extended question),
2. ‘Field of focus’ (scientific, socio-scientific/mathematical, social) and
3. ‘Impact range’ (impersonal, personal, local, and global).

It was found that majority of the scenario titles used either a traditional question or an extended question format (56 out of 77) and focused on socio-scientific/ mathematical, or social issue (43 out of 66). In terms of the impact level, it was detected that more than third of the titles were impersonal (25 out of 66), but the rest had an impact range of either personal, local, global, or a combination of these.

Findings from analysing scenario texts

Two categories, namely ‘impact range’ and ‘field of focus’ was applied to scenario text analysis, but one additional category ‘role of application’ was identified. The latter differed among scenarios in a way, that some scenarios (N = 14) included examples of how a scientific concept was applied, resulting in the subcategory ‘application as an example’. Other scenarios (N = 52) showed evidence that the scientific/mathematical/social concepts were put into practice for solving problems resulting with the subcategory ‘problem solving through application of scientific/mathematical/social concept’.

Congruence between scenario title and text

As the title was followed with a scenario, it was considered valuable to determine whether the scenario promoted relevance congruently with the title. For this, two categories were used: ‘the impact range’ and ‘field of focus’. It was found that the title indicating personal impact was not necessarily followed with a personally impacting scenario, and an impersonal title was rarely turned into a personal scenario (Figure 2 in Article I, p. 207). Moreover, impersonal titles and scenarios were mostly focusing on science only. These results were taken as an indication for the need to pay special attention on how well curriculum topics related to students’ everyday lives and with issues currently faced by the society.

4.2. The impact of implementing STEM career-related scenarios on students' study motivation

The intervention stage was the focus of Article II addressing research question 2a: 'How do STEM career-related scenarios impact on students' motivation (in terms of IRE) to study science topics at middle school level (Grades 7th–9th)?' The acronym IRE refers to three constructs—interest, relevance, and enjoyment (like) and those—mediated by prior knowledge—were considered as study motivation triggers and were used to determine, how well the scenarios supported the achievement of students' study motivation.

Altogether 32 scenarios were developed by MultiCO project partners and 29 of these are currently available on the MultiCO project website (http://www.MultiCO-project.eu/career-based-scenarios).

In this thesis, results from evaluating one scenario, namely *"Electricity in the air"* were analysed, by following the categorization determined with exploratory factor analysis. Evaluation outcomes of other scenarios developed within MultiCO project, could be found on the MultiCO website (http://www.MultiCO-project.eu/deliverables1) under deliverable D3.1. The results from evaluating motivational triggers perceived from "Electricity in the air" scenario (Article II) were as presented in table 9.

Table 9. Evaluation of motivational triggers perceived in scenario "Electricity in the air" *(Article II, table 3)*

Category	Items	Mean (N)/ Standard deviations
Learning value	1. This scenario enables me to gain new knowledge about the scenario's topic. 2. The knowledge I gain from the scenario may be useful in the future. 3. I can put knowledge gained from the scenario into practice, to solve problems. 4. From this scenario, I am able to gain new knowledge about possible career(s). 7. I find this scenario topic important for me personally. 8. I find this scenario topic important to my family. 10. I find this scenario topic important for learning school subjects. 26. I find the information in this scenario valuable to me.	2.85 (N=137)/.45

Category	Items	Mean (N)/ Standard deviations
Vocational value	12. I feel my future career may be connected with the topic covered in the scenario. 13. I think my future studies at the gymnasium or university level may be connected to the topic covered in the scenario. 14. I predict I will need to perform skills, described in the scenario, in my future career. 15. I predict I need to perform science-related skills described in the scenario, in my future career. 16. The scenario describes the science community, to which I relate. 28. The scenario makes me want to learn more about the topic.	2.30 (N=135)/.59
Scenario attributes	19. The scenario is easy to follow. 20. The scenario is easy to understand. 21. The find this scenario enjoyable. 22. I like the format of the scenario.	3.08 (N=135)/.60
Career awareness	5. This scenario enables me to understand the responsibilities of the persons in the career positions indicated. 6. This scenario enables me to understand the skills that are necessary in these professions.	3.34 (N=140)/.57
Social value	9. I find this scenario topic important for appreciating the work of our local community (town, country). 11. I find this scenario topic important for the whole world. 17. The scenario presents a scientific problem, which is socially relevant. 18. The scenario makes it easy for me to relate with the situation described.	3.03 (N=137)/.48
Like and interest	25. I find this scenario interesting to me. 27. I liked the scenario.	3.08 (N=142)/.90
Background knowledge	23. I know (...?) about the careers described. * 24. I know (...?) about the topic in the scenario. *	.99 (N=142)/.40 1.10 (N=140)/.39

Note: For items 1–22 the rating scale was defined as 1— 'totally disagree' to, 4— 'totally agree' and for items 25–28, a 3-point rating scale was defined as 'do not agree', 'cannot make up my mind', 'agree'). * Scale defined as 0—nothing, 1—a little, 2—a lot

Based on the analysis of students' responses as indicated in table 9, students

(a) positively perceived the learning value,
(b) considered the scenario well presented,
(c) claimed gaining awareness of work responsibilities and needed skills for the described careers,
(d) perceived the social value of the topic,
(e) and considered the scenario as interesting and enjoyable.

Nonetheless, the scenario was not enough to motivate most students to study the topic of renewable energy sources further, or to consider further studies and a career in relating fields as a future possibility.

An analysis of students' written answers, ascertaining why they perceived relevance, interest, enjoyment and motivation, or the lack thereof, gave further insight that study motivation was heavily influenced by the topic interest, as well as by the perceived practicality of gained information in the near, or more distant future.

Even though the topic of renewable energy was not considered as something students would like to learn more about in the future, students generally indicated that the scenario was interesting and enjoyable, based on the way it was presented and its connectedness with everyday life.

4.3 The impact of implementing STEM career-related modules (TLMs) on students' study motivation

The intervention stage additionally led to Article V, which focused on the research question 2b: 'How do STEM career-related modules (TLMs) impact on students' motivation (in terms of IRE) to study science topics at middle school level (Grades 7^{th}–9^{th})?' The findings gained with the module evaluation questionnaire were presented in Appendix 2.

Students' responses showed that students gained new knowledge regarding all TLM topics. All TLMs (except "Houses where we live"), enabled students to relate themselves with the situation described in the module. Students' perceptions of importance at different levels (personal, school, family, local community, global) varied between TLMs. Personal importance was perceived with three TLMs: "Electricity in the air", "Oil—the king of the World" and "CITES". Importance for learning school subjects was perceived with all TLMs except "Crime scene" and "Houses where we live". Importance for ones' family was perceived with only one TLM, the "CITES". Importance at local level was perceived with all modules except the "Crime scene" and at global level with all modules.

Module evaluation enabled students to indicate whether they could possibly apply the (science) skills in their future careers. It was found that for the first two modules, students indicated the possibility to apply developed skills for their future careers, whereas only for the fourth module ("Oil—the king of the World") developed science skills were applicable for students' future careers.

Interest and enjoyment were perceived by majority of students with all TLMs. However, none of the TLMs succeeded with motivating most students enough to be willing to learn TLM topics further. One noticeable exception is the first module "Electricity in the air" which supported students' study motivation among twenty students out of 51 (39%). The rest of the modules were considered as motivating for 22% of students ("CITES") or for considerably less students. (Table 6, Article V)

Results from open ended questions

Open ended responses gave further insight to why students (did not) perceive(d) interest, enjoyment, relevance, and motivation for studying science topics further when working with the modules. The first noticeable result from analysing the open-ended responses was the diversity of reasons.

The first two modules were considered as interesting mostly for their hands-on approach (constructing a solar panel and making experiments with soft drinks). "Crime scene" was mostly interesting due to the curiosity inducing effect. These students who were interested in geography and civil engineering, considered "Houses where we live" module as interesting. The fourth and the fifth module were interesting mostly due to their knowledge growth supporting properties.

Enjoyment was perceived mostly due to alignment with students interests but was also perceived based on how the TLMs and overall learning environment supported interestingness of the topic.

Table 10 presents the reasons for (not) perceiving relevance of the information gained from the TLMs.

Table 10. Students' reasons for perceiving relevance of the information gained from TLMs

TLM	Grade	Agree/ Disagree	No. of responses	Categories of the reasons (Frequency)
Electri-city	7	Agree	40	Usefulness (24), Knowledge (8), Environment (4), Career (2), Instructions (2)
		Disagree	8	Usefulness (5), Importance (2), Career (1)
Sugar tax	8	Agree	26	Knowledge (12), Usefulness (9), Career (2), Emotion (1), Environment (1), Subject (1)
		Disagree	5	Career (2), Importance (2), Usefulness (1)
Crime scene*	8	Agree	5	Usefulness (3), Career (2)
		Disagree	8	Usefulness (5), Importance (3)

TLM	Grade	Agree/ Disagree	No. of responses	Categories of the reasons (Frequency)
Houses*	8	Agree	7	Knowledge (5), Interest (2)
		Disagree	6	Usefulness (4), Career (1), Importance (1)
Oil	9	Agree	40	Usefulness (16), Emotion (10), Environment (10), Importance (3), Interest (1)
		Disagree	6	Usefulness (5), Importance (1)
CITES	9	Agree	50	Knowledge (24), Usefulness (13), Emotion (7), Importance (4), Career (1), Interest (1)
		Disagree	9	Usefulness (5), Importance (2), Career (1), Emotion (1)

Note: * Schools could choose either one of the TLMs

Whether students considered the information gained from TLMs as (not) relevant seemed to be mainly influenced by the perceived usefulness either for the near or more distant future. With most TLMs, students valued becoming more knowledgeable about TLM topics and plus about STEM careers introduced to them. Article V indicated that students' study motivation was mostly influenced by students' interests which did not align with the TLM topics for most of the students.

4.4. The impact of using STEM career-related modules (TLMs) on students' STEM career awareness (SCA)

The post-intervention stage resulted with Articles III and IV which focused on the research question 3a: 1. What impact do STEM career-related teaching and learning modules (TLMs) have on students' awareness about possible STEM careers and relevant competences?

Findings from the analysis of students' responses to the CAA questionnaire

When students were asked to evaluate the relevance of various competences for STEM careers in the CAA questionnaire, it was found that both the EG and the CG students considered all the competences except 'technological skills' (product design and production) as relevant (mean over 2.5 on 4-point scale) in 7^{th} grade (Table 3 in Article III, p. 1682). Further comparison between the pre- and post-intervention data resulted with detecting progress in relevance of several competences for STEM careers among the EG, but not among the CG. More specifically, competences like 'written presentation skills', 'logical thinking', ‘scientific knowledge’, ‘independent work’, ‘analysis skills’, ‘precision and accuracy’, ‘technological skills’ gained significantly more relevance among the EG students in 9th grade in comparison to 7th grade. Other competences remained as relevant for STEM careers among the EG students in 9th grade.

