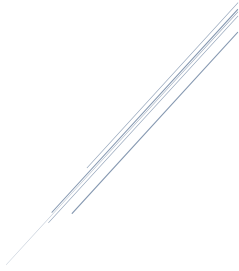




ACCOUNTING FOR DIVERSITY AND ACCESSIBILITY IN EUROPEAN STEM CLASSROOMS



Enlivened Laboratories within STEM Education (EL-STEM)

Motivating EU students to choosing STEM studies & careers and
improving their performance in courses related to STEM education



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Executive Summary:	The aim of this e-publication is to describe the contemporary learning approach that should be applied in using innovative learning environments for science, technology, engineering and math (STEM) learning and to review recent challenges in several European countries in adapting the criteria of this approach and related instructional design. The general aim of applying contemporary learning approach and innovative learning environments in our project is to foster inquiry-based science education (IBSE), in particular inquiry skills and computational thinking skills. In addition, our focus is on 21 st century skills, in particular on collaboration skills. Collaboration is integrated as a learning principle in most of the learning activities while contemporary learning approach is in general a student-centred self-regulated scaffolded collaborative learning. In case of innovative learning environments, we limit ourselves with motivating technology-enhanced augmented reality (AR) and mixed reality (MR) environments.

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List of Abbreviations/ Acronyms

Table 1: List of Abbreviations/ Acronyms

Abbreviation / Acronym	Description
AR	Augmented Reality
CY	Cyprus
CT	Computational thinking
CTSI	Computation Thinking Skills Inventory
EDL	Engagement vs Disaffection with Learning
EE	Estonia
EL	Hellas (Greece)
EL-STEM	Enlivened Laboratories within Science, Technology, Education and Mathematics
et al.	Latin: et alii (eng: and others)
EU	European Union
FI	Finland
HCTA test	Halpern Critical Thinking Assessment test
IBSE	Inquiry-based Science Education
ICT	Information Communication Technology
IO	Intellectual Output
IoT	Internet of Things
LO	Learning Object
LMT	Learning Motivation Test
MR	Mixed Reality
MSISA test	Middle School Inquiry Skills Assessment test
PT	Portugal
SMQ-II	Science Motivation Questionnaire II
STEM	Science, Technology, Education and Mathematics
TSI	Teamwork Skills Inventory
VR	Virtual Reality

EL-STEM Project Description

The Project objective is to develop a new approach, which combines Augmented Reality (AR)/Mixed Reality (MR) technologies with Remote and/or Local Laboratories, for encouraging 12-18 year-old students' STEM (Science, Technology, Education and Mathematics) engagement. In particular, we are targeting students of lower and upper secondary schools and irrespective of the expected varying individual inclination to STEM subjects, we are aiming to:

- (a) attract students who currently might not be interested in STEM related studies/careers and enhance the interest of those who have already chosen this field of studies/careers,
- (b) improve students' performance in courses related to STEM education.

Inspired by emerging technologies of IoT (Internet of Things) and AR (Augmented Reality), we wish to connect the physical laboratory and/or the remote laboratory to the digital world and turn it into an "Enlivened Laboratory". We aim to explore various digital solutions to "immerse" students within STEM laboratories while implementing experiments. Moreover, we aim to attract more students to STEM related studies/careers through intense hands-on experiences, where they can participate, transform and augment what they are implementing, thus applying digital competences, developing haptic skills, collaborating with peers and ultimately, becoming more engaged in STEM education. This approach will be supported at school as well as at home through the involvement of appropriate platforms offering remote access to laboratories.

Acknowledging the crucial role of teachers in any effort to bring about change and innovation, our project will make available the necessary knowledge, indicative tools, and will introduce underlying dynamics in teaching cultures that will enable STEM education to obtain the full benefits of AR/MR. This will be achieved by providing teachers with high quality professional development opportunities to acquire knowledge and skills to effectively embed AR/MR in teaching and learning. More specifically, we will create a comprehensive framework for providing teachers with innovative digital tools to enrich their laboratory-based courses, in order to not only attract students' attention towards STEM education but also to achieve better performance in STEM related subjects and in general competences expected today in labour market and in life-long learning process. Project outputs will include AR/MR educational scenarios implemented through Remote and/or Local Laboratories. The technologies used for the implementation of these scenarios explore where applicable, the utilization of (a) AR/MR Remote Laboratories, (b) AR/MR Local Laboratories, (c) Mobile Technologies (e.g. smartphones and/or tablets), and (d) AR hardware technologies (e.g. AR glasses) in the teaching and learning of STEM courses.

1. Introduction

This particular IO is providing a pedagogical framework for developing an inquiry-based STEM (science, technology, engineering, and mathematics) learning approach that could be used in designing instructional process and materials for using mixed reality (MR) and augmented reality (AR) in learning and in assessing outcomes of this learning process. Through this, the current IO contributes to the key objective of the project, which is achievement of relevant and high quality skills and competences. In particular, we focus on inquiry skills and computational thinking skills (which together characterise problem-solving) and critical thinking skills – the skills that are expected to be improved as a result of the EL-STEM project, and teamwork skills (representing a key skill of 21st century skills that are also expected to be promoted in the project). In addition, we will focus on students' engagement which, according to previous research (for a review see Akçayır & Akçayır, 2017), has been one of the major benefits of innovative technological solutions (e.g., MR and AR) in learning. Therefore, students' level of engagement with learning will be evaluated. Collaborative learning and students' engagement in a student-centred learning process should also lead to higher learning motivation towards the sciences (one of the aims of the EL-STEM project is to attract more students with STEM topics). Therefore, we also focus on this.

This pedagogical framework is further operationalised in the context of best practices in several European countries involved in the EL-STEM project. In particular, the situation in applying the framework in Estonia, Cyprus, Finland, Greece, and Portugal will be analysed and some cases of applying it will be described. This helps to specify targets for different countries involved in the project consortium, but other interested countries could also follow the ideas by finding an example that is analogous to their situation.

This Intellectual Output (IO) is considered to be a “theoretical overview” based on former studies and analysis of cases in Estonia, Cyprus, Finland, Greece, and Portugal. We consider it to be valuable material for teachers to review, prior to reading the guidelines for applying the EL STEM Methodology Guidelines (IO2) and creating new Learning Objects (LOs) and Lesson Plans (IO5-6).

IO1 is linked to all other Intellectual Outputs of the EL STEM project, and it is included as a fundamental part of the learning materials in Module 2 of the Teachers' Training Course (IO4), offered via the EL STEM online learning environment, at elstem.ouc.ac.cy.

2. Contemporary inquiry-based STEM learning approach

2.1. Inquiry-based STEM learning

Inquiry-based learning has been for the last decade considered as one of the key methods in STEM learning. The European report 'Science Education Now; A renewed pedagogy for the future of Europe' (Rocard et al., 2007) and Jonathan Osborne's and Justin Dillon's (2008) critical reflection on science learning in Europe show clearly that Europe needs more scientists (Zeidler, 2016) but, even more importantly, human resources in other fields also need to be equipped with 21st century skills, including understanding scientific reasoning, argumentation, theory-building, decision-making, etc. (Xue & Larson, 2015). It is important for all learners, including students of secondary education, to be able to frame any STEM-related topic in a personal, thoughtful and meaningful context to allow for inquiry, discourse, and evidence-based reasoning (Zeidler, 2016). Thus, there is a need in a long term to innovate and tackle new challenges in Europe and in the world.

The development of the ideas about inquiry-based learning (or initially stated as discovery learning) first started in the United States and the roots of this active learning process go back for more than a century to Dewey (1910). More than 20 years ago, inquiry-based learning was also defined in the National Science Education Standards in the United States: "Scientific inquiry refers to the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work. Inquiry also refers to the activities of students in which they develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world" (National Research Council, 1996, p.23). Later it was also adopted in many European countries.

The definition of inquiry-based learning has been also revised through times. Keselman (2003) defined inquiry-based learning as an educational strategy in which students follow methods and practices similar to those of professional scientists in order to construct knowledge. Pedaste et al. (2012) have specified it a bit more by emphasizing the self-directed manner of the process of discovering new causal relations – the learner formulates hypotheses and tests them by conducting experiments and/or making observations. The self-directed, partly inductive and partly deductive approach and students' activity in this has been also highlighted by many other researchers (e.g., de Jong & van Joolingen, 1998; Wilhelm & Beishuizen, 2003). Thus, the key elements of an inquiry-based approach are:

- 1) aim to solve a problem but even more importantly to acquire skills to solve these in the future as well – inquiry skills,
- 2) to start the learning process from a personal interest and continue with a self-directed process through defining the problem, planning data collection and making conclusions.

A more recently established focus of inquiry-based learning has been derived from socio-scientific learning approaches and the fact that collaborative learning and collaboration skills are defined as 21st century skills. Therefore, the frameworks describing inquiry-based learning have been also revised to emphasize presentation of the results to others, reflecting on learning process and communicating ideas with peer-students (see Pedaste et al., 2015). This has been important while several studies have shown that open inquiry is not as effective as guided inquiry. A thorough review on effects of guidance on inquiry-based learning has been made by Lazonder and Harmsen (2016). In the meta-analysis they showed that the guidance has in general an effect of .66, which is a significant effect. De Jong and Lazonder (2014) have specified six types of support that could be used in instructional design. These

are shortly presented in Table 1 (based on the earlier work of De Jong & Lazonder, 2014). These types of support could be also enabled in an augmented or mixed reality environment – activities could be designed so that the complexity of the real phenomena is restricted (process constraints), learners might be provided with an overview of the status of the learning process (what are the tasks, what is completed, what learning outcomes have been achieved), learners might be supported by prompts, heuristics and explanations that help them understand the learning content or regulate their study process more effectively. In the case of scaffolds, the support is designed in accordance with the learners’ needs so that it fades out when the needs are decreasing according to learners’ progress.

Table 2. Typology of inquiry-based learning guidance (Lazonder and Harmsen, 2016 based on De Jong and Lazonder, 2014).

Typology of inquiry learning guidance		
Type of support	Basic idea	Intended Audience
Process constraints	Restrict the comprehensiveness of the learning task	Learners who are able to perform and regulate the basic inquiry process, but still lack the experience to do so under more demanding circumstances
Status overviews	Make task progress or learning visible	Learners who are able to perform the basic inquiry process, but lack the skills to plan and keep track of their learning trajectory
Prompts	Remind to perform an action	Learners who are able to perform an action but may not do so on their own initiative
Heuristics	Remind to perform an action and suggest how to perform that action	Learners who do not know exactly when and how an action should be performed
Scaffolds	Explain or take over the more demanding parts of an action	Learners who do not have the proficiency to perform an action themselves or cannot perform the action from memory
Explanations	Specify exactly how to perform an action	Learners who are (largely) incognizant of the action and how it should be performed

Note: Based on T. De Jong & Lazonder (2014), with minor textual modifications.

One more widely used approach to guide inquiry-based learning is to structure the complex process. Therefore, inquiry phases should be specified. In order to do so, Pedaste et al. (2015) reviewed over 100 different terms found in contemporary educational literature describing inquiry processes (e.g.

observe, identify the problem, predict, investigate, find patterns, analyse, organize the data, draw conclusions, discuss, reflect, etc.) and then synthesized an inquiry learning framework to specify the activities that are conceptually distinct and fundamental to inquiry. Five distinct inquiry phases (Orientation, Conceptualisation, Investigation, Conclusion, and Discussion) and seven sub-phases (Questioning, Hypothesis Generation, Exploration, Experimentation, Data Interpretation, Reflection, and Communication) were specified. These are described in Table 3.

Definition of each of the general inquiry-based learning phases and their sub-phases are provided in Table 3. In addition, it is important to understand what should be the outcomes of each of those phases. These outcomes are used in other inquiry processes. Starting from the Orientation phase, its aim is to increase curiosity for solving a problem. Therefore, students get acquainted with a situation that should engage them. In this situation they should be faced with one or several problems that should be identified by them. By the end of the orientation phase students should have identified a problem and stated it clearly. This problem will guide the inquiry processes that will follow. It is also useful to discuss this problem and its relevance with a wider audience of peer-students. In this way students link Orientation with Discussion phase.

The next inquiry-based learning phase is Conceptualization. In this phase students should take the problem statement and identify it in a broader context. This is needed to come out with one or several research questions and/or hypotheses – the expected outcomes of the Conceptualization phase.

The research questions and/or hypotheses are taken to the Investigation phase and later used again in the Conclusion phase where it should be checked whether the conclusions really answer students' posed questions or enable them to confirm or reject the formulated hypotheses. During the Investigation phase, students have to plan an exploration or experiment for collecting the data needed to solve the problem. Later, data interpretation should provide information for formulating inferences (final outcome of the Investigation phase) that should be further used in the Conclusion phase.

Table 3. Phases of inquiry-based learning (Pedaste et al., 2015).

Phases	Process Description	Sub-Phases	Process Description
Orientation	Stimulating curiosity about a topic and addressing a learning challenge through a problem statement	-	-
Conceptualization	Stating theory-based questions and/or hypotheses	<i>Questioning</i>	Generating research questions based on the stated problem
		<i>Hypothesis Generation</i>	Generating hypotheses regarding the stated problem
Investigation	Planning exploration or experimentation, collecting & analysing data based on experimental design or exploration	<i>Exploration</i>	Systematic and planned data generation on the basis of a research question
		<i>Experimentation</i>	Designing and conducting an experiment in order to test a hypothesis
		<i>Data Interpretation</i>	Making meaning out of collected data and synthesizing new knowledge
Conclusion	Drawing conclusions from data – comparing inferences made, based on data with hypotheses or research questions	-	-

Discussion	Presenting findings of particular phases or the whole inquiry cycle by communicating with others and/or controlling the whole learning process or its phases by engaging in reflective activities	<i>Communication</i>	Presenting outcomes of an inquiry phase or of the whole inquiry cycle to others (peers, teachers) and collecting feedback from them. Discussion with others
		<i>Reflection</i>	Describing, critiquing, evaluating and discussing the whole inquiry cycle or a specific phase. Inner discussion

Figure 1 shows more specifically how different phases and sub-phases are linked with each other. According to Pedaste et al. (2015), inquiry begins with the Orientation phase. Next, in the Conceptualization phase learners formulate either research questions or hypotheses. In the Investigation phase, evidence to resolve the research question or hypothesis is gathered and analysed. In the beginning of the two alternative processes for investigation – exploration and experimentation – planning is needed. However, if the data collection or interpretation reveals a need for additional materials to be read or research questions or hypotheses to be specified, then the students can turn back to Conceptualization phase as indicated with backward arrows. If everything is going as planned, then the students can move forward to the Conclusion phase, where research findings from the inquiry are reported and justified by the results of the investigation. The Discussion phase, however, is unique because it is connected to all the other phases. It consists of communicating partial or completed outcomes, as well as reflective processes to regulate the learning process.