The only significant growth among the CG was detected with relevance of ‘problem solving’ for STEM careers. On the contrary, several competences like ‘open mindedness’, ‘collaboration’, ‘communication’, had significantly lost their relevance among the CG. ‘Technological’ skills remained irrelevant for science-related careers among the CG. The rest of the competences were still considered relevant for STEM careers in 9th grade.

Implementing the CAA questionnaire, additionally determined whether the intervention had any detectable impact on recognizing the relevance of various competences for careers to which students aspired. Table 4 in Article III (p. 1684) showed that the EG students in Grade 9 valued ‘reasoning’, ‘open-mindedness’, ‘activity-planning’, ‘analysis skills’, ‘evidence-based decision making’ and ‘technological skills’ significantly more for their aspired careers, in comparison to 7th grade. Moreover, ‘scientific problem solving’, ‘scientific knowledge’, ‘scientific experiments’, which were considered as irrelevant in 7th grade, were seen as more relevant in 9th grade, by exceeding the 2.5 relevance rating. On the contrary, these competences made a further drop in relevance ratings among the CG in 9th grade.

Findings from the analysis of students’ concept maps

Article IV approached research question 3a with implementing concept mapping technique (Novak, 1995). Table 1 in Article IV indicated that the results from analysing students’ concept maps showed positive impact on most boys’ and girls’ STEM career awareness. Significantly more occupations and competences were used by most boys and girls among the experimental group (EG) in 9th grade, whereas among the control group (CG), significant changes were detected only among girls.

‘Technological skills’ (product design and production) together with ‘creativity’ were the least used competences among the CG (both 3%) and similarly ‘technological skills’ was the least used among the EG (4%) in 7th grade in students CMs. ‘Technological skills’ became as often used as ‘creativity’, ‘computer skills’ (all 15%) among the EG, whereas among the CG it was used even less than in 7th grade (2% usage).

When 7th and 9th grade students from the additional students’ group (AG) were compared, it was found that boys were more aware of both occupations and competences, but no significant differences were detected among the AG 7th and 9th grade girls (Table 2, Article IV).

Further comparative analysis between the AG and the EG 9th grade students aimed to detect, whether career-awareness promoting intervention had greater impact on students’ SCA in comparison to regular teaching. It was found that among boys, no significant differences occurred. The girls in the AG were more aware of the relevant competences, whereas the EG girls showed greater awareness in STEM occupations in 9th grade.

Nonetheless, the overall use of competence concepts among both the EG and the CG in 7th and 9th grade was rather low reaching as high as 30% of possible uses for one competence ('scientific knowledge' among EG 9th grade), whereas among the AG in 7th grade most competences were around 30% of use and in 9th grade all were over 30%. The most used competence reached over 50% ('scientific knowledge') (Figure 3, Article IV).

Findings from the interviews conducted with the additional group of students (AG)

Noting the high relevance ratings of competences in the CAA questionnaire, thus indicating good SCA, but low use of competences on concept maps, thus demonstrating poor SCA, interviews were conducted with the additional student group (AG) regarding their concept maps, to understand students' thought process while constructing concept maps, and thus providing interpretive validity.

Article IV represented, in addition to changes in students' STEM career awareness, the AG students' thoughts regarding STEM careers, concept mapping and their SCA. Table 3 in Article IV showed that the need of scientific knowledge and its application at work was emphasized the most while describing STEM careers, followed with research and laboratories, and science disciplines taught at school, plus with nature and environment. This insight gave credence as to why 'scientific knowledge' was the most used competence in students' CMs and geologist, cell biologist, laboratory manager and laboratory worker, microbiologist, biochemist, and environmental protection specialist were considered as STEM occupations by large majority of the students, and why electrical and construction engineer by much less students.

The AG students' evaluation of their SCA were modest, reaching to 4 or 5 on 5-point scale for only 2 students, who both claimed to have undertaken independent research on STEM career possibilities. In general, the AG students claimed, that although they were familiar with the presented occupations and competences, they indicated that they lacked awareness about the specifics of STEM occupations. (Table 5, Article IV)

Concept maps were either considered as a total, or partial representation of their SCA by most students (25 out of 37), although some students also indicated it restricted them from being able to describe how some occupations were linked to science and why. In addition, for most AG students (27 out of 37), concept mapping was neither easy nor difficult (2 or 3 accordingly on a 5-point scale), but they indicated they had to think about several things at a time and some of them claimed being unsure on how narrow or wide they needed to think about the given task. The latter aspect was particularly well pronounced with considering occupations such as factory manager, journalist, being seen as potentially science-related or with competences considered relevant for STEM careers. A large proportion of students (22 out of 37) lacked the ability to consider provided competences relevant for all the occupations. (Article IV)

4.5. The impact of using STEM career-related modules (TLMs) on students' career aspirations

Article III focused on research question 3b: What impact do STEM career-related teaching and learning modules (TLMs) have on students' career aspirations? Figure 1 in Article III showed, that the EG students aspired the most to careers associated with science and engineering professionals' group (ISCO1), which included engineers', scientists', designers', and architects' occupations (62% in 7th and 52% in 9th grade). Additionally, the EG students' aspirations towards science and engineering professionals were more stable, in comparison to CG—39% of the EG and 19% of the CG students still aspired to a career in that field in 9th grade. Significantly more of the EG students indicated a consideration of two professionals' groups, namely teaching (ISCO3) and business and administration (ISCO4) professionals after the intervention. (Table 2 in Article III, p 1682)

5. DISCUSSION

The designed and tested teaching and learning modules were developed to support:

1. students' study motivation in science subjects, through perceived interest, relevance, and enjoyment (IRE) and
2. support the development of students' STEM career awareness.

It was predicted that when students' motivation was supported and when students were given the opportunity to 'step into the shoes' of a STEM occupation holder to experience what it is like to apply the skills and knowledge into practice, then students' aspirations towards STEM career fields would also be supported.

The following sections discuss:

1. which scenario characteristics support relevance?
2. how did STEM career-related a) scenarios and b) TLMs impact on students' motivation (in terms of IRE) to study science topics at middle school level (Grades 7–9)?
3. what impact did STEM career-related teaching and learning modules (TLMs) have on a) students' awareness about possible STEM careers and relevant competences and b) students' career aspirations?

5.1. Promoting relevance with scenarios

Relevance is a term, which does not have one particular definition (Stuckey, 2013). Levitt (2002) and Keller (1983) have looked at relevance from student's perspective and interpreted this through perceived usefulness, importance, and meaningfulness of learning instruction. Teaching and learning modules are one form of instruction for guiding the learning process, which have been used in different projects like the PROFILES (n.d.).

Contemporary content analysis conducted on the TLM titles and scenarios, drawn from the PROFILES project webpage, showed that educators, who had developed the scenarios, aimed to induce relevance in the scenario titles mostly through a question format, a socio-scientific problem setting and through relatable contexts.

The use of a question, or extended question format as a title have the potential to induce curiosity and familiarity among readers (Berlyne, 1960). To do that, cognitive conflict between what is already known and the new information, need to be perceived (Berlyne, 1960; Loewenstein, 1994). Thus, when the title is in a question format, but refers to scientific terminology in an unfamiliar context for students, little relevance is expected to be perceived by many students. Many researchers have pointed out that to make science content meaningful and interesting to students, there is a need to connect it with everyday life (Aikenhead, 2006; Broman, Ekborg & Johnels, 2011; Broman & Simon, 2015). For example, one module from the PROFILES project (n.d.) was titled:

"Why do cans of Coca-Cola sink, while cans of Coca-Cola Zero float?"

This title is expected to produce curiosity to explore, whether the claim that Coca-Cola sinks and Coca-Cola Zero floats is true or not. If it is true, then this leads to reflecting on what could be the reason. Also, Coca-Cola is expected to be known to most students, either through consumption or through commercials. Thus, it is fair to claim that this is probably part of students' everyday life and therefore relevant to students.

In the text passages which followed the title, additional characteristics describe the applicability of the scientific/mathematical/social concepts, and most scenarios indicate applying new concepts in a problem-solving situation. A comparison of the titles and the following text passages nevertheless show that personally impacting, thus relatable titles, are not always followed by personal text passages (Figure 2, Article I). Even more, titles and scenarios, which focused on pure science, point to a lack of reference to a personal impact.

The current study used the scenarios which were developed by 124 educators who participated in the PROFILES project. Analysing the scenarios separately from their developers had its limitations in that it was impossible to detect the rationale why educators chose to pursue an impersonal and pure science focused approach for developing scenarios, even though the scenarios were developed post-training related to how to develop scenarios for promoting relevance among students. Some explanation could be drawn from a study conducted by Rannikmäe (2001). She studied a group of science teachers who underwent an in-service teacher training course to promote the implementation of "scientific and technological literacy for all" philosophy in teaching. The participating teachers were introduced with principles behind this overarching teaching philosophy, including social issue based, student-centred approaches, enabling problem-solving, and a decision-making way of teaching science. Rannikmäe (2001) found that there was one group of teachers she described as "subject learning activity based" and their teaching focus continued to be on scientific facts, concepts, and preparation for examinations. Although these teachers valued collaboration among students while learning science, the scenarios they developed were full of scientific concepts and application of these were presented as an example. Rannikmäe (2001) linked this finding with teacher ownership and concluded that among this group of teachers, attitudes were hard to change, and these teachers were unable to make "scientific and technological literacy for all" philosophy as part of their teaching practices.

An alternative explanation might be linked with a perceived paradox in the portrayal of science conceptualisations in a school science context through scientific texts. Science tended to be mostly communicated in a passive voice and in an impersonal manner and pure science was promoted as being important and relatable to scientists (Osborne & Dillon, 2008). Thus, while it was probable that impersonal scenarios were suitable for those students, who were interested in science and wanted to pursue this career path, who were "learning to become a scientist" (ibid.). Nonetheless, most students fell into less specific category, among which many students had difficulty in being interested in science studies (Petersen & Hyde, 2017; Potvin & Hasni, 2014) and perceived little value in pursuing a STEM career path (Potvin & Hasni, 2014). While a socio-scientific issue context enabled the familiarising of science and making it relatable to students (Sadler, 2009), this was limited to only when the social context was part of students' lives, or they personally perceived the importance of the issue posed (Article II). Thus, when scenarios indicated that students were able to apply gained knowledge and skills, for example in resolving an issue then the usefulness of the learning activity was claimed to be induced. This claim was supported by the analysis of results based on students' feedback from the scenario "Electricity in the air" and from all developed modules (Articles II, V). Even more, this claim could be developed further in current learning situation by incorporating information and activities, to support STEM career awareness, in the scenarios and follow-up activities. The TLMs, developed in the MultiCO project (n.d.) implemented both information about, and activities, involving STEM careers to show the applicability of learning science.

5.2. Promoting study motivation with teaching and learning modules

For the intervention phase, 6 teaching and learning modules (TLM) were developed, with 5 implemented in all three experimental schools (Article V). The development of the TLMs and especially the scenarios, took into consideration findings from the scenario analysis (Article I). Furthermore, attention was given to promoting motivation triggers, namely relevance, interest, and enjoyment (like). Thus, the chosen contexts were made familiar and relatable to students, if not for all, then for most students. The inclusion of mobile phones, lemonade and public debate about sugar tax, local town planning, recent news about oil leakage in the coastal area and travelling with the bringing gifts were predicted to be part of students' lives and this was confirmed by the findings from students' feedback to the TLMs (Article V).

Each TLM was designed to include a socio-scientific issue, thus considered to show the importance of learning science to help with resolving issues faced by the society. Students were involved in building a renewable energy source—a solar mobile charger; participated in a debate about the pros and cons of sugar tax; simulated solving a murder mystery or helped to plan the making of old blocks of flats within a city more energy efficient and 'smart'; found a solvent for dissolving oil off from contaminated water birds' feathers; and dealt with the trade of endangered species often brought as gifts from exotic travel destinations. However, students' feedback regarding the personal importance of the module topics perceived by students varied. The 1st, 4th and 5th module were above 2.5 (on 1–4 scale), which could be considered as being personally important.

Importance at a family level was only perceived with the "CITES" TLM, whereas at a local and global level importance was perceived with all modules (Article V). One exception was detected: the murder investigation module was not seen as important topic at a local level.

These findings were similar to the findings presented by the Finnish partners of the MultiCO project. They found that students recognized the importance of the socio-scientific issue on a local and global level but not for themselves (Salonen et al., 2018). However, Tolppanen et al. (2019) in addressing the problem of over-consumerism through the implementation of life cycle analysis received personal value ratings from students slightly higher than 2.5.

Derived from the results presented by Salonen et al. (2018), Tolppanen (2019) and Article V, it seemed that some modules which focused on global issues, were considered as personally important to the students. Future research could meaningfully investigate, whether perceived importance at both a global and personal level helped students to take action in resolving societal issues such as over-consumerism, energy deficit and extinction of species. In addition, future research could investigate how actions were affected by not perceiving global societal issues as personally important.

To ensure a perception that the TLM activities were meaningful, modules followed the Estonian National Curricula for Basic schools (Estonian Government, 2011a). All the modules included collaborative hands-on and/or investigative activities: designing and constructing (1st module), conducting experiments (2nd, 4th modules), problem solving (3rd, 5th modules) (Article V). The feedback gained from students showed that they became more knowledgeable about the topics covered and saw the possible usefulness of gained knowledge for the future and in problem-solving situations (Table 3, Article V). There was, however, one exception: students did not see the applicability of knowledge gained from "Crime scene" module. These results were similar with the findings from Finnish studies, where students reported becoming more knowledgeable about life-cycle analysis (Tolppanen et al., 2019), evaluation of water quality in local lake (Salonen et al., 2018), but not so much about dentistry and the role of carbon in a toothpaste (Salonen et al., 2019b). These results showed that both Estonian and Finnish students recognized the learning fascilitated by the TLMs and appreciated the knowledge gained from learning with the TLMs. However, not all modules were perceived as providing information to students which was applicable. These findings seemed to be linked with students' attitudes towards learning and what they considered as valuable learning. Some students seemed to be certain that information gained from modules was not applicable in their future lives. This suggests that for those students it was very important to provide a rationale regarding the possible value of learning something that was perceived as irrelevant for them.

To increase the perceived usefulness of learning science in the near and more distant future, a range of STEM occupations were introduced: *e.g.* electrical engineer, electrician, environmental protection specialist, product designer, food technologist, chemist, biochemist, microbiologist, civil engineer, geographer, city planner, pharmacist, criminologist, customs officer, rescuer, firefighter, zoologist, biologist. After every module, students were asked to deliberate on which skills and knowledge they developed and for which occupations these could be applied. The perceived usefulness was shown to play major role in the overall value of the modules (Article V). As most of the students did not consider the introduced STEM careers as being for themselves, when measured after the end of each module (Article V; Salonen et al. 2018; Tolppanen et al. 2019), it was expected that they did not perceive the science competences as valuable for their future careers. Against this, when students were asked about the value of different competences for their future career, after the end of the intervention, science competences were valued by the experimental group, but not by the control group students (Article III). Therefore, this seemed to suggest that the implemented TLMs had a gradual effect on students' perception of their value competence-wise. This finding indicated a novel perspective to possible positive impacts provided by STEM career awareness promoting interventions, implemented in school science classes.

All modules were designed to support interest through providing novel experiences, activities, and visits. Findings showed that for most students, positive signs of situational interest were detected, based on the novelty of the experiences (Article V). This seemed to agree with Tolppanen et al. (2019) who detected that getting to know careers related with environmental issues provided an element of surprise. In the current research, positive emotions, such as excitement, were indicated by students and hands-on investigative and collaborative activities were perceived as interesting and enjoyable (Article V). Similar findings were reported by Salonen et al. 2018, Tolppanen et al. 2019 and Salonen et al. 2019b.

Findings further indicated that there were students who reported having individual interests in science topics, addressed within the modules, or towards science overall (Article V). But there were also students who claimed that they were not interested in the subject, or in the described careers, and as a consequence indicated that they did not consider the modules interesting. These findings related to interests in the TLMs could be interpreted from the perspective of SCCT theory (Lent et al., 1994) as indicators of students' cognised goal reflections and showing the role of interest as motivation trigger from the SCCT and SDT (Deci & Ryan, 2000) perspectives. This provided an explanation, seemingly indicating that motivation to learn more about module topics was not supported for most students. Students' open-ended responses were indicative of students' self-perceptions regarding modules: either having other interests or being certain of not needing the knowledge or skills developed in the modules. For some students, the modules were perceived to be too complex to allow further learning, whereas for other students perceived complexity was seen as an attainable challenge (Article V). This finding was an indication of the degree to which perceived effort (Wigfield & Eccles, 2000), students' self-efficacy (Lent et al., 1994) and competence perception (Deci & Ryan, 2000) either supported or hindered pursuing science studies, thus motivation. Therefore, the current research could be seen as providing support to findings by Van der Vleuten et al. (2016), which implicated the importance to pay attention to students' self-efficacy and competence perceptions in science classes to motivate students to learn science subjects and to pursue careers in science and related fields.

5.3. Intervention impact on students' STEM career awareness

The intervention on seeking to raise students' STEM career awareness was intended to serve a two-fold purpose. In addition to showing students the value of learning science, it was expected to develop an image, which was in line with characteristics of STEM careers presented by Jang (2016) and ILO (2012). This image of STEM careers was intended to be more than the ability to name more occupations, which apply scientific knowledge or skills, compared to the pre-experimental state. The desired image of STEM careers included a recognition that in addition to science competences, general skills were important, such as collaboration, communication skills, creative thinking (ILO, 2012; Jang, 2016). In undertaking this research, it was expected, that through engaging in activities mimicking work tasks of STEM occupations, students who recognized the value of creative thinking, collaboration, communication, and other general skills, would recognize that these skills were also applicable in learning science. Furthermore, science competences, such as experimenting, scientific problem solving, technological skills and scientific knowledge, would be seen as providing value for all occupations to which students aspired (not necessarily science-related). Although introducing STEM careers and the applicability of science skills and knowledge, as stated in the Estonian National Curricula (Estonian Government, 2011a, b), could be perceived as showing the usefulness of learning science, a holistic approach was seen as lacking for developing students' career awareness, which was proposed by Wise et al. (1976). Thus, career-awareness promoting science teaching should be recognized as also enabling self-reflections on how learning experiences benefit the achievement of students' career goals, related to career knowledge, personal values, work characteristics preferences and self-concepts levels. Nonetheless, whether science teachers were equipped to provide this kind of approach for developing students' STEM career awareness, could be perceived as an issue, which needed to be addressed in future research.

In the current study, science teachers were provided with teaching and learning modules, where mostly knowledge aspect of career awareness was addressed. More specifically, students were introduced to different STEM careers, related to curricular topics. Students were enabled to experience, through various hands-on activities, what it felt like to be an electrical engineer, a biochemist in a lemonade factory, a forensic scientist, a civil engineer, a volunteer in an oil catastrophe clean-up simulation and a customs officer involved in stopping the trade of endangered species (Article V). By asking for students' feedback regarding the modules enabled students to reflect on which skills/knowledge they gained and for which occupations these could be utilized. Furthermore, the module evaluation questionnaire enabled students to deliberate on their interests and values, and whether these were supported with module activities. Thus, the current study attempted to move towards providing a holistic approach to STEM career awareness promoting science teaching.

The positive effect of the intervention on students' career awareness was detected with the career aspirations and awareness (CAA) questionnaire (Article III), concept maps (Article IV) and module evaluation questionnaire (Article V). It was found through the CAA questionnaire, that the intervention helped to maintain the relevance of collaboration, communication, and open-mindedness for STEM careers among the experimental group students (Article III). In the module evaluation questionnaire, EG students claimed that they were most often involved in the development of collaboration and/or teamwork skills and plus practical skills during module activities (Unpublished), which added evidence to the intended intervention impact on shaping students' image of STEM careers. These findings were important in mitigating against the image where scientists were often considered as working in solitude (Finson, 2002) and work practices of STEM careers as lacking communal characteristics (Diekman et al., 2011).

Moreover, as expected, problem solving, scientific knowledge, analysis skills, gained importance for students' aspired careers (mean over 2.5) and evidence-based decisions, scientific experimenting, technological skills became significantly more relevant for students' career aspirations among the experimental group students after the intervention (Article III). However, among the control group, these competences made a further drop in relevance, with two exceptions being evidence-based decisions and technological skills (Article III). These findings indicated that learning science with TLMs impacted the perceived utility value of several science competences among the experimental group students.

One surprising finding was related with the value of creativity and technological skills (product design and production) for STEM careers. Salonen et al. (2019a) and Dewitt et al. (2013) found that creativity was not commonly associated with a STEM career path. Contrary to these findings, both the EG and CG students valued creativity as highly relevant for STEM careers: mean was around 3, on a 4-point scale among surveyed students in both 7th and in 9th grade (Article III). However, creativity was not commonly used in students' concept maps by both the EG and the CG. Thus, further research would be needed to determine how students perceive the role of creativity for STEM career holders.

Franz-Odentaal et al. (2019) determined, that middle school students did not know about the career of engineers. Designing and being part of production, was relevant to not only engineers but also for other STEM careers (ILO, 2012). In the current study it was found that technological skills were not considered as important for STEM careers among the EG in 7th grade but became significantly more valued in 9th grade (Article III). Among CG, technological skills remained irrelevant for STEM careers. Derived from the results gained with the CAA questionnaire (Article III) and the module evaluation questionnaire (Article V) it could be claimed that the students who were participating in the intervention, had developed an image of STEM careers, which was more in line with the actual STEM careers competence wise (ILO, 2012; Jang, 2016) compared to the image developed with traditional teaching.