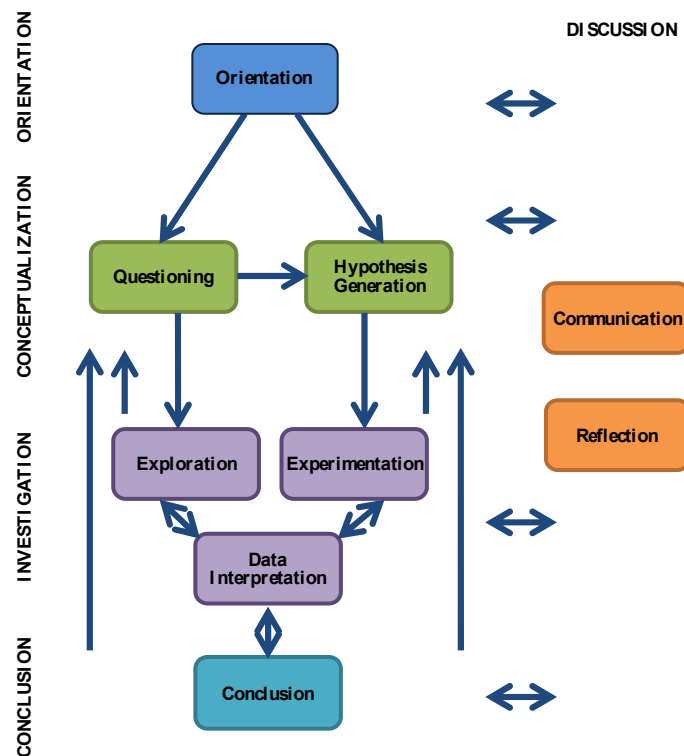


Figure 1. Inquiry learning framework (Pedaste et al., 2015).

This framework helps to systematically design learning activities and evaluate learning outcomes but also to support learning process. The learning process is not linear and could have different pathways and loops in the framework as indicated by uni- and two-directional arrows.

2.2. Contemporary learning approach

While inquiry-based learning has been more specifically emerged in the context of STEM learning, several other trends can be seen in changing learning approaches, in general, during the last decades. For example, the Estonian Lifelong Learning strategy (see <https://www.hm.ee/et/elukestva-oppe-strateegia-2020> and Figure 2) focuses on the learner, integration of different subjects and fields, teamwork, creative and critical thinking, key competences, and problem solving instead of gaining rigid factual knowledge. However, similar foci can be found worldwide. There are at least three reasons for that:

- 1) the needs of labour market have changed (speed of changes has increased and more generic skills are needed, as well as adaptability and tolerance of uncertainty),
- 2) global social changes have occurred (cultures are more mixed, social inequality is more visible),
- 3) technological advances provide new opportunities but have also raised new risks (replacement of people on many professions, data security, trustfulness of autonomous robots, addiction to virtual reality).

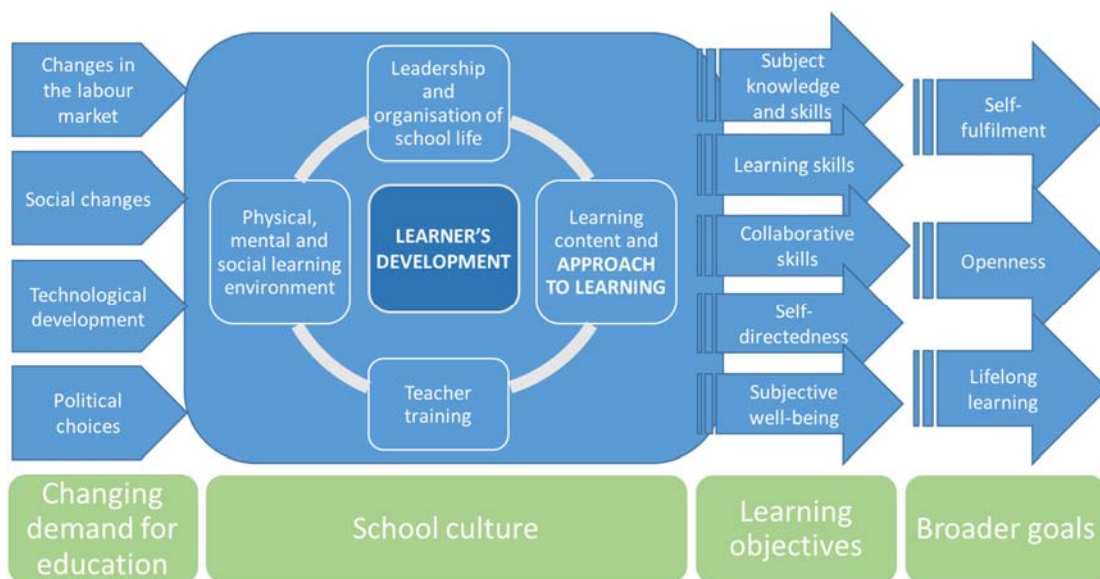


Figure 2. Approach to learning, reasons for changing it, factors supporting changes in school culture, objectives and the broader goals of the changes (<https://www.hm.ee/en/learning-approach>).

In addition to these three changes, at the societal level political decisions can often also guide the need for change in learning approaches (e.g., giving more autonomy to the schools and teachers, involving parents to the learning process, promoting inclusive education). One of the schemas that show how those changes have led to new goals of learning process have been developed in Estonian context (see <https://www.hm.ee/en/learning-approach>); however, this “contemporary learning approach” could be easily used world-wide because the pedagogical principles used in compiling it are not country-specific and derive from international research and policy-documents.

The contemporary learning approach brings together ideas from several studies that have been focusing in analysing effective learning and teaching strategies over decades. Thus, it is nothing very new but there are the ideas linked with each other and the needs of changes. The broader goals of contemporary learning approach are:

- 1) self-fulfilment (every person should develop his/her potential as much as possible),
- 2) openness (to new ideas, diversity, differences in cultures and viewpoints, learning new knowledge and skills while dropping outdated views),
- 3) lifelong learning (acknowledging that it is not possible to learn everything that we will need in five or ten years, competence to learn – including attitudes, skills and knowledge about learning strategies – is one of the key goals for every person).

The broader goals are needed to react on the needs that have been specified earlier (expectations of labour market, social changes, technological advances and political choices) but a way too general for assessing our particular needs to learn and, consequently, for guiding the learning process in a more specific level. Therefore, the Estonian schema (see Figure 2) also describes, what are the more specific learning objectives that could be evaluated and what changes are needed in school cultures to support acquiring these objectives.

One of the learning objectives according to the contemporary learning approach is the traditional subject knowledge and skills. However, the other four indicate how these should be achieved: through collaboration, self-directed learning, and subjective well-being that also leads to improved learning

skills. All of these could be seen as separate learning objectives that could be also assessed using one of the scales developed on international levels.

At the level of the school culture, the new learning approach emphasizes learner's development as the focus point of the learning and teaching process. This will be supported by shared leadership and transparent effective organisation of school life, adopting student-centred approach to learning, and developing learning materials that support this, providing teaching training to learn for the new demands, and organizing the physical, mental and social environments so that these support learning.

The learning objectives described earlier are also very much in line with the framework of 21st century skills (see <http://www.p21.org/our-work/p21-framework>, see Figure 3). This framework describes four areas of skills, knowledge and expertise students should master to succeed in work and life in the 21st century.

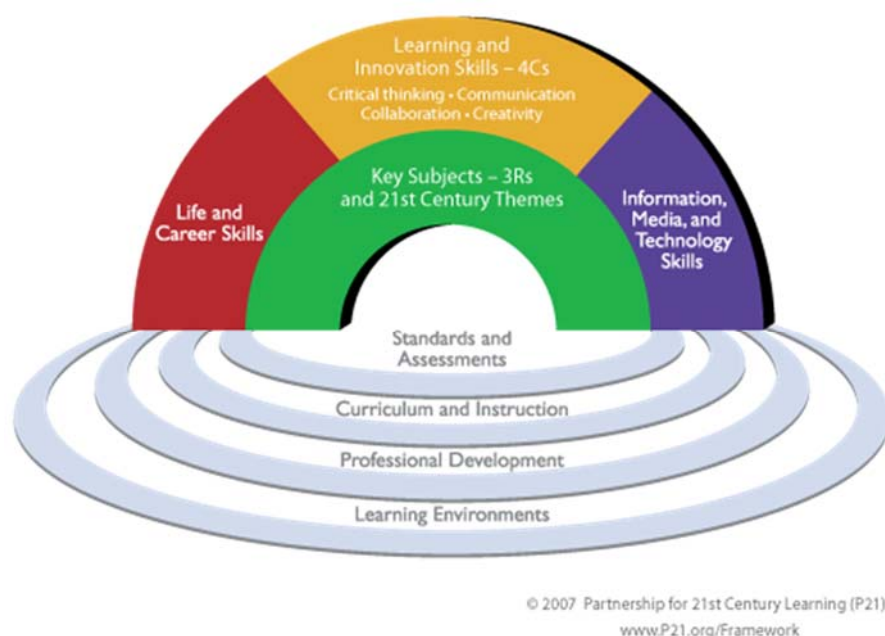


Figure 3. P21 framework for 21st century learning (<http://www.p21.org/our-work/p21-framework>).

First, indeed, there is need for some content knowledge, e.g., knowledge in languages, arts, mathematics, economics, science, geography, history, and governments and civics. However, according to the contemporary learning approach some of this knowledge might be more important today than in the past. For example, skills to communicate and learn together worldwide has a prerequisite to use a common language; therefore, the importance of learning languages has been increasing. For the same reason, we have to focus more on government and civics, so that we can better understand people from different cultures and societal groups. However, this framework also emphasizes several interdisciplinary themes that ensure better life for the future; e.g., global awareness, health literacy, or environmental literacy.

Second, the 21st century skills framework brings into focus learning and innovation skills. Here it is important to note that in addition to learning skills innovation is emphasized. This means that we need not only to learn, but also to innovate – to create something useful with our knowledge and skills. Innovation has been defined as **the process of translating an idea or invention into a good or service that creates value**. For that, creativity is needed. Creative thinking skills are missing in the Estonian schema of contemporary learning approach and this has been the main criticism of the schema. Learning and innovation skills together with creativity lead people towards successful work in the

future. However, this cannot be done in isolation. Therefore, learning and innovation skills in the framework, are also linked to communication and collaboration.

Third, information, media and technology skills are taken into focus to indicate the technological development are demands related to that: 1) access to an abundance of information, 2) rapid changes in technology tools, and 3) the ability to collaborate and make individual contributions on an unprecedented scale.

Finally, this framework brings out life and career skills, which could be linked to openness, life-long self-directed learning and subjective well-being in the framework of the contemporary learning approach. In particular, (a) flexibility and adaptability, (b) initiative and self-direction, (c) social and cross-cultural skills, (d) productivity and accountability, and (e) leadership and responsibility have been specified in this category.

The framework also provides guidance for achieving those skills, knowledge and expertise: new standards, assessment instruments, curriculum and instruction, professional development of teachers, and appropriate learning environments are needed. This is what is also aimed at EL-STEM project.

At the European level these ideas are very much in line with recommendations made by European Commission to support acquiring skills for life-long learning (<https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52018DC0024&from=EN>). There have been identified and defined eight key competences:

- Literacy competence;
- Languages competence;
- Mathematical competence, competence in science, technology and engineering;
- Digital competence;
- Personal, social and learning competence;
- Civic competence;
- Entrepreneurship competence;
- Cultural awareness and expression competence.

The list shows clearly the STEM related competences (mathematical competence, competence in science, technology and engineering but also digital competence) have an important role among others.

Next, we will describe the standard for using mixed and augmented reality according to the contemporary learning approach in the context of IBSE-based STEM learning, and how to assess outcomes of this process. Later in the project more specific learning scenarios will be developed together with instructional guidelines (IO2 and IO6), trainings will be provided to teachers (IO4), and MR/AR learning environments and learning objects will be designed for learning (IO3 and IO5).

3. Instructional Design for using MR/AR in IBSE-based STEM learning

Mixed and augmented reality (MR/AR) are forms of virtual reality where technology (head-mounted displays, handheld computers – tablets and smartphones, GPS) is used to enrich the real environment, it means that technology blends real and virtual information in a meaningful way (Klopfer, 2008). Wu et al. (2013) have specified based on Milgram et al. (1994) that mixed reality consists of augmented reality and augmented virtuality. According to Milgram et al. (1994), AR is a combination of the real and the virtual and there is more real than virtual, whereas AV refers to adding elements of reality to a virtual environment and has more virtual information. For example, virtual objects could be added to a real environment in AR, and a real object could be projected into a virtual environment in AV. Followed from that the benefits of MR/AR seem to be overlapping and the instructional design could be unified for both of them. More details concerning AR and MR specific characteristics are described in IO2, to enhance teachers' understanding of these technologies.

The main benefit of MR/AR is that these could provide users with technology-mediated immersive experiences in which real and virtual worlds are blended (Klopfer & Sheldon, 2010). The virtual objects in MR/AR could provide some information about the real objects but they could be also fully virtual objects immersed to the real environment. In a more advanced setting these virtual objects could be manipulated as real ones (e.g., in conducting experiments in a science lab and collecting data). What is good in case of MR/AR compared to fully virtual reality is that the real objects and even other learners are also immersed to the learning environment and; therefore, interaction (e.g., collaboration) between them is possible and there is also the possibility to fade out virtual support (as is expected according to the scaffolding approach) by guiding students towards more self-directed learning.

Wu et al. (2013) specify based on several studies five features and affordances of AR that according to our understanding are also applicable in the case of MR. AR enables:

- 1) **learning content in 3D perspectives** (manipulate virtual objects in 3D; e.g., spinning Earth or solar system, molecules – usually objects that cannot be manipulated in real world on a visible scale),
- 2) **ubiquitous, collaborative and situated learning** (handheld computers, wireless connection and location-registered technology makes possible situated learning in real environment where virtual information/objects are immersed; e.g., mobile AR-games like Environmental Detectives (Klopfer, 2008; Squire & Klopfer, 2007) and Mad City Mystery (Squire & Jan, 2007), but also PokemonGo (see <https://www.pokemongo.com>) or GeoCaching (see <https://www.geocaching.com/>)),
- 3) **learners' senses of presence, immediacy, and immersion** (group of students is in the same immersive environment and may recognise a community of learners (see Squire & Jan, 2007) that solves with IBSE based approach a real problem taken to their local environment (e.g., what would it be in our school if we would have a Nuclear Power Plant catastrophe at a distance of 12 km (see Chang, Wu & Hsu, 2012)), feedback could be provided immediately by the system behind the AR/MR environment and, hence, increase learners' motivation),
- 4) **visualizing the invisible** (e.g., unobservable phenomena, such as airflow or magnetic fields, molecules, force vectors), and
- 5) **bridging formal and informal learning** (showing how, for example, different scientific phenomena can be learned in school context and other contexts, and how concepts learned at school appear in everyday context in informal settings).

An AR system could support learning while detecting students' locations and working status. Based on this it could provide task reminders, offer alternative learning paths, suggest refocusing students' attention, and due to this to decrease task interruptions and manage students' attention (see Roda & Thomas, 2006). The network provides learners in AR/MR environments with a number of possibilities to interact with each other by finding learners with whom to collaborate, by asking/receiving and providing feedback, etc. (see Birchfield & Megowan-Romanowicz, 2009).