5.4. Intervention impact on students' career aspirations

The intervention addressed students in the grades 7–9 (average age 13–15 years old accordingly). This was seen as the age when students started to deliberate and make decisions about their future career (Gottfredson, 1981). Therefore, raising students' awareness of STEM careers in terms of work characteristics such as needed competences, forms of work, and about variety of career prospects, was expected to be most helpful for considering STEM career path for oneself. Nonetheless, empirically it was shown that even though students became more knowledgeable about STEM careers, their career aspirations remained unchanged (Archer et al., 2013; Salonen et al., 2018; 2019; Tolppanen et al., 2019). In the current study, through comparing students' career aspirations in the 7th and 9th grade, it was found that proportionally more students in the experimental group were still considering a STEM career path and less students had lost their aspiration towards STEM careers, in comparison with the control group (Article III).

Although career aspirations indicate students' career ideals (Wise et al., 1976) they still represent whether students consider STEM career path for themselves. As it is impossible to eliminate influencers from social contexts besides the school context as well as prior experiences, these inevitably influence students' final career decision which students need to make (Diekman et al., 2011; Eccles & Wang, 2016; Gottfredson, 1981). Nonetheless, it could be seen as the responsibility of science education to give an overview of STEM career prospects (Estonian Government, 2011a, b) so students could make career decisions based on knowledge, as opposed to be based on stereotypical images.

The evidence collected in the current research did not directly point to the causal relationship between the intervention and career aspirations. However, the evidence collected through the module evaluation questionnaire indicated that the intervention had an impact on guiding students to seeing the value of science studies, enabled science studies to become interesting and introduced STEM careers (Article V). Prior studies showed that the positive image of school science influenced students' career aspirations towards science fields (Maltese & Tai, 2011; Shirazi, 2017). Thus, the intervention supported the maintaining of students' STEM career aspirations arguably through sustaining a positive image of school science.

6. LIMITATIONS

The current study addressed the issue of students and especially girls not aspiring to a career in STEM fields through the implementation of teaching and learning modules (TLMs) in school science classes among middle school students. However, the issue was recognized as complex in its nature and its resolution required considerations of societal, psychological, and educational aspects. This attempt sought to include all these aspects, but its limited nature was recognized. In addition, the author recognized that the current thesis did not resolve the issue in its entirety with its focus on science education. However, the results of this thesis identified possible benefits of implementing TLMs on STEM career awareness in schools.

The content analysis of scenarios focused on scenario texts separately from their implementation in the classroom. Although most scenarios contained relevance promoting characteristics, it was recognized that teachers and the overall learning environment had an influence on how relevant students perceived the scenarios in real learning situations. Additionally, as the focus was set on relevance inducing characteristics, other factors such as the length and the readability of the scenario texts, were not taken into consideration. However, it was known that these characteristics were also important and could influence text comprehension and reading interest.

Students' concept maps were analysed quantitatively for the current study. However, students' concept maps varied based on their structure and organisation of concepts. Future research with students' concept maps would help to determine the relationship between the organisation and the structure of concept maps, and the use of STEM career awareness representing concepts such as occupations and competences. An additional limitation regarding concept maps was the limited inclusion of both competences and occupations concepts provided to students. This led to excluding specific competences relevant for some specific STEM occupation holders. For example, ICT and medicine related occupations were left out from the list due to their relative popularity among adolescence. Although the number of concepts was limited, students could still be overwhelmed when constructing their concept maps within the set time limit. This might have impacted on how many concepts students used for constructing their concept maps. Thus, there remained the possibility that students were more knowledgeable about STEM careers than was detectable through the constructed concept maps.

The study design used, did not enable determination of causal effects on students' STEM career awareness and on career aspirations. This study took place in schools, which was one of the social contexts faced by students. However, students' STEM career awareness and career aspirations were probably influenced by other social contexts like the home, parents, friends, and the media. Thus, the effects of other social contexts could not be totally ruled out. A follow-up study with the experimental group students would be needed.

This research implemented a longitudinal quasi-experimental, pretest-posttest design with non-equivalent experimental and control groups. Two limitations arise from the chosen research design:

1. The intervention lasted altogether 3 years, thus student maturation occurred inevitably.
2. The control group was not the same size as the experimental group, therefore the results needed to be handled with caution.

The current study included 4 different Estonian schools in its sample, however according to *Haridussilm* (2021) there were 230 middle schools in Estonia. Thus, the results of the current study could not be generalized to all Estonian schools. Further research with larger representative sample should be conducted to determine Estonian students' knowledgeability about STEM careers. In addition, no Russian speaking schools were included in the sample. As Russians are the biggest minority in Estonia, it would be relevant to conduct similar research with Russian students.

7. CONCLUSIONS

The current doctoral dissertation covered a 3-stage study, which was driven by the following aims:

1. Determining, which scenario characteristics promote relevance to study science topics.

2. Determining the impact of STEM career related teaching and learning modules (TLM) on:
   a. Students' motivation to study science topics.
   b. Students' awareness of STEM careers (including awareness of possible occupations and competences needed in STEM careers).
   c. Students' career aspirations.

The pre-intervention stage found an answer to research question 1 (Which scenario characteristics support perception of relevance for studying science topics?) by analysing the scenario title and the associated text passages. Three inductive categories were produced for describing the titles: 1. 'format of the title' (a statement, a question, or extended question), 2. 'field of focus' (scientific, socio-scientific/mathematical, social) and 3. 'impact level' (impersonal, personal, local and global). It was found that the preferred ways for inducing relevance in the titles were through using socio-scientific context, question format and aiming for impact either on personal, local, global or through a combination of these impact levels. For inducing relevance in the scenario texts, two categories from title analysis applied (2 & 3). Nonetheless, it was found that less than half of the scenario texts were using socio-scientific context, and more than half of the scenario texts were impersonal. An additional category, 'role of application' with two subcategories 'application as an example' and 'problem solving through application of scientific/mathematical/social concept' were detected. In most of the analysed scenario texts, relevance was induced through indication of applying new concepts in a problem-solving situation. These findings regarding scenario titles and associated text passages were indications of TLM developers' perceptions about relevance inducing characteristics. These findings were important for educators who developed teaching and learning materials with scenarios to draw their attention to characteristics which were more likely to support or reduce the perception of relevance for learning science among students.

During the intervention stage, 6 STEM career-related TLMs were developed and 5 TLMs were implemented in 3 experimental schools with 5 classes (N = 104). The evaluation of the first scenario and the TLMs determined, how do STEM career-related a) scenarios and b) TLMs impact on students' motivation (in terms of interest, relevance and enjoyment) to study science topics at middle school level (Grades 7–9) (RQ2). The analysis of students' responses to the scenario and module evaluation questionnaire (Articles II, V) showed that STEM career awareness promoting TLMs were successful in providing enjoyable learning experiences and were perceived as interesting and relevant in different levels for most participating students. However, for the majority of students the TLM topics or careers did not align with their interests or career aspirations, thus the majority of students were not motivated to study science topics, addressed in the TLMs, further.

The post-intervention stage aimed to determine, what impact do STEM career-related teaching and learning modules (TLMs) have on students' awareness about possible STEM careers (RQ3a). To address this aim, a longitudinal quasi-experimental, pretest-posttest research design with non-equivalent experimental and control groups, was implemented. It was found that the intervention supported both boys' and girls' STEM career awareness, specifically raising awareness of STEM careers and competences relevant for STEM careers (Article III, IV). Furthermore, the intervention enabled students to become more aware of competences (both science competences and general skills) relevant for STEM careers (ibid.). However, among the control group, who did not participate in any STEM career awareness promoting intervention activities, several competences such as 'open mindedness', 'collaboration', 'communication', had significantly lost their relevance and technological skills (product design and production) remained irrelevant for STEM careers among the control group students. The current thesis provides a unique perspective about the effects of implementing STEM career awareness promoting intervention at school by showing that the intervention helped to support career awareness among both boys and girls. Thus, the intervention helped to create equal opportunities for both boys and girls to make informed decisions either towards or away from science and relating fields.

The last aim of the current thesis was to determine, what impact do STEM career-related teaching and learning modules (TLMs) have on students' career aspirations (RQ3b). It was found that among the students involved in learning through the use of STEM career awareness promoting TLMs, career aspirations within science and engineering field were more strongly supported than among the control group. Thus, the current thesis showed promising results which could potentially help with sustaining students' career aspirations in science and related fields.

8. RECOMMENDATIONS

Scientific recommendations

A recommendation from scenario and module evaluation open-ended responses analysis to the theory would be the detection of interest and relevance not having same sources or overlapping properties (in most cases). When students were describing, why they considered the module interesting, the mention of usefulness or other facets of relevance was rare. When students were asked to reason their perception of relevance, its interestingness or interest was rarely mentioned. Thus, the findings suggested that it was not justified to use relevance and interest interchangeably in research.

A recommendation from the current thesis to science education research is that the development and testing of a scenario evaluation instrument and its derivate module evaluation instrument enable to determine motivational triggers such as interest, relevance, and enjoyment when TLMs are used for learning science. In addition, career aspiration and awareness questionnaire (CAA) can be used for determining changes in students' career aspirations and in perceived relevance of competences for STEM careers plus for students' career aspirations, which are not necessarily science related. Concept mapping together with interviews can serve as a helpful technique for collecting visual data of students' STEM career awareness.

Practical recommendations

When developing scenarios aiming to be perceived as relevant and thus motivating for students to study science, one should pay attention to both the title and the follow-up texts being perceived as impacting students personally, linking scientific concepts with everyday life and with real and actual problems. Without showing the link between science and everyday life, students may question the usefulness of science studies possibly leading to reduced study motivation.

A recommendation from the evaluation of teaching and learning modules (TLM) is that students' study motivation is not directly linked with interest, relevance and enjoyment (IRE) while using TLMs for learning science topics. Students may feel IRE and motivated to learn when TLMs are implemented, but without the supportive learning environment, motivation can be lacking and thus needs constant nourishment through relevant and interesting science teaching. Therefore, in the situations when motivation to learn science topics is lacking, TLMs, as described in the current thesis, can support the positive feelings gained from science classes.

The use of concept mapping together with interviews encouraged students to deliberate on what they knew and how aware they were about STEM careers. Thus, concept mapping could be used by science teachers in science classes with students to visualize students' STEM career awareness and to encourage discussions regarding STEM careers and their characteristics.

The results of students' STEM career awareness and career aspiration changes indicate the importance of including STEM career awareness promoting TLMs, as described in the current thesis, in science teaching. Such TLMs help both the teachers and students to become more aware of STEM careers and competences needed in STEM careers, but also contribute towards a more positive image of science studies, its value, and its outcomes. Therefore, providing the teachers with STEM career awareness promoting TLMs and in-service courses, for supporting students' career awareness development in science classes, is highly recommended.

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SUMMARY IN ESTONIAN

Loodusteadustega seotud karjäärivalikut toetavate õppemoodulite kavandamine, rakendamine ja hindamine

Sissejuhatus

Loodusteaduste ja tehnoloogia (LTT) valdkonna spetsialistide järelkasvu tagamine on oluline, sest nendel on täita vastutusrikas ülesanne aidata ühiskonnal toime tulla keeruliste probleemidega, nagu fossiilkütuste asendamine taastuvate energiaallikatega, kasvav inimpopulatsioon ja sellega kaasnev suurem toiduvajadus, vananev elanikkond lääneriikides ja sellest tulenev surve tervishoiuteenustele. Võttes arvesse LTT valdkonnas töötavate inimeste vananemist ja pensionile suundumist, on selle valdkonna spetsialistide vajaduseks Euroopa Liidu piires hinnatud seitse miljonit inimest 2025. aastaks (Caprile *et al.*, 2015). Sealjuures ei ole LTT valdkonda suunduvate inimeste üldarv suurenenud ja naiste esindatus on väike (*ibid.*).

2015. ja 2018. aasta PISA testide alusel on Eesti põhikooliõpilased rahvusvahelises võrdluses loodusteaduste alal väga võimekad (OECD, 2016, 2019). Seetõttu on Eesti õpilastel suur potentsiaal saavutada edu loodusteadustega seotud erialadel. Samas ilmneb PISA uuringutest, et nii nagu teistes lääneriikides, näeb vaid väike osa Eesti õpilastest oma tulevikku seotuna LTT valdkonna elukutsetega ning see tendents ei ole kahe viimase PISA testi küsitluste järgi muutunud. LTT valdkonna spetsialistide nappust süvendab asjaolu, et tüdrukute seas on huvi inseneriteaduste ning info- ja kommunikatsioonitehnoloogia (IKT) erialade vastu võrreldes poistega tundavalt väiksem. (*Ibid.*) Töötasud nendel erialadel on ühed suurimad ning naiste vähene esindatus süvendab erinevusi naiste ja meeste palgas, samuti elatustasemes. Sellist tendentsi peetakse problemaatiliseks nii rahvusvahelisel (Dorph *et al.*, 2018; Van Griethuijsen *et al.*, 2015) kui ka riiklikul tasandil (Kukk *et al.*, 2017).

Õpilaste vähest huvi LTT valdkonna elukutsete vastu on seostatud puudujääkidega loodusteaduslike ainete õpetamisel (Krapp & Prenzel, 2011). Leitakse, et praegune õpetamisviis ei toeta õpilaste huvi LTT valdkonna vastu, LTT valdkonna väärtustamist (Potvin & Hasni, 2014; Sjøberg & Schneider, 2010) ega õpilaste LTT-alase karjääriteadlikkuse kujunemist (Blotnicky *et al.*, 2018; Soobard & Rannikmäe, 2014; Vaino *et al.*, 2015). Seetõttu on mitmed Euroopa Liidu rahastatud projektid, nagu PARSEL (Rannikmäe *et al.*, 2010), PROFILES ja ESTABLISH, loonud õppemooduleid, mida õpetajad saaksid loodusteaduslike ainete tundides kasutada, et toetada huvi ning LTT valdkonna ja erialade väärtust õpilaste silmis. Eelmainitud projektides loodud õppemoodulid järgivad kolmeastmelist mudelit (Holbrook & Rannikmäe, 2010) ja on oma olemuselt uurimuslikku laadi, lisaks algavad kõik moodulid sotsiaal-loodusteaduslikku probleemi sisaldava stsenaariumiga (Rannikmäe, 2001; Teppo & Rannikmäe, 2003). Ka siinse töö raames arendati ja rakendati õppemooduleid, mille lisafookus oli loodusteaduslike ainete õppimise kõrval LTT-alase karjääriteadlikkuse kujundamisel projekti MultiCO raames.

Stsenaariumil kui õppeprotsessi algataval õppemooduli osal nähakse suurt rolli õpitava olulisuse teadvustamisel, huvi tekitamisel ning stsenaariumile järgnevaks õppetegevuseks motiveerimisel (Bolte *et al.*, 2014). Õpimotivatsiooni toetamine loodusteaduslike ainete ja matemaatika tundides aitab suunata karjäärivalikuid, suurendades õpilaste pingutust õppimisel, mis omakorda avaldab mõju nende õpitulemustele (Lent & Brown, 2019). Kehvad õpitulemused mõjutavad õpilaste uskumust oma ainealasest võimekusest negatiivselt, vähendades nende motivatsiooni jätkata haridusteed LTT suunal (*ibid.*). Samas on õppemoodulite ja eraldi ka stsenaariumite hindamine pälvinud vaid vähest tähelepanu (erandina Teppo & Rannikmäe, 2003) ning puuduvad uurimisvahendid, mis võimaldaksid koguda karjääriteadlikkust toetavate õppemoodulite läbimise järel õpilaste tagasisidet siinses töös motivatsiooni päästikeks nimetatud konstruktide (huvi, väärtustamise ja meeldivuse) tajumise kohta. Need vahendid oli vaja doktoritöö raames luua.

Karjäärivalikuid mõjutavad ka eri karjäärivaldkondadega seotud stereotüübid, mis väljendavad inimeste karjääriteadlikkust (Gottfredson, 1981, 2002). Karjääriteadlikkus sisaldab peale teadlikkuse enda võimekusest, huvidest ja väärtustest ka teadmisi erinevatest elukutsetest, nende eripäradest ja vajalikest pädevustest (Wise *et al.*, 1976). Kuigi kõigil on õigus teha karjäärivalikuid ise, on oluline, et otsustamisel lähtutaks asjakohasest teabest. Õpilaste LTT-alase karjääriteadlikkuse suurendamise vajadusele osutatakse ka mitmes teadusuuringus, mis näitavad ühiskonnas juurdunud stereotüüpide negatiivset mõju õpilaste ja eriti tüdrukute karjäärivalikutele (Cleaves, 2005; Diekman *et al.*, 2011; Eccles & Wang, 2016; Gottfredson, 1981, 2002).

Stereotüüpselt on LTT valdkonda esindav inimene üksi töötav mees, kellel on prillid, valge kittel ja sassis juuksed. Ta on äärmiselt intelligentne ja ta on ümbritsetud ohtlikest kemikaalidest, meenutades hullu teadlase tegelaskuju Tartu Ülikooli muuseumis. IT valdkonnas on stereotüüpne pilt ilmselt teistsugune, kuid siiski on tegu mehega. Tal on juuksed patsis ja prillid ees ning ta töötab üksi arvuti taga. Problemaatiliseks muutuvad üldlevinud stereotüübid ja vähene teadlikkus variatsioonidest LTT karjäärimaastikul siis, kui õpilane tajub, et tal ei ole stereotüübile vastavaid omadusi. Kui õpilase minapildi ja stereotüüpse pildi vahel tekib tajutud konflikt, siis valitakse pigem karjääritee, mis läheb minapildiga rohkem kokku (Gottfredson, 1981).

Kool koos loodusteaduslike ainete õpetajatega võib kas kinnistada üldlevinud stereotüüpset pilti LTT valdkonnast või, vastupidi, aidata kujundada sellist pilti, mis näitab LTT valdkonna mitmekesisust. Õpilaste minapildi kujunemisele aitab kaasa see, kui kool toetab tajutud võimekust loodusteaduslikes ainetes ja huvi LTT õppeainete vastu ning rõhutab LTT valdkonna olulisust. Kombineerituna mõjutavad need õpilaste motivatsiooni LTT valdkonnaga edasi tegeleda.

Osaliselt on eelmainitu sõnastatud ka põhikooli ja gümnaasiumi riiklikus õppekavas (Vabariigi Valitsus, 2011a, 2011b), milles nii keemia, füüsika, geograafia kui ka bioloogia ainekavas on välja toodud ainealase huvi toetamine, ainega seotud elukutsete tutvustamine ning loodusteaduslikes ainetes omandatud teadmiste ja oskuste rakendusväärtuse teadvustamine. Sellest hoolimata on uuringutest selgunud, et näiteks gümnaasiumiõpilaste arvates ei ole nende teadlikkust LTT elukutsetest ja valdkonnas töötavatele inimestele vajalikest pädevustest arendatud (Soobard & Rannikmäe, 2014). Lisaks on õpilaste teadlikkust LTT elukutsetest hinnatud väheseks (Kivistik *et al.*, 2019). Kuna ka õpetajate teadlikkus LTT valdkonna elukutsetest on vähene (*ibid.*), on neil keeruline toetada õpilaste LTT-alase karjääriteadlikkuse kujunemist.

Uurimuse eesmärgid

Doktoritöö eesmärk oli loodud õppemoodulite kaudu tutvustada LTT valdkonna elukutseid ja neis vajaminevaid pädevusi ning toetada õpilaste motivatsiooni õppida loodusteaduslikke õppeaineid põhikooli III astmes. Uurimistöö spetsiifilisemad eesmärgid olid järgmised.

1. Selgitada välja need stsenaariumite omadused, mis aitavad õpilastel väärtustada loodusteaduslike ainete tundides õpitavat sisu
2. Teha kindlaks, kuidas mõjutavad LTT-alase karjääriteadlikkuse suurendamiseks loodud õppemoodulid õpilaste:
   a. motivatsiooni õppida loodusteaduslikke teemasid
   b. teadlikkust LTT valdkonna elukutsetest ja neis vajaminevatest pädevustest
   c. karjäärivalikuid

Uurimiseesmärkidest lähtudes otsiti vastuseid järgmistele uurimisküsimustele.

1. Millised stsenaariumite omadused aitavad kaasa sellele, et õpilased väärtustaksid õpitavat loodusteaduslikku sisu?
2. Kuidas mõjutavad LTT-alase karjääriteadlikkuse suurendamiseks loodud a) õppemoodulite stsenaariumid ja b) õppemoodulid tervikuna 7.–9. klassi õpilaste motivatsiooni õppida loodusteaduslikke teemasid?
3. Kuidas mõjutavad LTT-alase karjääriteadlikkuse suurendamiseks loodud õppemoodulid 7.–9. klassi õpilaste
   a. karjääriteadlikkust LTT valdkonna elukutsetest ja neis vajaminevatest pädevustest;
   b. karjäärivalikuid?

Kirjandusülevaade

Motivatsiooni päästikud: huvi, väärtustamine ja meeldivus

Mitmed haridusteaduste valdkonnas tuntud motivatsiooniteooriad, nagu isemääramisteooria (Deci & Ryan, 2000), ootuste-väärtuste teooria (ingl *expectancy-value theory*, Wigfield & Eccles, 2000) ja sotsiaal-kognitiivne karjääriteooria (Lent *et* *al.*, 1994), sisaldavad konstruktidena huvi, väärtustamist ja meeldivust, et kirjeldada, miks miski motiveerib. See osutab, et motivatsiooni käsitlemisel on need tajud olulised.

1. Huvi jaguneb personaalseks ja olukorraspetsiifiliseks. Personaalne huvi on indiviiditi erinev, konkreetse inimese jaoks oluline, kuid võib olla kollektiivselt jagatud, näiteks linnuhuvilised ornitoloogiaklubis. Olukorraspetsiifiline huvi või huvitavus on tingitud olukorra omadustest ja eri inimesed tajuvad seda sarnaselt. (Krapp *et al.*, 2014) Olukorraspetsiifilist huvi soodustavad muu hulgas huumor, toit, aktiivne osalus, olukorra või info uudsus (Bergin, 1999).
2. Väärtustamine tähistab siinses töös isiklikku relevantsust. Et kirjeldada väärtustamist õppimise kontekstis, kasutatakse ka sõnu *oluline*, *vajalik*, *kasulik* ja *tähendusrikas* (Levitt, 2002).
3. Meeldivus on positiivne taju, mis kaasneb, kui tegeletakse huvidega või huvitavate olukordadega (Krapp & Prenzel, 2011). Meeldivana tajutakse ka olukordi, mis on inimese jaoks praktilise väärtusega (Ainley & Ainley, 2011; Gaspard *et al.*, 2015).