Wu et al. (2013) also specified a number of instructional and learning approaches that have been effectively used in designing AR environments: game-based learning, place-based learning, participatory simulations, problem-based learning, role playing, studio-based pedagogy, and jigsaw method. Based on studies using one of these approaches they generalise that there are three major categories of instructional designs that are used in applying AR:

- 1) engaging learners in "roles" (that need to collaborate with each other in order to solve a problem),
- 2) emphasizing interactions with physical "locations" (so that the students get the sense of an authentic environment that increases the feeling of reality and potentially knowledge transfer from learning situation to everyday life and work contexts) and,
- 3) providing specific "tasks" (different tasks to different students to enhance collaboration and avoid cognitive overload, tasks focusing on problem-solving and knowledge application rather than simple information gathering and learning of facts).

On the basis of the descriptions of IBSE and contemporary learning approach in integration with instructional designs used in MR/AR and their affordances and features we synthesize for the EL-STEM project the instructional design process that uses MR/AR in IBSE-based STEM learning (see Table 3). In the centre of this design is the pedagogical approach, supported by available designs for using MR/AR that all have specific affordances and features supporting application of the contemporary learning approach. In particular, we will follow the learning phases of the IBSE framework developed by Pedaste et al. (2015). In each of the learning scenarios designed according to EL-STEM instructional design there should be five phases: Orientation, Conceptualization, Investigation, Conclusion and Discussion. Depending on the topic, a problem should be specified that could be solved in a MR/AR environment. Next, different roles needed when the same problem would be solved in the real life should be specified. These are the roles that will be assigned to students who should solve the problem collaboratively. Next, students should be provided with information that is specific to their roles and here MR/AR solutions could be used. In addition, students' collaboration but also knowledge acquisition and other learning processes should be supported by hints that could be again provided in the MR/AR environment (augmented informative windows in the real environment). A special focus should be set on guiding students towards active communication (sharing information, asking and giving feedback, reflecting on the learning, including collaboration and learning skills). Finally, the MR/AR environment should collect relevant information about the learners in order to give immediate feedback where appropriate. These aspects could be applied in all IBSE learning phases; however, investigation phase has an additional focal point. Namely, for this phase it is important to design 3D learning objects that can be manipulated by the learners.

The Instructional Design in IBSE-based STEM learning suggested in Table 4 could be either totally implemented in an AR/MR environment (if possible) or partially. This means that the AR/MR technologies selected by the teachers could be integrated either in all learning phases of IBSE or in some of them.

Table 4. Instructional Design for using MR/AR in IBSE-based STEM learning.

Learning phase of IBSE framework	Link with contemporary learning approach	Instructional design for using MR/AR	Affordances and features in focus
Orientation	Self-regulated problem-formulation activities should be supported and personal challenges and curiosity highlighted (to guide learners towards self-fulfilment)	Students should be assigned to different roles with specific identities (e.g., in an AR/MR game, a local and/or remote laboratory, a real environment where STEM learning will take place) that should be used throughout the learning process while solving a problem	Students should be provided with immediate feedback to their ideas (augmented information) and a possibility to ask and receive feedback from peer-students and/or the teacher
Conceptualization	Subject knowledge and skills needed to solve the problem should be specified, collaboration in collecting and sharing information is needed	Learning to know different concepts should be organised in a group of learners using jigsaw approach	Immediate feedback should be given, augmented information (e.g., texts, heuristics, vectors) should be available for objects that are important in the problem situation
Investigation	Self-regulated collaborative experiment-planning and data-gathering and analysis processes should be supported; openness to new ideas and variety of explanations should be supported	Learning should be taken “out” from the regular classroom – it might be in a corridor, outside, museum - or even in a regular classroom or a STEM laboratory that is augmented with virtual objects and placed into a new surrounding; problem solving might be organized using jigsaw method	3D learning objects should be used where appropriate, e.g., visualizing invisible phenomena and objects that are too small or large; digital objects of different formats (e.g. figures, videos, sound, links) providing augmented content should be used where appropriate, e.g., viewing additional information concerning the topic under investigation; learning should be situated in a meaningfully

			augmented real environment; alternatives should be available through AR/MR so that the students could realise the results of their choices, e.g., an explosion could happen or the result of the fermentation could be something different than cheese; outside the classroom, location-based services should be used to make available desired information/data
Conclusion	Acquired subject knowledge and skills should be emphasized	Learners should follow the roles assigned to them and participate in making conclusions and evaluating their validity	The conclusion should be taken from formal learning context to informal or vice versa (it should be possible to learn to solve the problem in both contexts)
Discussion	Reflection on learning should focus not only on learning outcomes but also on learning skills and subjective well-being	Learners should follow the roles assigned to them and contribute through that the authentic feeling of team-based problem-solving	Students should be provided with guidelines to effective teamwork and scaffolded to ask and give feedback and to reflect on their learning

More use cases and examples of integrating AR/MR into real classrooms are described in IO2, to enhance teachers' understanding of these technologies within an educational context.

4. Assessment of IBSE based STEM learning outcomes

The MR/AR environments have been thoroughly studied in comparison of several other forms of learning environments. These studies have showed that MR/AR have had benefits in learning some skills and acquiring knowledge, navigating information, understanding of dynamic models and complex causality, increasing learning motivation and interest, spatial abilities, transfer of learning, psychomotor-cognitive skills, learning invisible concepts and phenomena, abstract concepts (for an overview see Wu et al., 2013). However, MR/AR environments have not been often used for improving inquiry skills, and to our knowledge no study has been conducted to assess the effect of MR/AR scenarios on inquiry skills (nor have scenarios been specifically designed to support IBSE). In the context of the EL-STEM project, IBSE is the key focus and; therefore, inquiry skills should be assessed in the learning situations. However, in addition to that there is expected improvement of problem solving skills. We see that inquiry is itself an approach for solving problems but in addition to that we expect that in using advanced educational technologies students' computational thinking (CT) skills should improve. These are skills that are expected to be very important in the future labour market where technology should be applied more extensively. However, the labour market also needs some other even more generic skills; e.g., critical thinking skills and collaboration or teamwork skills (also specified in the framework of contemporary learning approach). And finally, we plan to assess students' learning motivation and engagement vs disaffection with learning while these are needed to acquire learning skills, to support self-regulated learning process, and to achieve subjective well-being. Thus, we will provide schools with the following assessment instruments (this is a toolkit and not all tools should be used by all teachers in case of EL-STEM studies):

- 1) Middle School Inquiry Skills Assessment (MSISA) test,
- 2) Computational Thinking Skills Inventory (CTSI),
- 3) Halpern Critical Thinking Assessment (HCTA) test,
- 4) Teamwork Skills Inventory (TSI),
- 5) Engagement vs Disaffection with Learning (EDL),
- 6) Science Motivation Questionnaire II (SMQII).

4.1. Middle School Inquiry Skills Assessment (MSISA) test

This test has been developed in Estonia and is useful in the context of EL-STEM project while it follows specifically the IBSE framework developed by Pedaste et al. (2015) that is taken as the guiding framework in EL-STEM project. Its quality has been tested and improved in a series of four studies using expert discussions and Item Response Theory 1-parameter models to describe reliability of the test and on item level discrimination and difficulty of each item as well as items difficulty's resonance with the test difficulty. Based on the items' difficulty measures all items are divided between six difficulty levels so that finally a comparatively short test consisting of three items on each difficulty level (18 items in total) could be administered in about 30 minutes. The test is filled in online while it's important that the students cannot move back in answering some of the questions. In Appendix 1 are presented the test items.

Table 5. Learning outcomes assessed with the MSISA test.

Inquiry phase	Outcomes	Items
Orientation	<p>...understands scientific text and creates a simple scientific test</p> <p>...identifies a problem in a situation and formulates it clearly</p>	<p>students read a text and answer questions or create a sentence</p> <p>students read a text and formulate a problem that is described there</p>
Conceptualisation	<p>...formulates research questions and hypotheses</p> <p>...finds scientific information from different sources and evaluates it critically</p>	<p>students are provided with a problem description and have to formulate or select from a list a research question or hypothesis that contains all elements of a correct question or hypothesis</p> <p>students have to answer a question by finding information from three web-sites they have to search, the addresses of the web-sites are copied as evidences of search process and the pages are compared to find the most trustful one</p>
Investigation	<p>...designs an experiment for collecting data, selects appropriate tools and materials and conducts the experiment</p>	<p>students read a research question or hypothesis and list all tools and materials needed in an experiment for answering the question or testing hypothesis; or plan a sequence of activities needed in this experiment; or conduct the experiment using web-based simulations</p>
Conclusion	<p>...uses or creates models in explaining phenomena, processes or systems</p> <p>...solves everyday life science-related problems and makes decisions based on scientific knowledge, skills and values</p> <p>...analyses and interprets scientific information and draws conclusions and makes decisions based on this</p>	<p>students select an appropriate model or figure; or improve a partly prepared model or figure</p> <p>students synthesize different textual and visual information with data and make decisions based on more than one type of arguments</p> <p>students describe data in a table or figure and draw conclusions based on these</p>

Discussion	...explains and analyses objects, phenomena and processes and cause-effect relationships between them ...correctly uses scientific concepts, symbols and units	students combine information that is presented in the task with their own knowledge students fill in a blank in a text with an appropriate scientific concept
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Please note: due to copyright restrictions the MSISA test is currently unavailable for dissemination. Therefore, will provide alternative assessment scales for evaluating students' inquiry skills in Appendix 1. The scales are intended to be used by teachers to map their students' skills as well as potential areas of development.

4.2. Computational Thinking Skills Inventory (CTSI)

CTSI focuses on five dimensions of computational thinking (Selby and Woollard, 2014):

- 1) the ability to think in abstractions,
- 2) the ability to think in terms of decomposition,
- 3) the ability to think algorithmically,
- 4) the ability to think in terms of evaluations, and
- 5) the ability to think in generalizations.

According to Selby and Woollard (2014):

- **Abstraction** is an ability to decide what details of a system or problem are important and what details should be ignored to avoid complexity.
- **Decomposition** is a skill of breaking a system or problem into smaller elements. It is required when dealing with large problems, complex systems, or complex tasks.
- **Algorithmic thinking** is a method to define step-by-step instructions that can be carried out by a human or machine (for example, to solve a problem).
- **Generalization** is the ability to express a problem solution in generic terms, which can be applied to new problems. It is an ability to move from specific to broader applicability.
- **Evaluation** is analysing processes to assess and recognize the processes and the outcomes in terms of efficiency and resource utilization, e.g., how fast and sustainable is our solution, how resource-effective it is, etc.

A more thorough overview of assessing skills of computational thinking is given by Palts et al. (2017) and the CTSI for assessing computational thinking skills can be found in Appendix 2.

- Please find the test demo here: <https://survey.ut.ee/index.php/291219?lang=en>

You are able to access the test by typing in the following code: TcS9u

Please note: this is only a demo test and answers are not saved!

4.3. Halpern Critical Thinking Assessment (HCTA) test

Many tests for assessing critical thinking skills usually consist of multiple-choice items that are focusing on the cognitive ability to think critically and do not take into account the respondents intention to think and to recognize the importance of good thinking (for an overview of the issues, see Ku, 2009). This results in low correlation of knowledge about critical thinking and actual behaviour to think critically. Several studies have differentiated cognitive component and disposition component in critical thinking (see Ku, 2009). The first one could be assessed with a multiple-choice test while the recognition of the second one needs open-ended questions as well. In addition, the widely used tests for assessing critical thinking tend to have serious problems with factor structure and internal consistency of the scales. In conclusion, Ku (2009) suggest measures that combine open-ended and multiple choice items as is the case of The Halpern Critical Thinking Assessment (HCTA; Halpern, 2007) that is based on scenarios from everyday situations.

The HCTA was also selected for the EL-STEM project while our focus is on IBSE-based learning and Ku has with her colleagues (Ku et al., 2014) applied this instrument successfully in testing the effect of inquiry-based interventions on critical thinking. The HCTA consists of 25 scenario-based questions; each asks for open-ended responses as well as multiple-choice responses, in total 50 questions. As Ku (2009, p. 74) specifies, “The questions of the HCTAES represent five categories of skills: verbal reasoning (e.g., recognizing the use of pervasive or misleading language), argument analysis (e.g., recognizing reasons and conclusions in arguments), hypothesis testing (e.g., understanding sample size, generalizations), using likelihood and uncertainty (e.g., applying relevant principles of probability, base rates), as well as decision making and problem solving (e.g., identifying the problem goal, generating and selecting solutions among alternatives).”

Administering lengthy HCTA which has 25 open-ended questions in addition to the multiple-choice questions takes a lot of time. It is done online in the VIENNA testing system where the data is collected and open-ended answers coded (see more information about the test at <https://sites.google.com/site/dianehalperncmc/home/research/halpern-critical-thinking-assessment>). It needs time to collect data and to code the open-ended answers. Therefore, it is very valuable, that Ku et al. (2014) have showed that this instrument can be also used while only a small number of scenarios have been selected for the assessment of students' critical thinking ability and disposition. The only preference that should be followed is that in case of each selected item both open-ended and multiple-choice questions are asked. By selecting the scenarios from the instrument we have to keep in mind the age group we are focusing on in a particular case in the EL-STEM project. HCTA was developed for college students and has been also used in high-school but there are no studies known on upper-primary school level. Therefore, some of the scenarios might be too demanding for them although the scenarios are related to everyday life and not directly to the content learned at school. Currently, we are in discussion with the HCTA testing team in order to figure out if and how this test could be used in the EL-STEM project, how it could be translated to different languages and what would it cost taking into account that we need to use it in the pre- and post-test design two times with at least 200 students in four countries.

- Please find the test demo here: <https://survey.ut.ee/index.php/458374?lang=en>

You are able to access the test by typing in the following code: A0ooh

Please note: this is only a demo test and answers are not saved!

4.4. Teamwork Skills Inventory (TSI)

TSI is an instrument developed by Strom and Strom (2011). This questionnaire has had good internal consistency when students have assessed themselves or their peer-students. The validity has been defined through high correlations between self-evaluations, peer-evaluations and teachers' evaluations. TSI has 25 items in 5 categories. The only issue of the TSI in the context of EL-STEM project might be that it has been used in the context of high school while our target group overlaps with this only partly. However, considering the content of the items these should not be too difficult for executing with lower secondary school students. Indeed, this is something that needs to be tested and; therefore, the factor structure of the TSI should be checked in the EL-STEM project when enough data (at least from 200 students for Confirmatory Factor Analysis) have been collected.

The five categories of teamwork (or collaboration) skills detected with TSI are the following:

- 1) attends to teamwork (a student shows acceptable attendance at team meetings, arriving on time for meetings, staying focused on tasks, fulfilling individual roles, and doing a fair share of work expected of everyone),
- 2) seeking and sharing information (admitting when in doubt about what should be done, asking questions to improve group understanding, helping peers by explaining or reviewing lessons, bringing reading materials for the team to examine, and referring to reading materials during team discussions),
- 3) communicating with teammates (sharing experiences, feelings, ideas, or opinions, speaking clearly and using easily understood vocabulary, limiting length of comments so that others get to talk, listening to everyone and respecting their views, and encouraging and recognizing contributions of others),
- 4) thinking critically and creatively (considering views that differ from personal opinion, using logic to challenge group thinking or work methods, thinking carefully about ideas before reaching conclusions, building on the ideas of others, and offering new ways of looking at problems or events), and
- 5) getting along with teammates (willingness to accept criticism, avoids blaming other people for problems, accepts compromise as a way to handle conflict, keeps trying when a task is hard, and expresses hope about group success).

These categories have been theoretically constructed based on review of research literature on cooperative learning, small group dynamics, creative thinking, critical thinking and personnel evaluation methods in business and industry (see Strom & Strom, 2011). The authors also specify conditions that should be met before using TSI. First, the students have to work in a team long enough to be able to assess the quality of teamwork. The authors recommend the period of four weeks at minimum (for formative assessment; for summative assessment even eight weeks is recommended). Thus, TSI should be used in EL-STEM when the students have already worked together on different MR/AR scenarios at least for one month or even better if for two months. This also means that in the scenarios students should work for longer period in the same teams. Time needed to fill in TSI is 15 to 20 minutes.

The items of TSI in the work of Storm and Storm (2011) were assessed on a simple true-false scale and in case of peers only these items were assessed about what the students were confident. While there was five members of each of those groups then the scores of four peers showed how typical one or other aspect is to their teammate. It means that in the original questionnaire the authors have

a binary scale but the result of peer-assessment was found on or a 4-point scale. Indeed, the self-evaluation was on binary scale (true – not true about me). While the studies showed that there is a high correlation between peer-evaluations and self-evaluation (and even with teacher's evaluation) we decided to use only self-assessment tool in EL-STEM project while it gives information about the all items most accurately (peers and teachers might not have seen evidences about each of the items and; therefore, cannot judge about them). However, we decided to make one adaptation to the original scale in order to increase variability in students' evaluations. Namely, we changed the scale to a four-point scale as it was used in the case of peer-assessment. Indeed, while the factor structure of this TSI self-assessment version with 4-point Likert-type scales has been not confirmed we have to run Confirmatory Factor Analysis when we have collected enough data (at least from 200 students). The adapted version of the TSI is presented in Appendix 3. There are also presented the dimensions of teamwork skills but these should be removed when the TSI is used with students. The sequence of the items could be still as it is (according to the categories).

- Please find the test demo here: <https://survey.ut.ee/index.php/733367?lang=en>

You are able to access the test by typing in the following code: wgThy

Please note: this is only a demo test and answers are not saved!

4.5. Engagement vs Disaffection with Learning (EDL)

EDL questionnaire has been developed by Skinner, Kindermann and Furrer (2009). They have conducted a thorough validation study where they compared the 6th grade students' self-evaluations with teachers' evaluations and classroom observation data. They theoretically identified four indicators of engagement and developed a scale using these as dimensions: behavioural engagement, emotional engagement, behavioural disaffection, emotional disaffection. According to their definition, "engagement refers to the quality of a student's connection or involvement with the endeavour of schooling and hence with the people, activities, goals, values, and place that compose it" (Skinner, Kindermann & Furrer, 2009, p. 494). However, they also specify based on Connell and Wellborn (1991) that engagement includes behavioural and emotional participation in the classroom but in conceptualizing engagement conceptualization of its opposite term disaffection is also required. In their analysis Skinner et al. (2009) showed that engagement and disaffection are not simply two opposites of the same scale but the four dimensions – behavioural and emotional engagement and disaffection – could be all differentiated in a multi-dimensional model.

The work is interesting and especially useful in the MR/AR context, since it distinguishes between emotional and behavioural engagement (and disengagement). It means that it is possible to distinguish if the MR/AR environment triggers only one or other – often there is hypothesized in case of using innovative technologies that the learners might be emotionally motivated but they are not cognitively involved and this might result in poor learning outcomes. This might be also one of the reason why teachers often do not get enthusiastic in adopting modern technologies in classrooms. However, these hypotheses have been not tested and the EL-STEM project might be a good test-bed for this.

The items of EDL in Appendix 4 are presented according to the dimensions of the questionnaire. However, these should be sequenced randomly for the students. In addition, there are used asterisks (*) in the appendix to indicate which items should be coded in reverse – before analysis the scores of them should be changed so that 1=4, 2=3, 3=2, 4=1. After that, the mean should be calculated for each of the four dimensions and the full questionnaire.

- Please find the test demo here: <https://survey.ut.ee/index.php/433452?lang=en>

You are able to access the test by typing in the following code: FFs99

Please note: this is only a demo test and answers are not saved!

4.6. Science Motivation Questionnaire II (SMQ-II)

SMQ-II is a questionnaire developed by Glynn (2011). One of the values SMQ-II is its availability in different languages (English, Chinese, Dutch, German, Greek, Japanese, Korean, Russian, Spanish, and Turkish). This questionnaire has been validated with students who have science as a major and also with those who do not. More information and translations of the questionnaire can be found at <https://coe.uga.edu/outreach/programs/science-motivation>.

SMQ-II differentiates five scales: intrinsic motivation, self-efficacy, self-determination, grade motivation and career motivation. In each dimension of science motivation there are five statements that should be evaluated by students on a 5-point Likert-type scale (never, rarely, sometimes, often, always). In Appendix 5 the questionnaire items are presented according to the scales but each of the items has a question number and for students the items should be sequenced according to this without indicating the titles of the dimensions.

- Please find the test demo here (in English): <https://survey.ut.ee/index.php/485855?lang=en>

You are able to access the test by typing in the following code: quzdT

Please note: this is only a demo test and answers are not saved!

5. Challenges and success stories in applying contemporary IBSE based STEM learning in innovative learning environments

The current chapter is a report of partners' analysis of the challenges and description of success stories that are linked to the formerly described instructional design for using MR/AR in IBSE-based STEM learning and its expected outcomes to be assessed in the project. First, we describe the methods for collecting data from the partners. After that, the results are presented.

5.1. Methods for identifying challenges and collecting success stories

Based on the previous chapters the following research questions were formulated:

- 1) What is the attractiveness of STEM studies and how engaged and motivated the students are in STEM studies in different countries?
- 2) How familiar are teachers and teacher educators in different countries with innovative emerging technologies and what are the challenges in applying them?
- 3) How familiar are teachers and teacher educators in different countries with innovative pedagogies and contemporary learning approach used in EL-STEM project and what are the challenges in applying them?

It was decided to collect data for answering these research questions using an online survey, while this is a good data collection method that can be administered very easily. However, we also decided to ask the respondents to share voluntarily their contact information in order to contact with them for clarifying their open-ended answers if needed (e.g., information about success stories).

We did not set a minimum required number of respondents and let this to be decided by each partner (if possible, then based on saturation point – if additional data collection does not give new ideas or does not affect the average scores then there is no need to collect more data). However, we recommended partners to share the survey with representatives of two different target groups: a) teacher educators and educational researchers, and b) in-service secondary education teachers.

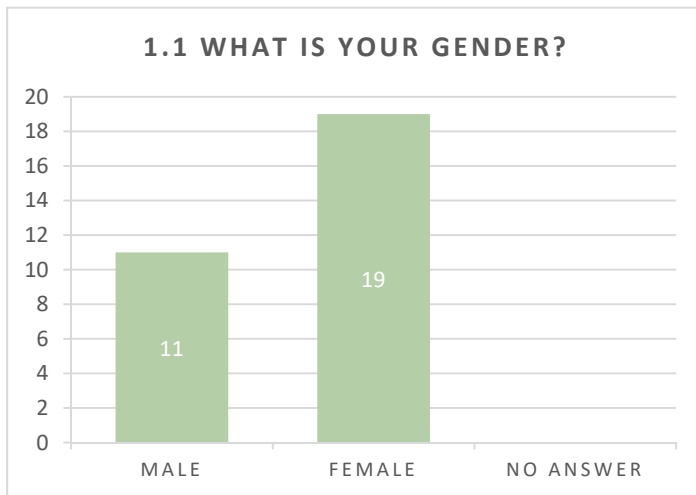
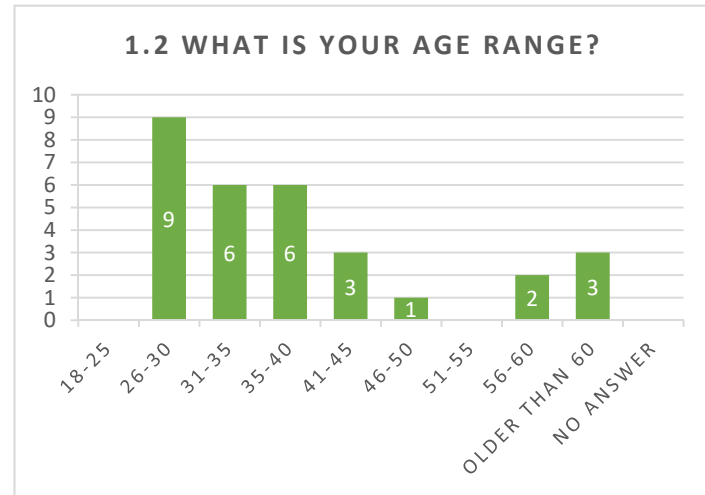
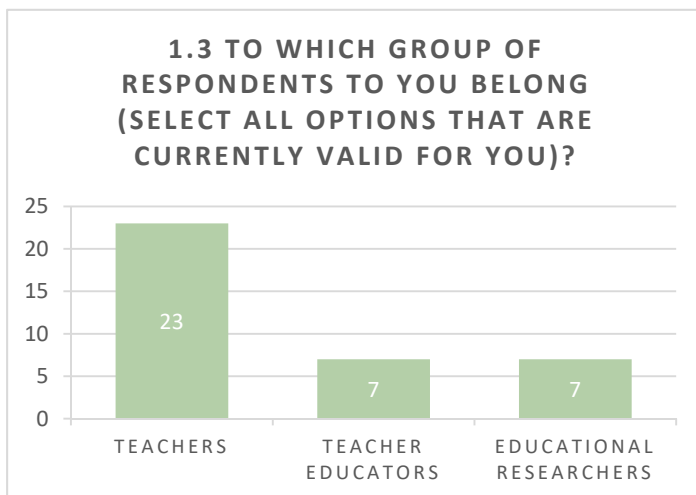
The survey was first designed in English, then discussed and revised in collaboration with other partners of the EL-STEM project. The final version of the survey was translated into partners' native languages in cases deemed necessary by the local representative of the EL-STEM project. The survey is presented in Appendix 6. The online version was created using LimeSurvey.

5.2. Findings from different European countries

5.2.1. Estonia

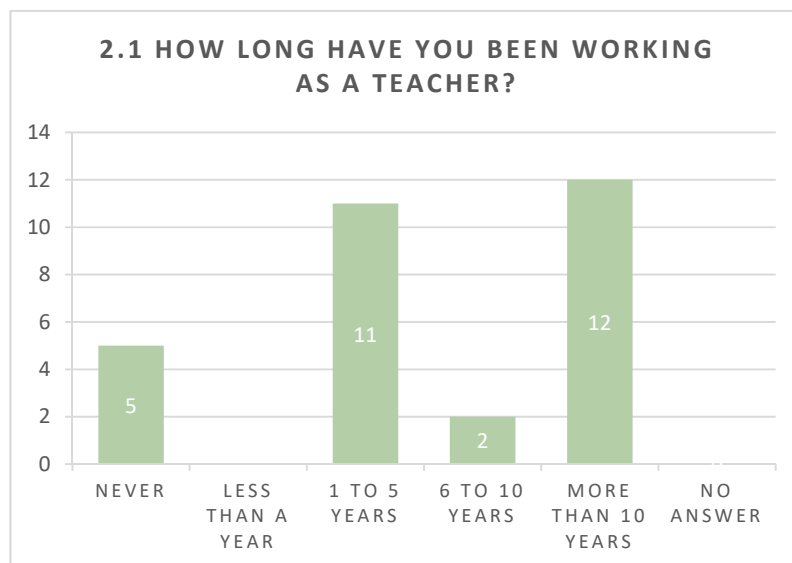
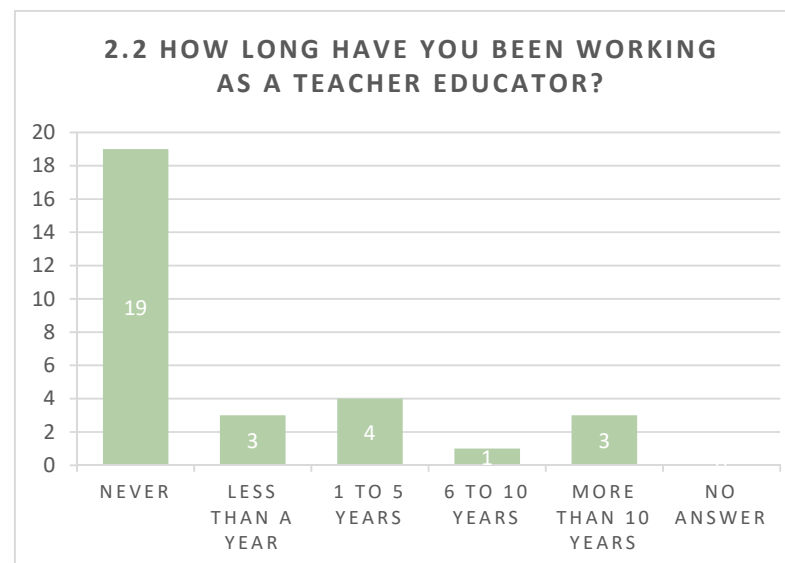
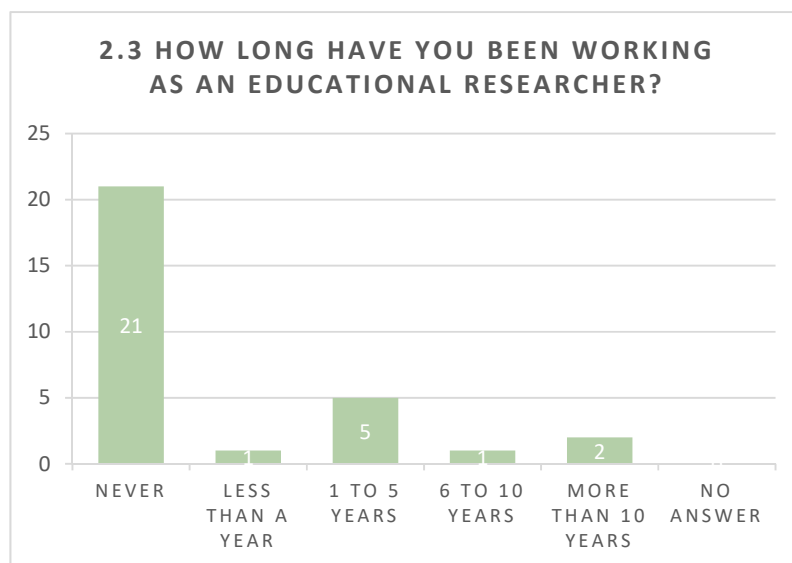
Altogether **30 people** responded to the survey from Estonia. An overview of the respondents' profile and responses will be given in the charts below.

1. Background information



Majority of 30 respondents in Estonia are **aged between 26-40**: 26% are aged between 26-30 and respectively 18% between 31-35 and 35-40. Other participants' ages vary from 41 to over 60. Respectively 9% are aged between 41-45 and over 60, 6% between 56-60 and 3% between 46-50.