Uurimused, milles käsitletakse motivatsiooni, jätavad huvi, väärtustamise ja meeldivuse tihti defineerimata ja eristamata (Murphy & Alexander, 2000; Potvin & Hasni, 2014). See omakorda muudab keeruliseks uuringute kordamise ja tulemuste tõlgendamise. Siinses töös kasutatud stsenaariumi ja mooduli hindamise vahendite puhul on lähtutud mudelist (joonis 1, artikkel II), mille kohaselt on huvil ja väärtustamisel õppemooduliga töötamise kontekstis erinevad tajumise põhjused. Siiski mõjutavad mõlemad õpimotivatsiooni teket ja hoidmist. Ka meeldivusel on täita oma osa motivatsiooni toetamisel, kuid õpisituatsiooni meeldivuse tajumisele võivad mõju avaldada nii huvi kui ka väärtustamise taju põhjused (artikkel II).

Karjääriteadlikkus ja karjäärivalikute kujunemine

Karjääriteadlikkus on kompleksne mõiste, mis koosneb neljast komponendist (Wise *et al.*, 1976).

1. Teadmised
   a. tööalastest tegevustest
   b. saadavatest hüvedest
c. konkreetse elukutse omandamiseks vajalikest eeldustest, sh pädevustest
2. Väärtushinnangud
   a. ühiskondlikud *vs.* isiklikud
   b. töötamise väärtustamine üldiselt *vs.* mõne tööga seotud komponendi (hea palga, hea maine, ühiskondliku olulisuse) väärtustamine
3. Isiklikud eelistused
   a. huvipakkuvad ja meeldivad tegevused
   b. elukutsete eelistus

4. Enesetaju
   a. uskumused enda pädevustest
   b. võimalikust edust mingi tegevuse sooritamisel

Siit nähtub, et karjääriteadlikkus hõlmab teadlikkust elukutsetest ja nende omadustest ning indiviidi teadlikkust iseendast. Kõik eespool mainitud komponendid mõjutavad karjäärivalikuid (Wise *et al.*, 1976).

Doktoritöö sihtrühm on põhikooli 7.–9. klassi õpilased vanuses 13–15 eluaastat. Selles vanuses õpilased on oma arengus jõudnud faasi, kus nad hakkavad end kujutlema eri elukutsete esindajatena (Gottfredson, 1981, 2002). Teadvustatud või teadvustamata valik mõne karjääritee kasuks või kahjuks sõltub sellest, mis elukutseid teatakse, millisena neid ette kujutatakse ja kas elukutse oma omadustega samastub indiviidi tajuga endast (*ibid.*). Hiljutine uuring on näidanud, et tegelikkusele mittevastav pilt teadlastest ja selle lahknevus minapildist vähendasid huvi LTT valdkonna elukutsete vastu (McPherson *et al.*, 2018). Et karjääriotsused oleksid teadlikult tehtud, on tähtis kujundada õpilaste LTT-alast karjääriteadlikkust.

LTT-alase karjääriteadlikkuse suurendamise eesmärgil on koolides ellu viidud mitmeid projekte. Näiteks Ameerika Ühendriikide Põhja-Carolina osariigis läbi viidud CareerStarti projekti põhifookus oli eri õppeainetes, sh loodusteaduslikes ainetes ja matemaatikas omandatud teadmiste ja oskuste seostamisel eri elukutsetega (Orthner *et al.*, 2013). Suurbritannias projekti ASPIRES raames tehtud sekkumine sisaldas erinevaid karjääriteadlikkust kujundavaid tegevusi: ekskursioone teaduskeskustesse, LTT elukutsete esindajate koolikülastusi ja LTT-ga seostuvate uurimisprojektide tegemist koolitundides (Archer *et al.*, 2014). Samas on need projektid olnud lühiajalised, seisnedes näiteks kuuenädalases (Archer *et al.*, 2014) ja üheaastases sekkumises (Fouad, 1995). Erandiks on Orthneri ja tema kolleegide (2013) kolmeaastane projekt, kuid sellised kestusuuringud on pigem harvad.

Karjääriteadlikkust kujundavate projektide mõju on uuritud enamasti küsimustikega, milles palutakse õpilastel nimetada loodusteadustega seotud elukutseid (nt Archer *et al.*, 2013) ja nende jaoks vajalikke pädevusi (Salonen *et al.*, 2018). Kuigi selliselt küsitledes on õpilastel võimalik nimetada nii palju LTT-ga seotud elukutseid ja pädevusi, kui neil parasjagu meelde tuleb, ei pruugi õpilased isegi kaaluda elukutseid, mis väljuvad LTT elukutsete tüüpilistest raamidest. Näiteks võiks arutleda, kas pagar-kondiiter, ehitaja, statistik ja arst on loodusteadustega seotud elukutsed. Põhikooli ja gümnaasiumi riiklik õppekava soosib loodusteaduslike ainete tundides õpilaste teadlikkuse suurendamist nii LTT elukutsetest kui ka loodusteaduslikes ainetes omandatud oskusi ja teadmisi rakendavatest elukutsetest (Vabariigi Valitsus, 2011a, 2011b). Seetõttu on Eesti oludes õpilaste LTT karjääriteadlikkuse hindamiseks põhjendatud kasutada uuringuvahendeid, mis hõlmavad mõlemat tüüpi elukutseid.

Uuringu ülevaade

Metodoloogiliselt jagunes uurimistöö kolme etappi: sekkumiseelseks etapiks, sekkumisetapiks ja sekkumisjärgseks etapiks.

1. Sekkumiseelne etapp

Uurimistöö sekkumiseelses etapis tuvastati stsenaariumite omadused, mis aitavad kaasa loodusteadusliku sisu väärtustamisele õpilaste hulgas (artikkel I). Selleks analüüsiti kvalitatiivse sisuanalüüsi meetodil kokku 77 õppemooduli pealkirja ja 66 stsenaariumi teksti, mis pärinesid projekti PROFILES kodulehelt.

Eeltoodule lisaks selgitati välja nii katse- kui ka kontrollrühma õpilaste sekkumiseelne teadlikkus LTT valdkonnaga seotud elukutsetest ja neis vajaminevatest pädevustest ning õpilaste karjäärivalikud. Selleks kasutati kahte mõõtevahendit: kolmeosalist küsimustikku (artikkel III) ja mõistekaardi meetodit (artikkel IV).

- Kolmeosalises küsimustikus tuli õpilastel: a) märkida oma karjäärivalikud; b) hinnata, kui olulised on LTT-ga seotud elukutsete jaoks 27 etteantud pädevust; c) hinnata, kui olulised on needsamad 27 pädevust õpilaste valitud elukutsete jaoks. Pädevuste nimekiri koostati rahvusvahelise ametite standardklassifikaatori (ISCO, International Standard Classification of Occupations) teaduse ja inseneeria rühma töökirjelduse (ISCO-08) ning LTT valdkonna inimeste poolt vajalikeks peetud pädevuste (Jang, 2016) põhjal.
- Mõistekaarti tegid õpilased lauaarvutit kasutades pilverakenduses IHMC Cmap Cloud. Nad said ligipääsu omanimelistele kaustadele, mis sisaldasid töölehte eelsisestatud elukutsete (n = 22) ja pädevustega (n = 18). Õpilasi juhendati kahe suunava küsimuse kaudu: a) *Millised elukutsed on sinu arvates LTT-ga seotud?*; b) *Milliseid oskusi ja teadmisi on LTT-ga seotud elukutsete esindajatel sinu arvates vaja?*.

Õpilastelt koguti andmeid enne sekkumist 2016. aasta kevadel loodusainete tunni ajal. Lisaks võrreldi katserühma õpilaste tulemusi kontrollrühma õpilaste omadega.

2. Sekkumisetapp

Sekkumine seisnes viie LTT karjäärivalikuid toetava õppemooduli kasutamises erinevate loodusteaduslike ainete õpetamisel. Need õppemoodulid olid (artikkel V):

a) „Õhus on särtsu“ (7. klass, 5 × 45 min)
b) „Suhkrumaks: poolt või vastu?“ (8. klass, 4 × 45 min)
c) „Kes mõrvas Juliana?“ või „Majad, kus me elame: Smart City projekt“ (8. klass, 3 × 45 min)
d) „Nafta: inimkonna Achilleuse kand“ (9. klass, 3 × 45 min)
e) „Mida mitte reisilt kaasa osta: ohustatud liikide kaitse CITES-i konventsiooniga“ (9. klass, 3 × 45 min)

Sekkumise viisid läbi eriväljaõppe saanud loodusteaduslike ainete õpetajad samade õpilastega kolme õppeaasta jooksul 2016. aasta kevadest kuni 2018. aasta kevadeni. Sekkumises osalesid õpilased kolmest Eesti tavakoolist ($N = 104$, 45% tüdrukud, 55% poisid).

Õppemoodulite loomisel lähtuti kolmeastmelisest mudelist (Holbrook & Rannikmäe, 2010), mille kohaselt algab õppimine kontekstipõhise ja sotsiaal-loodusteadusliku probleemi esitamisega. Sellele järgneb loodusteadusliku sisu ja muu olulise õppimine uurimusliku õppe ja teiste aktiivõppe meetoditega. Õppemoodul lõpeb omandatud teadmiste rakendamisega, mille tulemusena pakuvad õpilased sotsiaal-loodusteadusliku probleemi kohta välja võimalikke lahendusi. Doktoritöös kasutatud õppemoodulid teeb eriliseks see, et õpitav on esitatud LTT valdkonna elukutse esindaja tööülesandena. Sellise lähenemisviisi kaudu püüti näidata õpilastele õpitava ainesisu rakendusväärtust, tutvustada eri elukutseid ja anda õpilastele võimalus reflekteerida probleemi lahendamiseks vajalike pädevuste üle.

Et tuvastada, kuivõrd toetasid õppemooduli stsenaarium ja õppemoodulid tervikuna õpitava loodusteadusliku ainesisu väärtustamist, huvi, õpisituatsiooni meeldivust ja seeläbi ka õpimotivatsiooni, töötati kirjandusele tuginedes välja stsenaariumi hindamise küsimustik (artikkel II), mida kohandati ka terve mooduli hindamiseks. Stsenaariumi ja mooduli hindamise küsimustik sisaldas kokku 27 skaalaküsimust, lisaks oli õpilastel võimalik vabalt selgitada, mis põhjusel nad tajusid huvi, väärtustamise, meeldivuse ja ka õpimotivatsiooni toetamist õppemoodulis. Stsenaariumi hinnati esimese õppemooduli („Õhus on särtsu“) juures ning mooduleid kõigi õppemoodulite läbimise järel.