2. How long have you been working as a... (select an answer in case of all options)



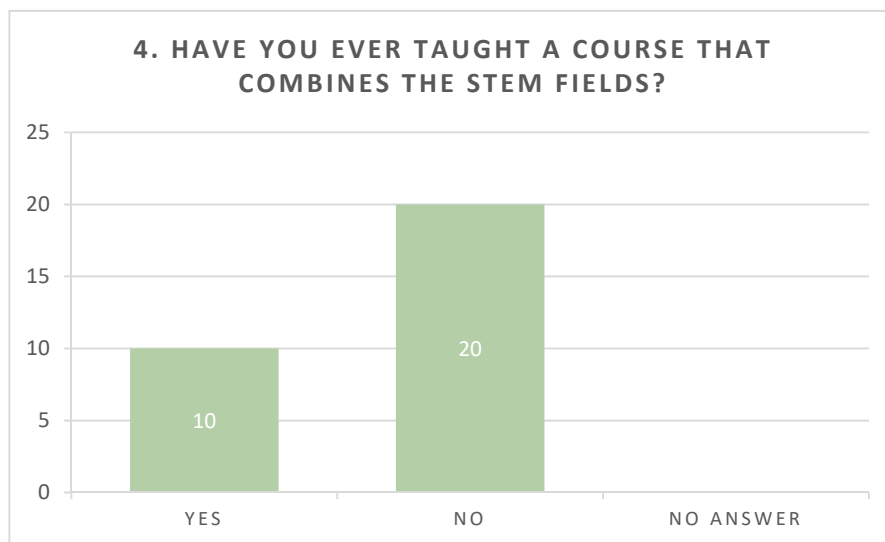
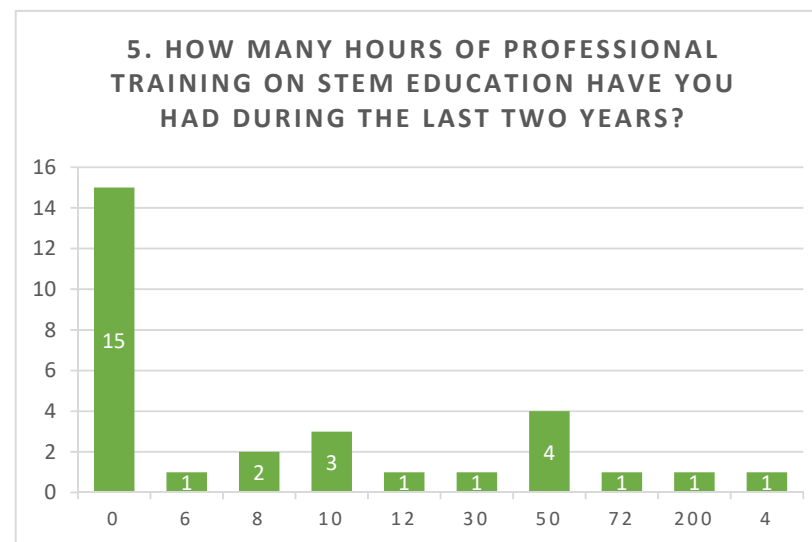
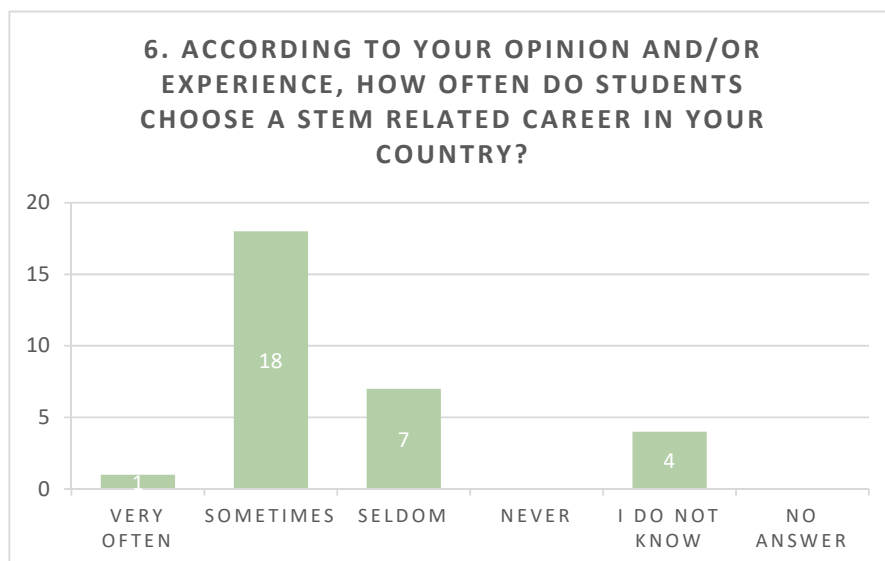
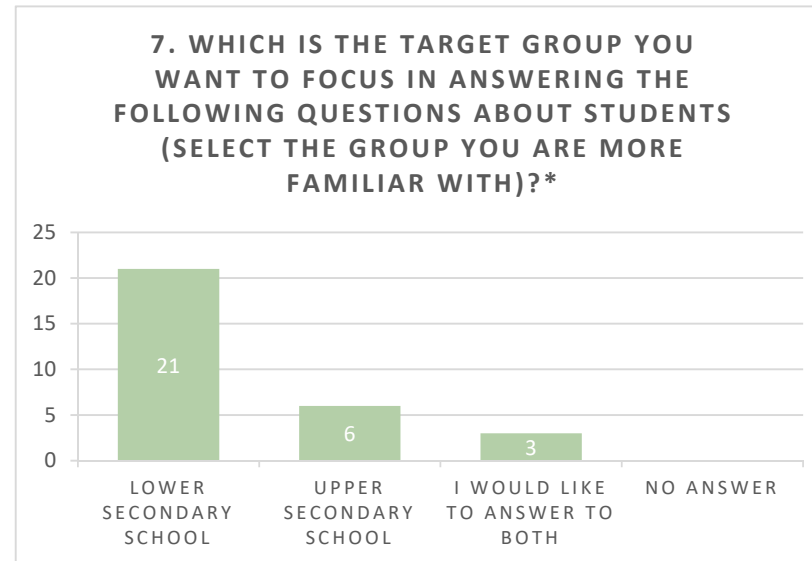
Majority of the respondents are working as **teachers** (68%) with experience spanning between less than a year (44%) to over 10 years of experience (48%). Fewer people are working as **teacher educators** (21%) with experience also spanning between less than a year (27%), 1 to 5 years (36%), 6 to 10 years (9%) to over 10 years of experience (27%) and **educational researchers** (21%) with experience from less than a year (11%), 1 to 5 years (56%), 6 to 10 years (11%) to over 10 years of experience (22%).

3. How do you understand the concept of STEM (use up to 1000 characters)?

Altogether, 25 people responded to the question. The answers were categorised and an overview of the responses will be given in the table below.

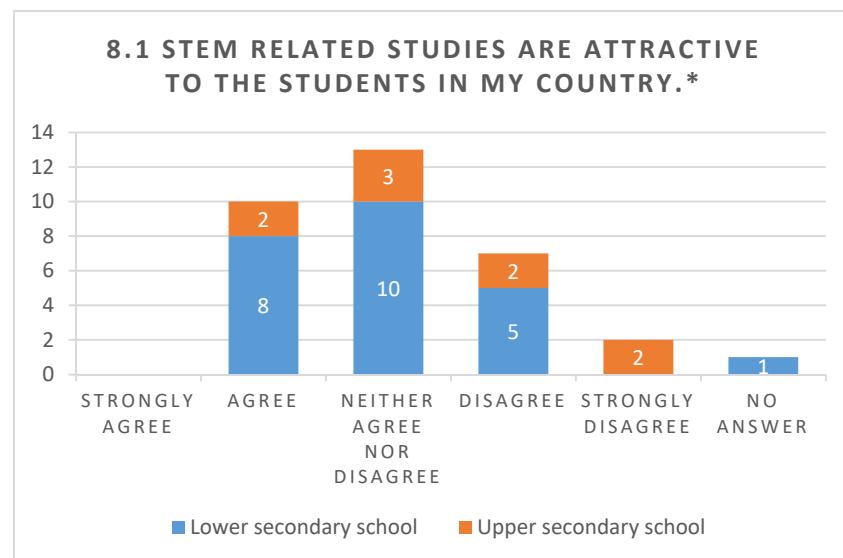
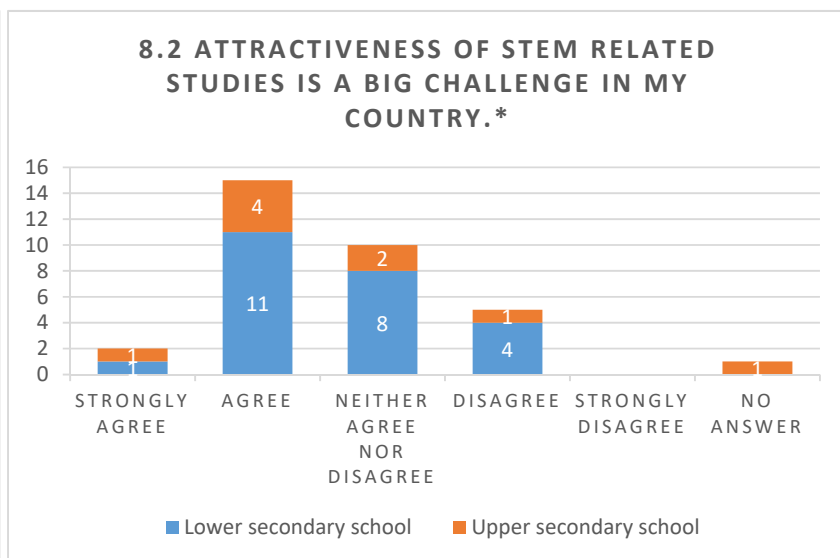
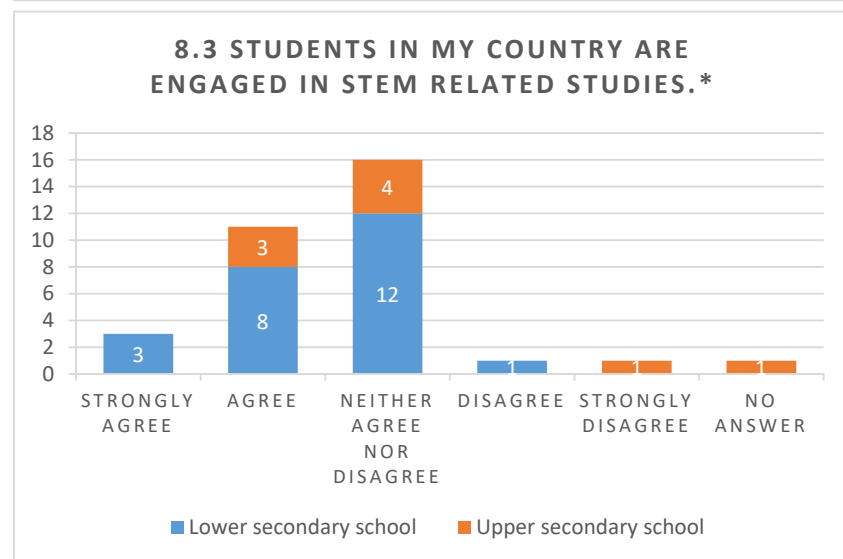
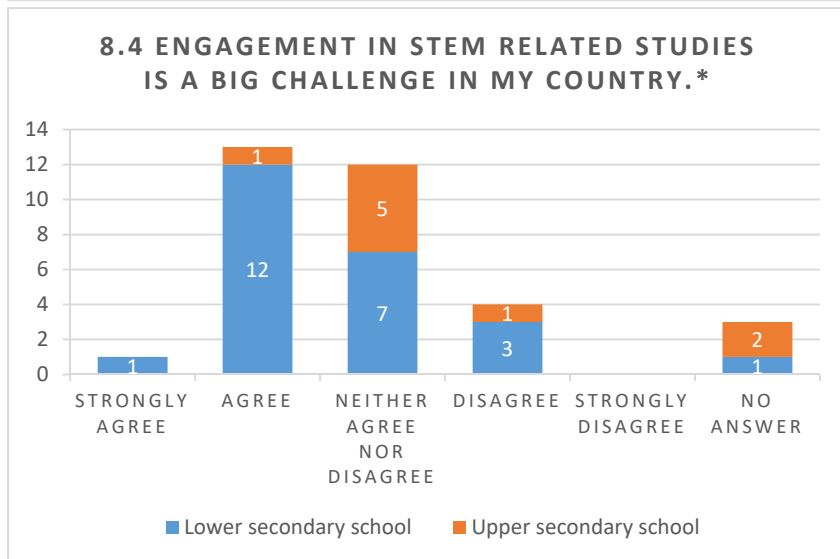
Category	Freq.
Science Technology Engineering Mathematics	16
Science Technology Engineering Mathematics and the integration of these disciplines/use of research based learning method/use of applied approach	6
Science Technology Engineering Mathematics and the integration of these disciplines with applied approach, in order to foster understanding and connecting theoretical knowledge to practice and to develop computational, critical thinking, teamwork and collaboration skills.	2
Not replied to the question	1

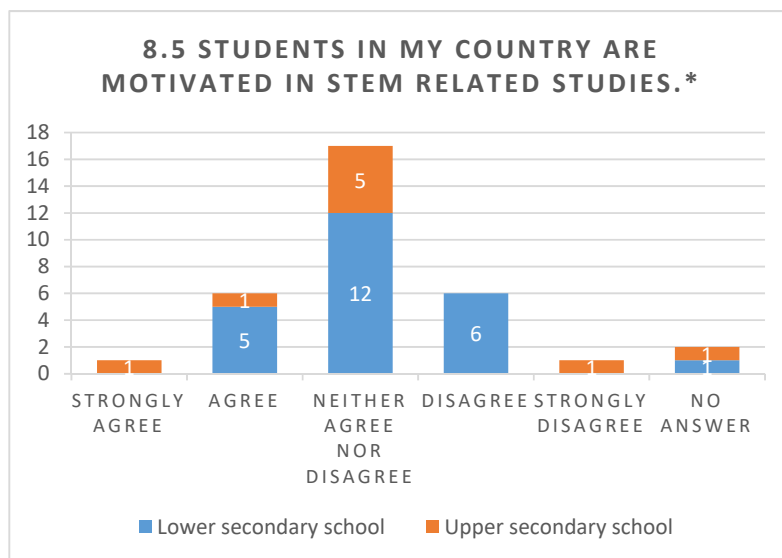
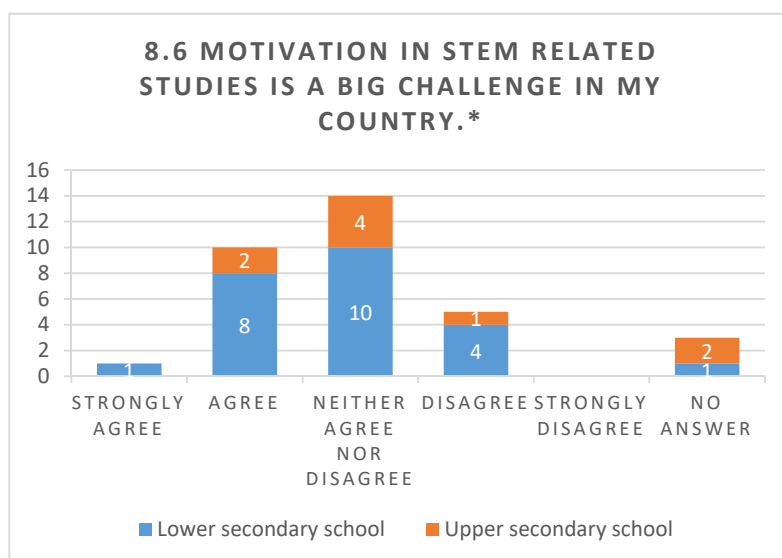
Nearly half of respondents (47%) answered only by **writing the names of disciplines which compose the STEM acronym** (i.e. Science, Technology, Engineering, Mathematics). Fewer participants (24%) **explained the acronym and described one or two aspects of the concept**. 8% **explained the acronym and added a further explanation to the concept**. The answer of one respondent (4%) was **not relevant to the question**.



*** Note:** There were two types of questions: Firstly, questions which asked about the respondents' familiarity and experience with specific technologies or methods (to which all participants responded only once). Secondly, questions which required answering in the context of lower or upper secondary school. As 3 participants responded the questions twice (from both lower and upper secondary school), 33 responses are counted in total for these questions. These questions will be marked with an asterisk (*).

8. What is the attractiveness of STEM studies and how engaged and motivated the students are in STEM studies in different countries? Please reply by selecting the level of agreement with the following statements.

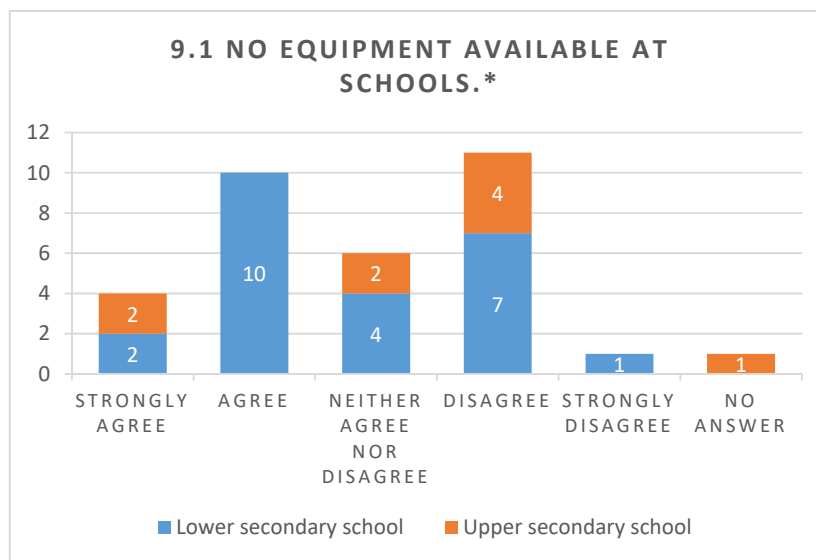
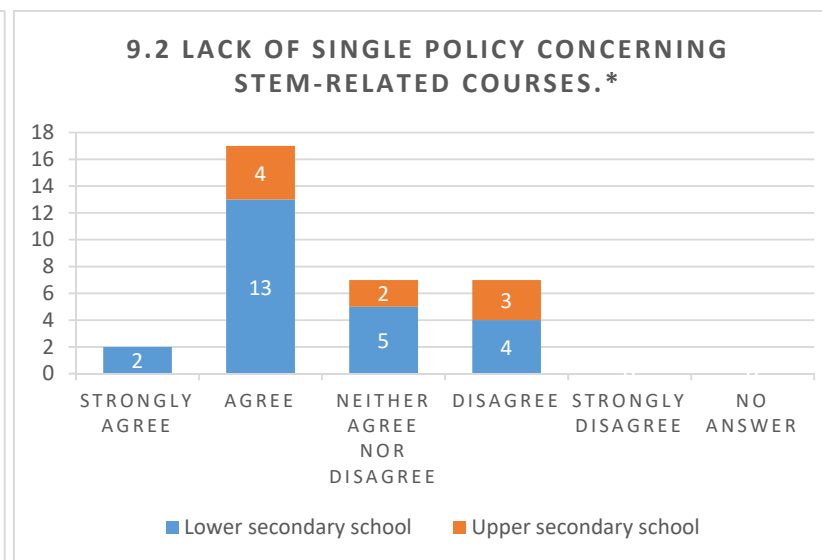
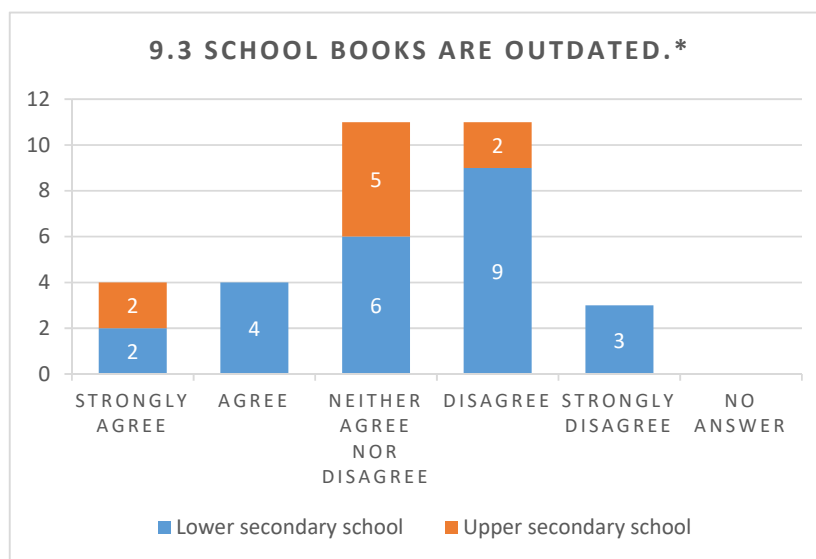
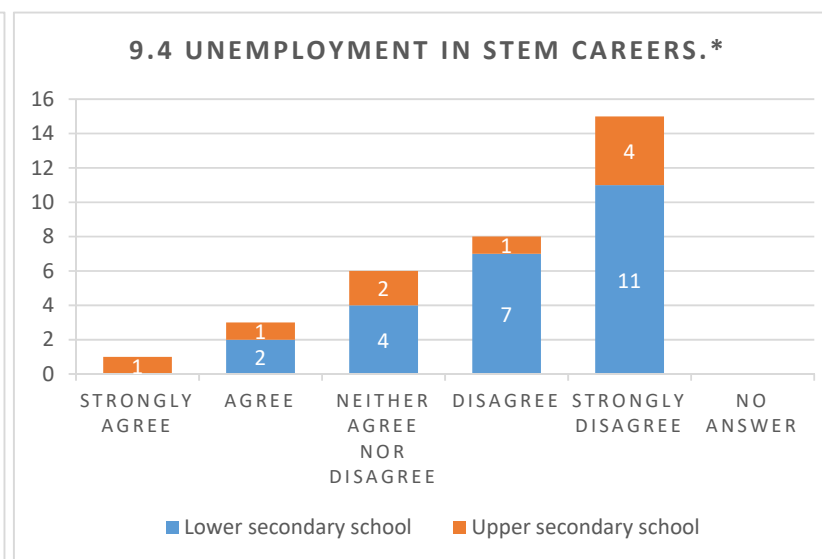




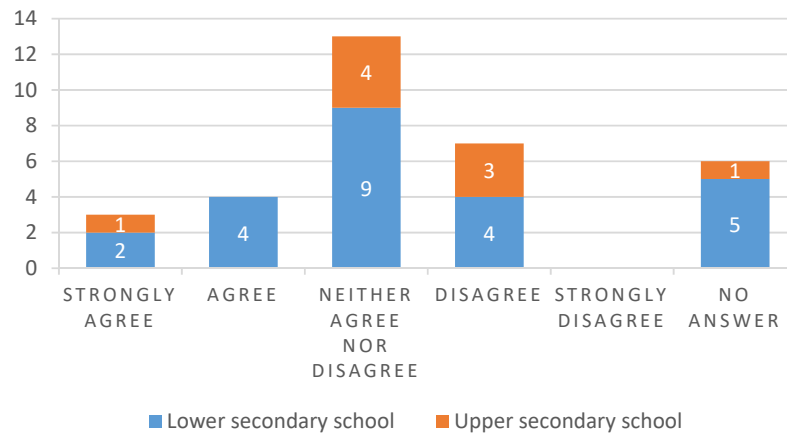
The responses indicate **contradictory results**: while slightly less than half of respondents found that **students are engaged in STEM related studies** in Estonia (42% of respondents agreed or strongly agreed while 6% disagreed or strongly disagreed), same percent also found **engagement to be a big challenge** (42% of respondents agreed or strongly agreed while 12% disagreed or strongly disagreed). Similar notion could be noted as follows: **students are motivated in STEM related studies** (21% of respondents agreed or strongly agreed while 21% disagreed or strongly disagreed), **motivation in STEM related studies is a big challenge** in Estonia (33% of respondents agreed or strongly agreed while 15% disagreed or strongly disagreed).

Slightly clearer pattern could be identified in the following statements: while approximately 1/3 of respondents both agree and disagree that **STEM related studies are attractive** in Estonia (30% of respondents agreed or strongly agreed while 27% disagreed or strongly disagreed), over half of respondents found **attractiveness of STEM related studies to be a challenge** (52% of respondents agreed or strongly agreed while 15% disagreed or strongly disagreed).

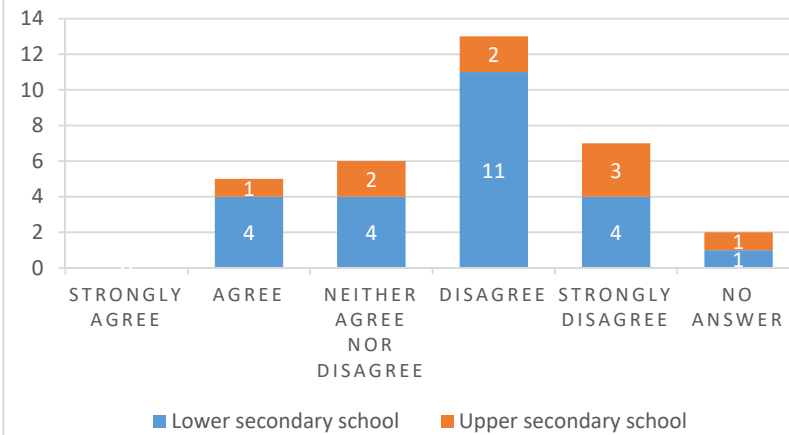
9. What are the main challenges in your country in making STEM studies attractive, to engage students more and to increase their motivation towards STEM studies and careers? Please reply by selecting the level of agreement with the following statements.



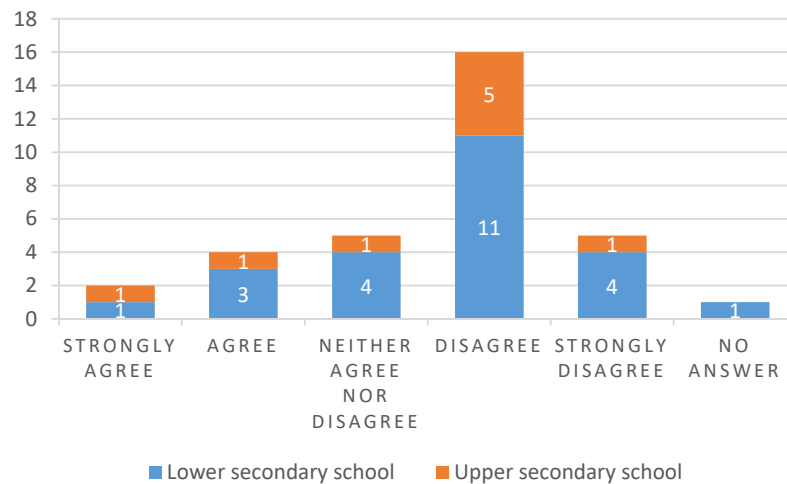
9.5 STEM EDUCATORS' PEDAGOGICAL APPROACHES.*



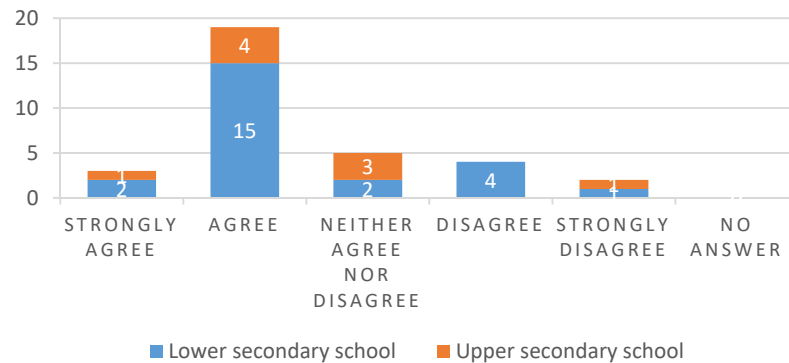
9.6 GENDER STEREOTYPES CONCERNING STEM STUDIES.*



9.7 LACK OF PROFESSIONAL DEVELOPMENT OPPORTUNITIES.*



9.8 THE SCHOOL COURSES/LESSONS/UNITS OF SCIENCE, TECHNOLOGY, ENGINEERING & MATH, AS WELL AS THEIR EDUCATIONAL MATERIAL, DO NOT BUILD LINKS TO TEACH THEM FROM AN INTEGRATED STEM PERSPECTIVE (HOW THESE SHOULD BE LINKED IN PRACTICE).*



If you would like to describe challenges not listed in the previous question, do so here.

Altogether 5 people responded to the question whose answers were categorized and will be given in the table below.

Category	Freq.
Constraints derived from the curriculum (not enough time for additional activities, curricula outdated, does not support integration of subjects)	4
Lack in teachers' preparation/knowledge	1
Little opportunity to collaborate with other teachers (no suitable classrooms, not enough time, overloaded with work, not interested in collaboration)	1
Quality control for online resources	1
Lack of practical and well paid jobs where knowledge in STEM subjects is a prerequisite	1

The results indicate two main challenges in increasing students' motivation and engagement towards STEM studies: **school curriculum does not build links between the disciplines** (67% of respondents agreed or strongly agreed while 18% disagreed or strongly disagreed) and the **lack of single policy concerning STEM-related courses** (58% of respondents agreed or strongly agreed while 21% disagreed or strongly disagreed).

Respondents are divided approximately in half regarding the **availability of equipment at schools** (42% agreed or strongly agreed while 36% disagreed or strongly disagreed). What must be noted is that the distinction might be derived from the differences between schools, i.e., there are many schools in Estonia who are well equipped for teaching STEM subjects, while other schools have little resources to do that.