3. Sekkumisjärgne etapp

Sekkumise järel tuvastati 9. klassi jõudnud õpilaste karjääriteadlikkus LTT valdkonna elukutsetest ja neis vajaminevatest pädevustest ning õpilaste karjäärivalikud. Selleks rakendati uuesti kolmeosalist küsimustikku ning mõistekaardi meetodit sarnaselt sekkumiseelses etapis kirjeldatuga. Eel- ja järeltestimise tulemuste võrdlusel tuvastati nii katse- kui ka kontrollrühma tulemuste erinevused.

Tulemused ja arutelu

Õppemooduli esimese osa, stsenaariumi pealkirjade analüüsimisel tuvastati kolm kategooriat: pealkirja vorm, pealkirja temaatiline fookus ja mõju tase. Eelistatuimad õppesisu väärtustamist toetavad omadused pealkirjas oli küsimuse vorm, sotsiaal-loodusteaduslik kontekst ning püüd mõjutada õppemooduli abil õppijat kas isiklikul, kohalikul või globaalsel tasandil. Stsenaariumi tekstide puhul leiti, et vähem kui pooltes neist kasutati õppesisu väärtustamiseks sotsiaal-loodusteaduslikku konteksti ning rohkem kui pooltes analüüsitud stsenaariumites puudus viide potentsiaalse isikliku mõju kohta. Et näidata õpitava sisu rakendusväärtust projekti PROFILES raames loodud stsenaariumi tekstides, kasutati eelistatult probleemide lahendamise poole suunamist. (Artikkel I)

Kõrvutades analüüsi tulemusi teaduskirjanduses kajastatuga, nähtub, et küsimuse vormis pealkirjal on kognitiivse konflikti tekitamise kaudu potentsiaal äratada lugejas uudishimu. Samas tuleb leida tasakaal juba tuttava ja uue sisu vahel. (Berlyne, 1960; Loewenstein, 1994) Et mõtestada õpitavat ainesisu ja siduda muidu tundmatu sisu tuttava kontekstiga, on loodusteaduslike ainete õpetamisel eriti oluliseks peetud just õpitava sidumist igapäevaeluga (Aikenhead, 2006; Broman *et al.*, 2011; Broman & Simon, 2015). Rakendusväärtuse tajumisele aitab kaasa sotsiaal-loodusteadusliku probleemi kaudu ainesisu õpetamine (Sadler, 2009). Õpilased ei pruugi iseseisvalt olla võimelised nägema seost õpitava ja selle rakendusvõimaluste vahel. Seetõttu on tähtis, et õppemooduli loomisel võimaldataks rakendada uusi teadmisi ja oskusi mõne päriselt eksisteeriva probleemi lahendamiseks, et väärtustada loodusteaduslike ainete tundides õpitut. Doktoritöös seoti õppemooduli ainesisu probleemide või tööülesannetega, millega puutuvad kokku erinevad loodusteadustega seotud elukutsete esindajad.

Õpilaste hinnangutest nii stsenaariumile kui ka õppemoodulitele tervikuna selgus, et õppemoodulite jaoks valitud kontekstid võimaldasid enamikul õpilastel end seostada õpitava teemaga. Erandi moodustas vaid õppemoodul „Majad, kus me elame: Smart City projekt“. Samas olid väärtustamise tasandid mooduliti erinevad. Isiklikul tasandil väärtustamist tajus enamik õpilasi esimese, neljanda ja viienda õppemooduli puhul, samas kui perekonna tasandi kaudu väärtustamist tajuti vaid mooduli „Mida mitte reisilt kaasa osta: ohustatud liikide kaitse CITES-i konventsiooniga“ puhul. Kohaliku ja globaalse tasandi kaudu väärtustamist tajuti kõigis moodulites, välja arvatud moodulis „Kes mõrvas Juliana?“. (Artikkel V)

Kõigi rakendatud õppemoodulite fookuses oli mõni sotsiaal-loodusteaduslik probleem, millega tuleb tegeleda ühiskonnal tervikuna. Taastuvatele energiaallikatele üleminek, toidukriis, keskkonnareostus, liigilise mitmekesisuse vähenemine – kõigi nende puhul tajusid õpilased, et need probleemid on globaalselt olulised. Murettekitav on aga see, et paljud õpilased ei pea neid probleeme siiski isiklikult oluliseks. Sarnase tulemuseni on jõudnud ka Soome partnerid projektist MultiCO (Salonen *et al.*, 2018; Tolppanen *et al.*, 2019).

Õppemoodulite loomisel peeti tähtsaks, et moodulid toetaksid ainesisu omandamist tähendusrikkal viisil. Kõigi moodulite õppetöö sisaldas rühmatöid, mis võimaldasid aktiivset osalust. Esimeses moodulis disainiti ja valmistati mobiili laadiv päikesepaneel, teises ja neljandas moodulis tehti erinevaid loodusteaduslikke katseid ning kolmandas ja viiendas moodulis otsiti arutelu kaudu lahendusi fookuses olnud probleemidele. Õpilaste tagasiside näitas, et õppemoodulitest (v.a õppemoodul „Majad, kus me elame: Smart City projekt“) saadi uusi teemakohaseid teadmisi, mida on tulevikus võimalik rakendada näiteks ettetulevate probleemide lahendamisel (artikkel V). Ühtlasi ilmestavad need tulemused, et õppemoodulid täitsid oma rolli õppimise toetamisel, aga ka õpitu väärtuse tajumisel.

Et suurendada õpilaste huvi loodusteaduslike teemade vastu, püüti õpilastele pakkuda uudseid kogemusi ja tegevusi nii koolis kui ka väljaspool kooli. Kogutud tagasisidest nähtus, et vähestel õpilastel on personaalne huvi LTT valdkonna vastu.

Leidus ka õpilasi, kes ei olnud kas loodusteaduslikest õppeainetest või tutvustatud elukutsetest huvitatud. Sellest hoolimata pidas enamik õpilasi mooduleid huvitavaks, tuues huvitavuse põhjustena välja praktilisi tegevusi, rühmatöid ja tavapärasest erinevaid ainetunde (lisa 2; artikkel V; Salonen *et al.*, 2018, 2019b; Tolppanen *et al.*, 2019). Samas ei väljendanud enamik õpilasi valmidust õpimoodulite teemasid edasi õppida, põhjendades oma vastust teiste huvidega, tutvustatud elukutsete ühtimatusega nende elukutsevalikutega või omandatud teadmiste ja oskuste ebavajalikkusega. Osa õpilaste motivatsiooni vähendas moodulite liigne keerukus, mida mõned õpilased pidasid siiski huvitavaks väljakutseks (artikkel V).

Õpilaste sekkumiseelse ja -järgse karjääriteadlikkusega seotud tulemuste võrdluses selgus, et rakendatud õppemoodulid toetasid nii poiste kui ka tüdrukute teadlikkust LTT valdkonna elukutsetest ja neis vajaminevatest pädevustest (artikkel IV). Sekkumises osalenud õpilaste hinnangud erinevate pädevuste vajalikkusest LTT elukutsete jaoks püsisid kõrgena ka pärast sekkumise lõppu, samas kui kontrollrühma õpilaste seas langesid selliste pädevuste nagu avatus uutele ideedele, koostöö, suhtlemisoskus ja tehnoloogilised oskused (disain ja tootmine) olulisuse hinnangud olulisel määral (artikkel III). Viimati nimetatud pädevusteta ei saa LTT valdkonnas töötades aga hakkama (Jang, 2016; ILO, 2012). See tulemus ilmestab vajadust toetada õpilaste teadlikkust LTT valdkonnas vajaminevatest pädevustest, et kujundada neis reaalsusele vastav pilt LTT valdkonna elukutsete olemusest.

Sekkumiseelsete ja -järgsete karjäärivalikute võrdluse tulemusel tuvastati, et sekkumises osalenud õpilaste karjäärivalik LTT valdkonna kasuks oli stabiilsem kui kontrollrühma õpilastel. Lisaks ilmnes, et sekkumises osalenud õpilaste seas oli oluliselt suurenenud nende õpilaste osakaal, kes valiksid elukutse õpetamise või ettevõtlusega seotud valdkondadest (artikkel III).

Soovitused

Töös esitletud tulemused kinnitavad, et loodusteaduslike ainete tundides on vaja kujundada karjääriteadlikkust nii LTT valdkonna elukutsete kui ka neis vajaminevate pädevuste kohta. See aitab kaasa kõigi õpilaste teadvustatud karjäärivalikute tegemisele. Töös kirjeldatud õppemoodulid on üks viis, kuidas edukalt toetada loodusteaduslike ainete õpetajaid õpilaste LTT-alase karjääriteadlikkuse kujundamisel. Selliseid õppemooduleid tasub kasutada loodusteaduslike ainete õpetamisel, sest need aitavad õpilastel tajuda õpitava sisu väärtust ja suurendada huvi õpitava vastu, isegi kui sisemisest motivatsioonist jääb puudu.

Soovitatav on korraldada loodusteaduslike ainete õpetajatele täiendkoolitusi, mis aitaks õpetajate teadlikkust LTT elukutsetest suurendada, sest varem on viidatud loodusteaduslike ainete õpetajate vähesele teadlikkusele LTT valdkonnaga seotud elukutsetest (Kivistik *et al.*, 2019). Rohkem uuringuid oleks aga vaja, et välja selgitada õpetajate võimekus ja valmidus õpilaste seas LTT karjääriteadlikkust kujundada.