Majority of respondents found that **unemployment in STEM careers is rather not a problem in Estonia** (12% agreed or strongly agreed while 70% respondents disagreed or strongly disagreed), along with the **lack of professional development opportunities** (18% agreed or strongly agreed while 64% disagreed or strongly disagreed). In addition, **gender stereotypes** are not considered a problem for STEM studies (15% agreed or strongly agreed while 61% disagreed or strongly disagreed) and the statement **school books are outdated** (24% of respondents agreed or strongly agreed while 42% disagreed or strongly disagreed). Regarding **STEM educators' pedagogical approaches**, 21% people agreed or strongly agreed to the statement while 21% disagreed or strongly disagreed.

Additional challenges mentioned by 5 respondents were also constraints derived from the curricula, lack in teachers knowledge, little opportunity to collaborate with other teachers, quality control for online resources, lack of practical and well paid jobs.

Some success stories of how STEM studies have been made attractive were as follows: robotics classes, enabling students to carry out experiments in classes or visiting science centers/museums/organisations/laboratories, visiting a science theater and a TV programme "Rocket

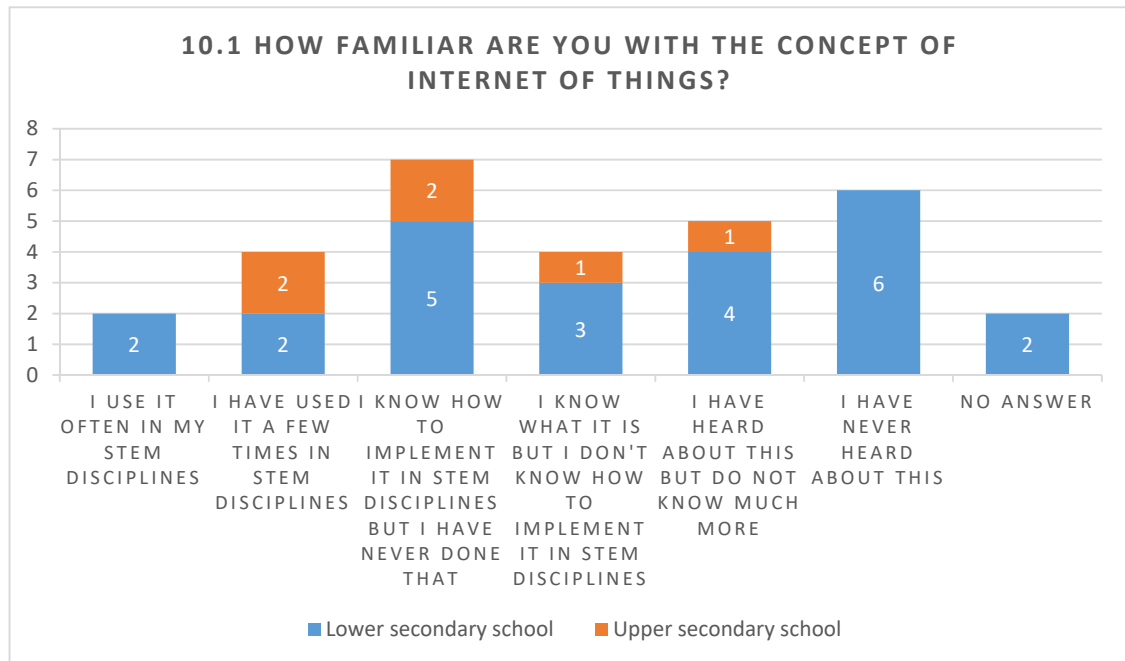
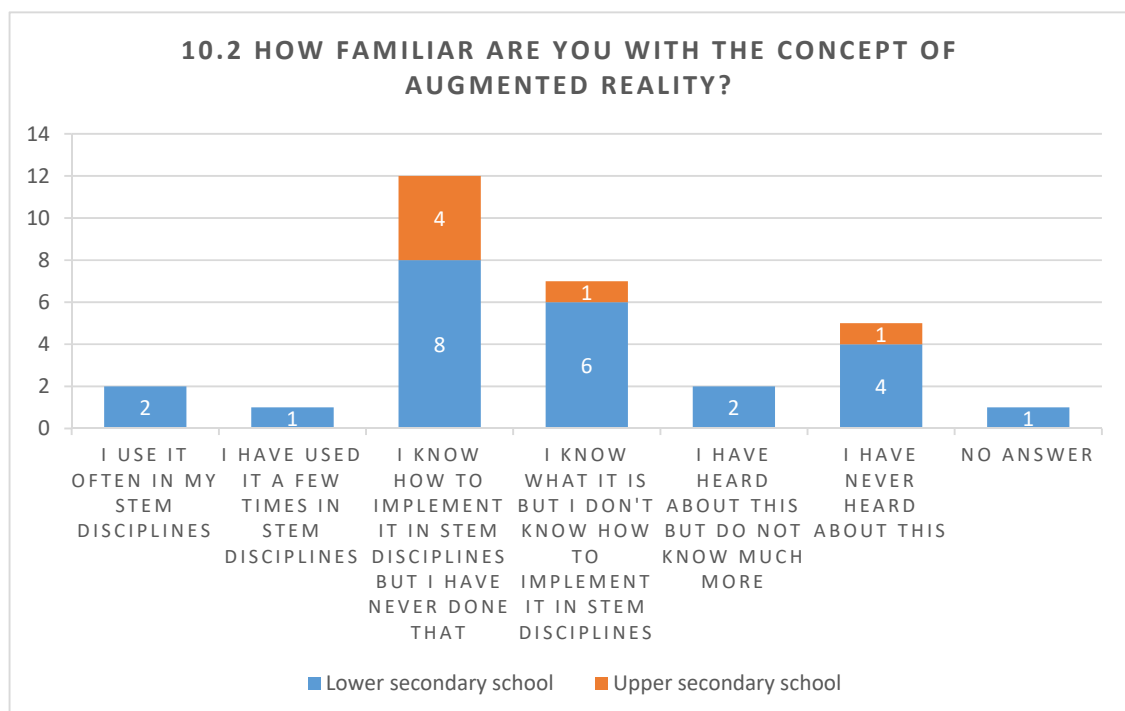
69” (competition between students where various tasks involving physics, chemistry and mathematics are given).

If you know then please describe one success story how STEM studies have been made attractive, and students are engaged and motivated. Think on a story that could be useful to learn in other countries as well. Please provide any additional material such as links to the materials about this story (e.g., descriptions, learning materials, guidelines, videos, photos). If you have some useful files to share, then please send these to your national contact mentioned in the beginning and end of the questionnaire.

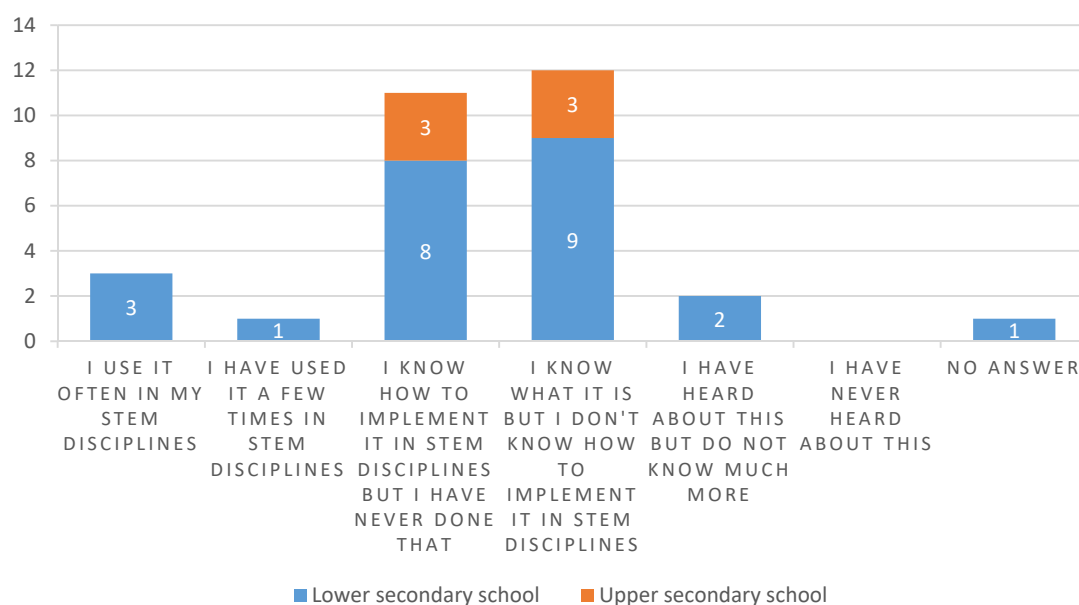
Altogether 8 people responded to the question, whose answers will be given below.

- Students’ inclusiveness and motivation has raised visits to science centres, companies and laboratories where professionals work. This way, students are able to see how theoretical knowledge is put into practice and can be convinced that their studies will be beneficial to themselves and others in the future.
- Dividing the class into smaller group and practicing in laboratory, in order to allow students to get more practice in hands-on activities.
- Hobby classes for robotics and natural sciences, Lego FLL festivals, Science Theater, robotics competitions, Class+ projects, science centres (AHHAA, Energiakeskus, Tartu Nature House) etc.
- Using GeoGebra software to learn mathematics, editing statistical data with Wolfram software etc.
- TV show/science competition “Rakett 69” has increased students’ interest towards science, especially among primary school and lower secondary school students.
- In vocational education, integration between sciences has been accomplished by teaching hands-on courses on the topic student is specializing on and theoretical courses (e.g. physics, mathematics) at the same time. This enables to create a thorough understanding of the profession, while creating links between theory and practice.

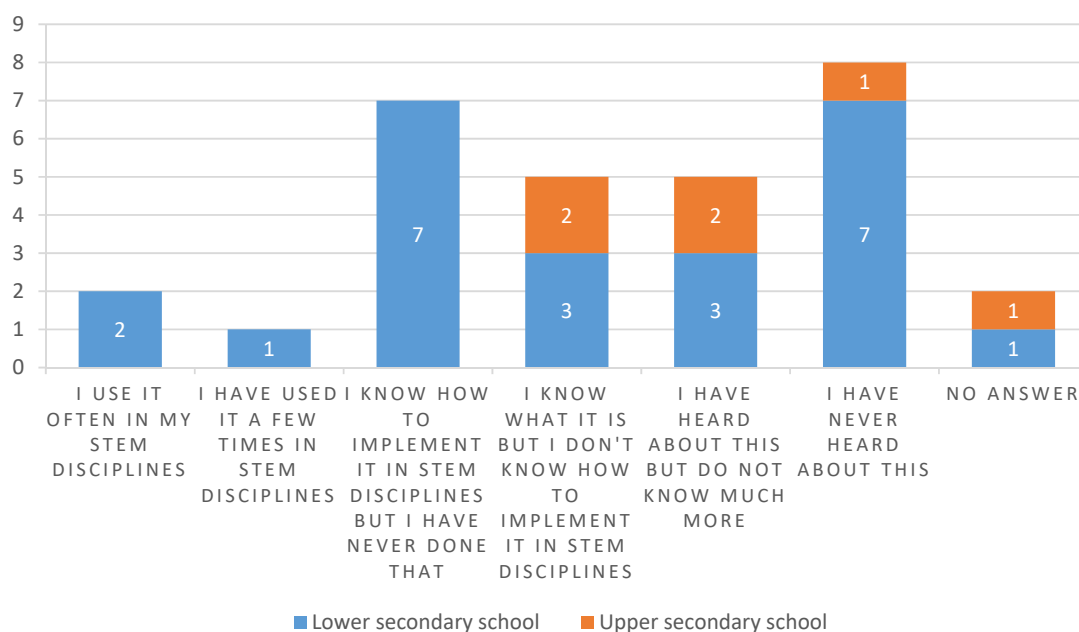
10. How familiar are you with the following innovative emerging technologies? Please reply by selecting the level of familiarity with the following statements.



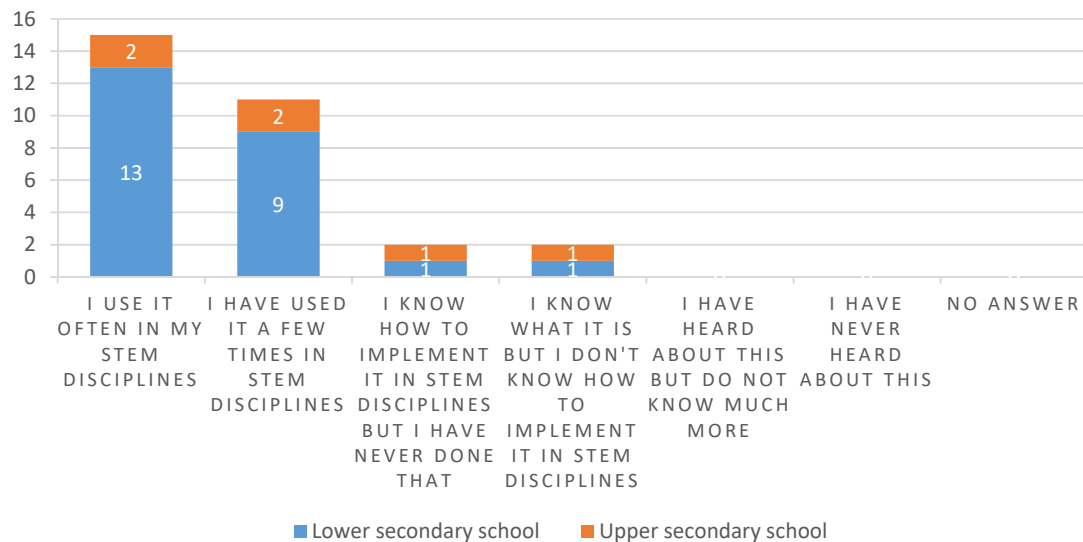
10.3 HOW FAMILIAR ARE YOU WITH THE CONCEPT OF VIRTUAL REALITY?



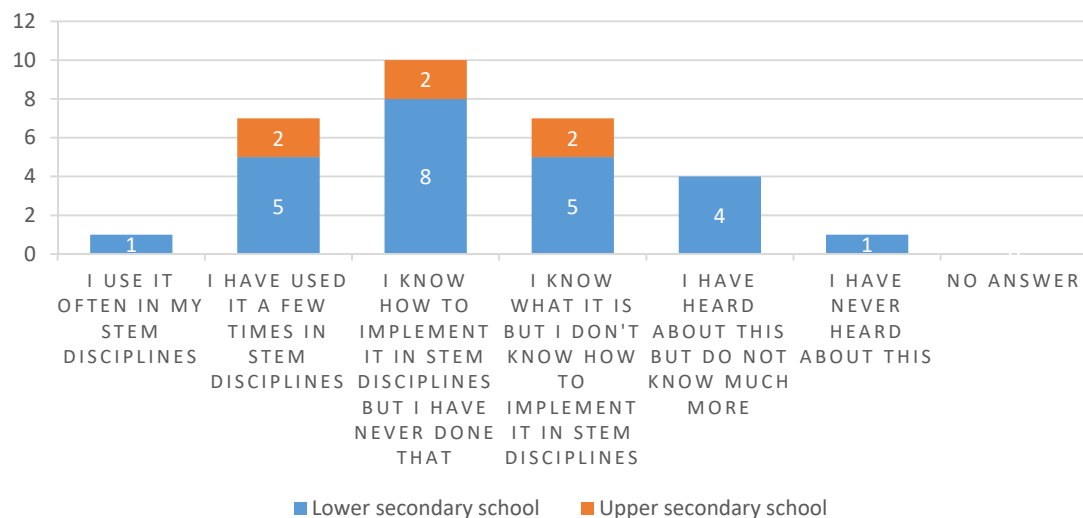
10.4 HOW FAMILIAR ARE YOU WITH THE CONCEPT OF MIXED REALITY?