APPENDICES

Appendix 1. The items of the scenario and module evaluation questionnaire and their theoretical categorisations

<table>
<tr><th>Items</th><th>Scenario</th><th>M1 Electricity in the air</th><th>M2 Should there be a sugar tax?</th><th>M3.1 Crime scene</th><th>M3.2 Houses where we live</th><th>M4 Oil—the king of the world</th><th>M5 CITES</th></tr>
<tr><td>This scenario/ module enabled me to gain new knowledge about the scenarios/ module topic. (Role of Knowledge)</td><td></td><td colspan="6" rowspan="3">Please explain what you found out from this module (OE).</td></tr>
<tr><td>The knowledge I gained from the scenario/ module may be useful in the future. (Usefulness)</td><td></td></tr>
<tr><td>I could put knowledge gained from the scenario/ module into practice, to solve problems. (Usefulness)</td><td></td></tr>
<tr><td>From this scenario, I was able to gain new knowledge about possible career(s). (Role of Knowledge)</td><td></td><td colspan="6">–</td></tr>
<tr><td>This scenario enabled me to understand the responsibilities of the persons in the career position indicated. (Role of Knowledge)</td><td></td><td colspan="6">–</td></tr>
<tr><td>This scenario enabled me to understand the skills that are necessary in this profession. (Role of Knowledge)</td><td></td><td colspan="6">–</td></tr>
<tr><td>Which skills did you develop during the module (OE)</td><td>–</td><td colspan="6" rowspan="2">Combined into one table.</td></tr>
<tr><td>Which occupations benefit from these skills (OE)?</td><td>–</td></tr>
<tr><td>I found the scenario/ module topic important for me personally. (Impact level)</td><td colspan="7"></td></tr>
</table>

Items	Scenario	M1 Electricity in the air	M2 Should there be a sugar tax?	M3.1 Crime scene	M3.2 Houses where we live	M4 Oil—the king of the world	M5 CITES
I found the scenario/ module topic important to my family. (Impact level)							
I found the scenario/ module topic important for appreciating the work of our local community (town, country). (Impact level)							
I found the scenario/ module topic important for learning school subjects. (Impact level)							
I found this scenario/ module topic important for the whole world. (Impact level)							
I feel my future career may be connected with the topic covered in the scenario. (Usefulness)					–		
I think my future studies at the gymnasium or university level may be connected to the topic covered in the scenario. (Usefulness)					–		
I predict that my future career will require me to perform skills, which were developed in the module. (Usefulness)			Please specify which skills (OE).				
I predict that my future career will require me to perform **science skills**, which were developed in the module. (Usefulness)			Please specify which skills (OE).				
The scenario described the science community, to which I relate. (Relatedness)					–		
The scenario presented a scientific problem, which is socially relevant. (Relatedness)					–		

Items	Scenario	M1 Electricity in the air	M2 Should there be a sugar tax?	M3.1 Crime scene	M3.2 Houses where we live	M4 Oil—the king of the world	M5 CITES
The scenario/ module activities made it easy for me to relate with the situation described. (Relatedness)			–				
The scenario/ module was easy to follow. (Scenario/ Module Attributes)			–				
The scenario/ module texts was/ were easy to understand. (Scenario/ Module Attributes)							
The found this scenario enjoyable. (Scenario Attributes)					–		
I liked the format of the scenario. (Scenario Attributes)					–		
I liked the module experimental/ practical tasks. (Scenario/ Module Attributes)	–						
I knew (...?) about the career described. (Background Information)					–		
I knew (...?) about the topic in the scenario. (Background Information)					–		
I found this scenario/ module interesting to me. Please explain (OE). (Affective Reaction)							
I found the information in this scenario/ module valuable to me. Please explain (OE). (Usefulness)							
I liked the scenario/ module. Please explain (OE). (Affective reaction)							
The scenario/ module made me want to learn more about the topic. Please explain (OE). (Role of Knowledge)							

<table>
<tr><th>Items</th><th>Scenario</th><th>M1 Electricity in the air</th><th>M2 Should there be a sugar tax?</th><th>M3.1 Crime scene</th><th>M3.2 Houses where we live</th><th>M4 Oil—the king of the world</th><th>M5 CITES</th></tr>
<tr><td>The materials provided helped to solve the problem, posed in the module. (Module Attributes)</td><td>–</td><td></td><td>–</td><td></td><td></td><td></td><td></td></tr>
<tr><td>The instructions provided during the module were understandable. (Module attributes)</td><td>–</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Teacher/ instructor provided additional explanations when needed. (Teacher effect)</td><td>–</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Teacher/ instructor guided the module enthusiastically. (Teacher effect)</td><td>–</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Teacher linked industry visit with the follow up activities at school. (Teacher effect)</td><td>–</td><td>–</td><td></td><td colspan="4">–</td></tr>
<tr><td>Industry visit introduced various science-related occupations. (Module attributes)</td><td>–</td><td>–</td><td></td><td colspan="4">–</td></tr>
<tr><td>How would you evaluate your participation in the module activities on a 5-point scale (1-was not active; 5-I participated actively in every activity)? (Effort)</td><td>–</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>What would you change in this module (OE)? (General feedback)</td><td>–</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Note: Present; – item not applied; OE-open ended; (theoretical category)

Appendix 2. Evaluation results of the modules

	Items	**M1.** Electricity in the air			**M2.** Should there be a sugar tax?			**M3.1.** Crime scene			**M3.2.** Houses where we live			**M4.** Oil–the king of the World			**M5.** CITES		
		N	**Mean**	**Std. Dev.**	**N**	**Mean**	**Std. Dev.**	**N**	**Mean**	**Std. Dev.**	**N**	**Mean**	**Std. Dev.**	**N**	**Mean**	**Std. Dev.**	**N**	**Mean**	**Std. Dev.**
Role of Knowl-edge	The module enabled me to gain new knowledge about the topic.	84	3.50	0.53	86	3.42	0.52	36	2.94	0.75	23	2.96	0.71	85	3.45	0.61	62	3.71	0.52
Use-fulness	The knowledge I gained from the module may be useful in the future.	84	3.18	0.62	87	2.99	0.64	36	2.72	0.74	23	2.70	0.88	84	2.94	0.80	62	3.29	0.71
	I could put knowledge gained from the module into practice, to solve problems.	84	3.11	0.62	85	2.80	0.63	36	2.89	0.85	22	**1.91**	0.75	84	2.82	0.82	62	2.98	0.74
	I predict that my future career will require me to perform skills, which were developed in the module.	82	2.52	0.74	86	2.69	0.80	36	**2.47**	0.91	23	**1.91**	0.67	85	**2.40**	0.88	62	**2.47**	0.76
	I predict that my future career will require me to perform science skills, which were developed in the module.	82	**2.37**	0.69	86	**2.16**	0.75	35	**2.26**	0.70	23	**2.17**	0.65	84	2.76	0.80	62	**2.35**	0.68

	Items	**M1.** Electricity in the air			**M2.** Should there be a sugar tax?			**M3.1.** Crime scene			**M3.2.** Houses where we live			**M4.** Oil–the king of the World			**M5.** CITES		
		N	**Mean**	**Std. Dev.**	**N**	**Mean**	**Std. Dev.**	**N**	**Mean**	**Std. Dev.**	**N**	**Mean**	**Std. Dev.**	**N**	**Mean**	**Std. Dev.**	**N**	**Mean**	**Std. Dev.**
Related-ness	The module activities made it easy for me to relate with the situation described.	83	2.88	0.71	NA			36	2.86	0.80	21	**2.43**	0.68	83	2.90	0.79	62	3.39	0.58
Module attri-butes	The materials provided helped to solve the problem, posed in the module.	83	3.16	0.63				36	3.19	0.58	23	**2.39**	0.78	84	3.02	0.69	61	3.46	0.59
	The module was easy to follow.	82	2.78	0.82				36	3.14	0.54	23	3.00	0.67	85	3.15	0.73	62	3.53	0.53
	The module texts were easy to understand.	82	2.83	0.83	87	3.08	0.55	36	3.28	0.51	23	3.09	0.51	85	3.35	0.70	62	3.48	0.65
	The instructions provided during the module were understandable.	81	3.11	0.63	87	3.20	0.57	36	3.25	0.55	22	2.86	0.71	85	3.35	0.65	60	3.57	0.53
	Industry visit introduced various science-related occupations.**				84	3.20	0.55												
	Teacher linked industry visit with the follow-up activities at school.**				87	3.41	0.66												
	I liked the module experimental/practical tasks.	84	3.38	0.67	86	3.33	0.69	35	3.37	0.55	23	2.91	0.85	85	3.28	0.78	62	3.58	0.67

	Items	**M1.** Electricity in the air			**M2.** Should there be a sugar tax?			**M3.1.** Crime scene			**M3.2.** Houses where we live			**M4.** Oil–the king of the World			**M5.** CITES		
		N	**Mean**	**Std. Dev.**	**N**	**Mean**	**Std. Dev.**	**N**	**Mean**	**Std. Dev.**	**N**	**Mean**	**Std. Dev.**	**N**	**Mean**	**Std. Dev.**	**N**	**Mean**	**Std. Dev.**
Teacher effect	Teacher/Instructor provided additional explanations when needed.	84	3.70	0.46	87	3.47	0.61	36	3.61	0.49	23	3.30	0.82	85	3.55	0.65	62	3.87	0.34
	Teacher/Instructor guided the module enthusiastically.	82	3.55	0.52	86	3.45	0.61	36	3.39	0.64	22	3.32	0.65	85	3.38	0.79	61	3.67	0.57
Impact level	I found the module topic important for me personally.	83	2.66	0.74	86	**2.47**	0.65	36	**2.42**	0.65	21	**2.24**	0.83	84	2.62	0.85	62	2.89	0.81
	I found the module topic important for my family.	84	**2.48**	0.74	85	**2.08**	0.66	36	**1.86**	0.72	23	**2.04**	0.71	84	**2.31**	0.81	62	2.53	0.92
	I found the module topic important for the local community (town/country).	81	3.02	0.65	86	2.84	0.67	35	**2.49**	0.78	23	3.48	0.59	84	2.96	0.91	61	2.98	0.74
	I found the module topic important for learning school subjects.	81	2.94	0.66	87	2.91	0.66	36	**2.31**	0.71	23	**2.00**	0.80	84	3.25	0.73	62	2.52	0.78
	I found the module topic important for the whole world.	84	3.20	0.71	85	2.81	0.78	36	2.81	0.82	23	3.30	0.82	85	3.68	0.62	61	3.67	0.54

	Items	**M1.** Electricity in the air			**M2.** Should there be a sugar tax?			**M3.1.** Crime scene			**M3.2.** Houses where we live			**M4.** Oil–the king of the World			**M5.** CITES		
		N	**Mean**	**Std. Dev.**	**N**	**Mean**	**Std. Dev.**	**N**	**Mean**	**Std. Dev.**	**N**	**Mean**	**Std. Dev.**	**N**	**Mean**	**Std. Dev.**	**N**	**Mean**	**Std. Dev.**
Overall affect (Interest, Enjoy-ment)	I found this module interesting to me.*	83	0.57	0.61	87	0.68	0.56	36	0.61	0.49	23	0.35	0.57	85	0.44	0.70	62	0.79	0.52
	I liked the module.*	84	0.54	0.63	87	0.74	0.54	36	**–0.08**	0.69	23	0.43	0.59	85	0.53	0.63	62	0.82	0.46
Overall value	I found the information in this module valuable to me.*	84	0.46	0.63	87	0.26	0.60	36	0.75	0.44	23	0.13	0.76	85	0.47	0.68	62	0.74	0.51
Moti-vation	The module made me want to learn more about the topic.*	84	**–0.12**	0.78	86	**–0.36**	0.61	36	**–0.47**	0.74	23	**–0.39**	0.66	85	**–0.32**	0.83	62	**–0.24**	0.59
Effort	How would you evaluate your participation in the module activities on a 5-point scale?	78	4.30	0.63	87	4.45	0.62	36	4.61	0.60	23	4.33	0.63	84	4.30	0.72	61	4.63	0.56
	Cronbach's alfa	.93			.87			.88			.80			0.89			.87		

Note: Mean interpretation: < **2.5** negative tendency; > 2.5 positive tendency *Scale defined as: –1 Disagree. 0 cannot make up my mind. 1 agree; ** used only for 2nd module

ORIGINAL PUBLICATIONS

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Soobard, R., Kotkas, T., Holbrook, J. & Rannikmäe, M. (2020). Students' Perceptions of an Intervention Course Designed to Raise Science-Related Career Awareness. *European Journal of Educational Research*, 9(4), 1539–1555.

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