10.5 HOW FAMILIAR ARE YOU WITH THE POSSIBILITIES OF USING SMARTPHONES OR TABLETS IN STEM STUDIES?



10.6 HOW FAMILIAR ARE YOU WITH THE POSSIBILITIES OF USING AUGMENTED OR VIRTUAL REALITY TECHNOLOGIES (E.G., GLASSES, TABLETS, SMARTPHONES) IN STEM STUDIES?



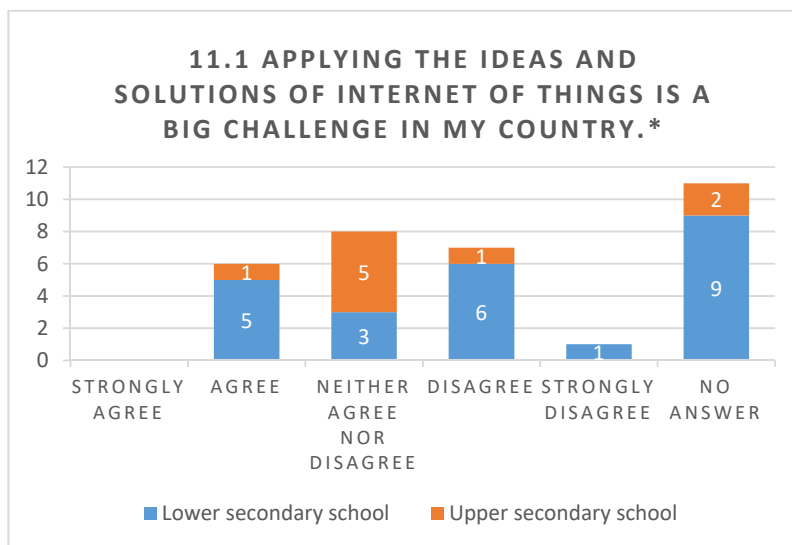
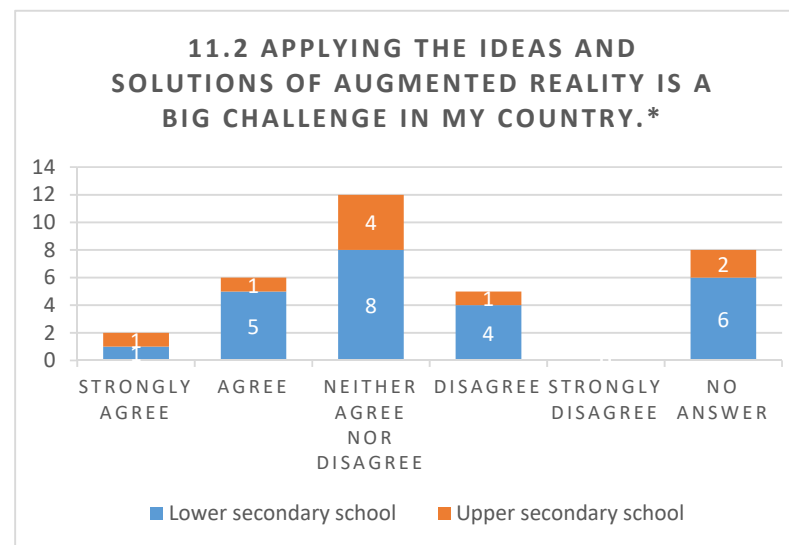
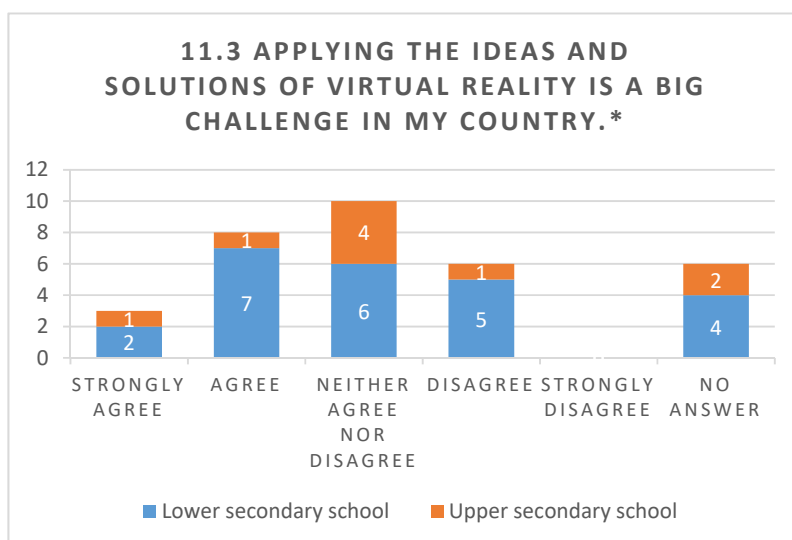
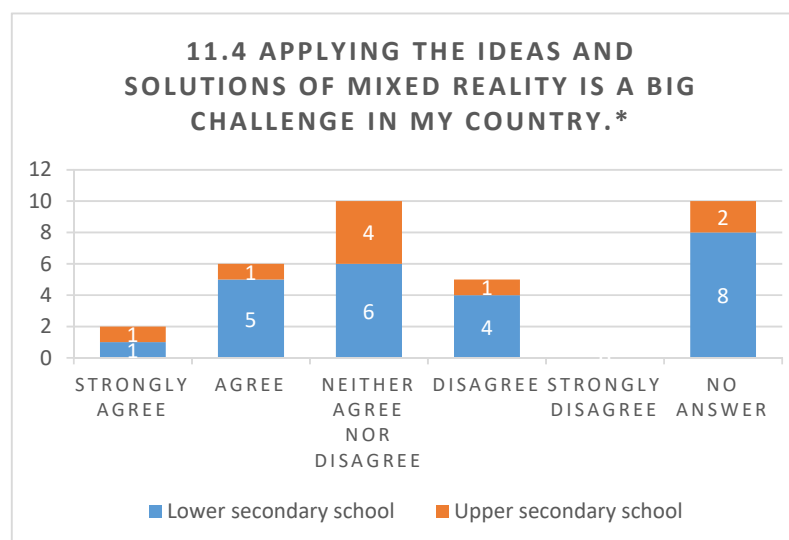
The results indicate that respondents are most familiar with **using smartphones for STEM studies** (86% of respondents have used it a few times or are using it often in STEM disciplines, 7% know how to implement it but have never done that).

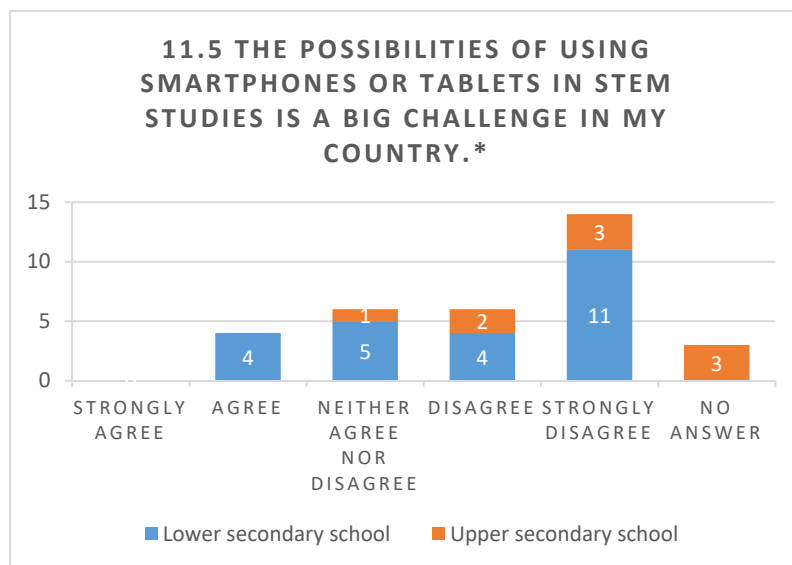
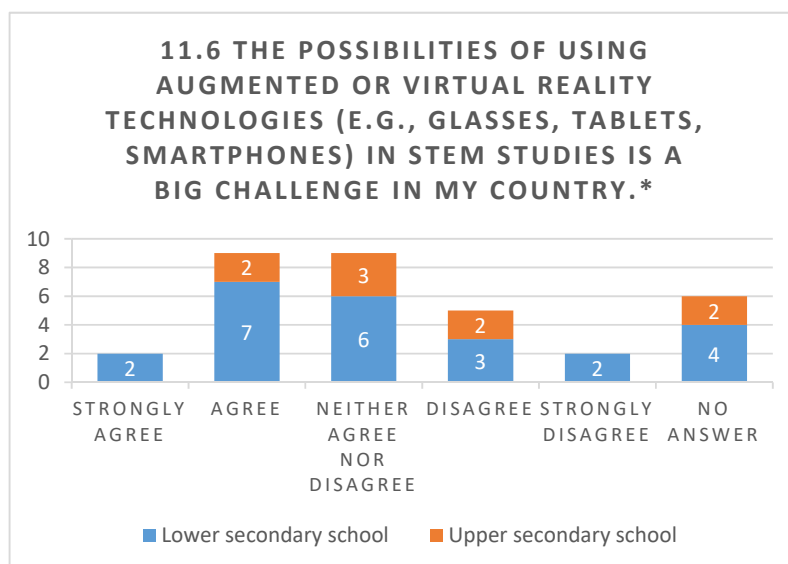
Significantly less familiarity and use was reported with the **possibilities of using augmented or virtual reality technologies in STEM studies** (27% of respondents have used it a few times or are using it often in STEM disciplines, 33% know how to implement it but have never done that), the **concept of augmented reality** (10% of respondents have used it a few times or are using it often in STEM disciplines, 40% know how to implement it but have never done that), the **concept of virtual reality** (13% of respondents have used it a few times or are using it often in STEM disciplines, 37% know how to implement it but have never done that) and the **concept of internet of technologies** (20% of respondents have used it a few times or are using it often in STEM disciplines, 23% know how to implement it but have never done that).

Fewer respondents are familiar with the **concept of mixed reality** (10% of respondents have used it a few times or are using it often in STEM disciplines, 23% know how to implement it but have never done that).

What can be clearly defined from majority of responses is that even if respondent is aware of the technology and its possibilities to use in STEM disciplines, majority have not used the technologies in their work.

11. What are the challenges in applying emerging technologies? Please reply by selecting the level of agreement with the following statements.





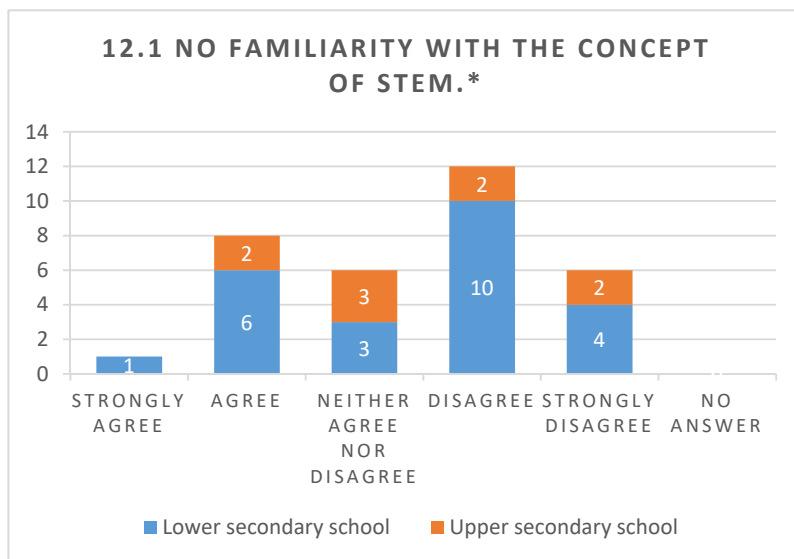
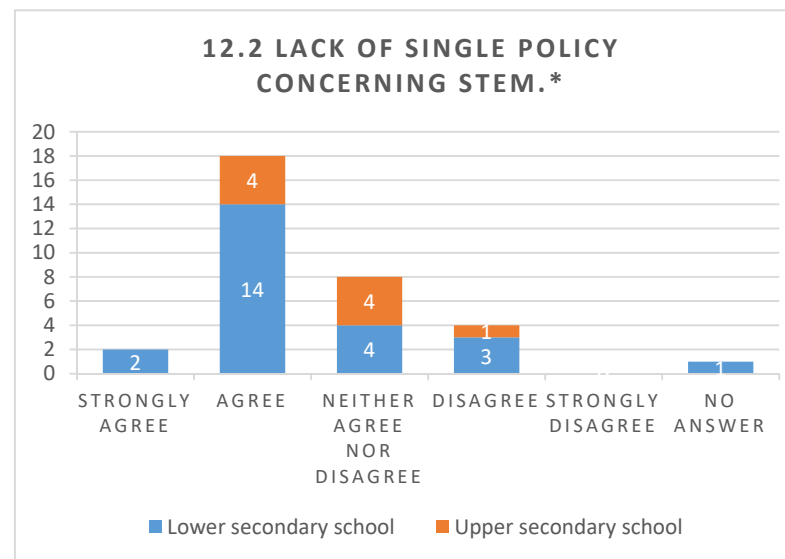
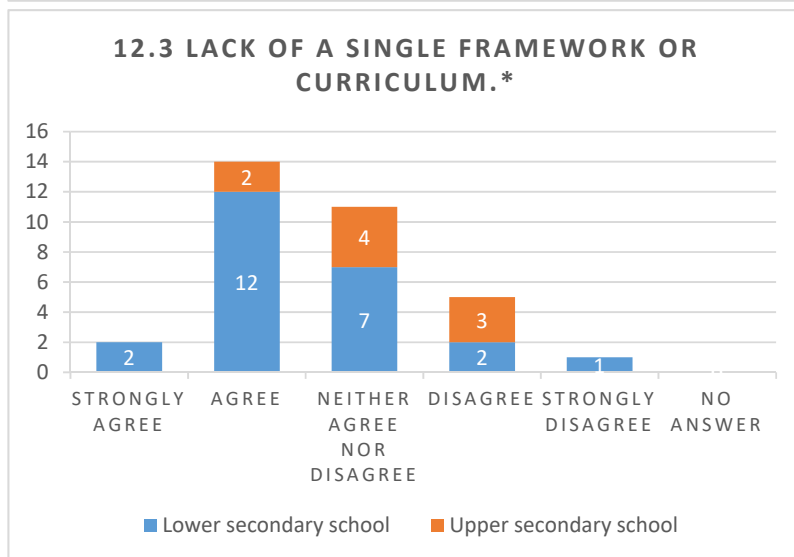
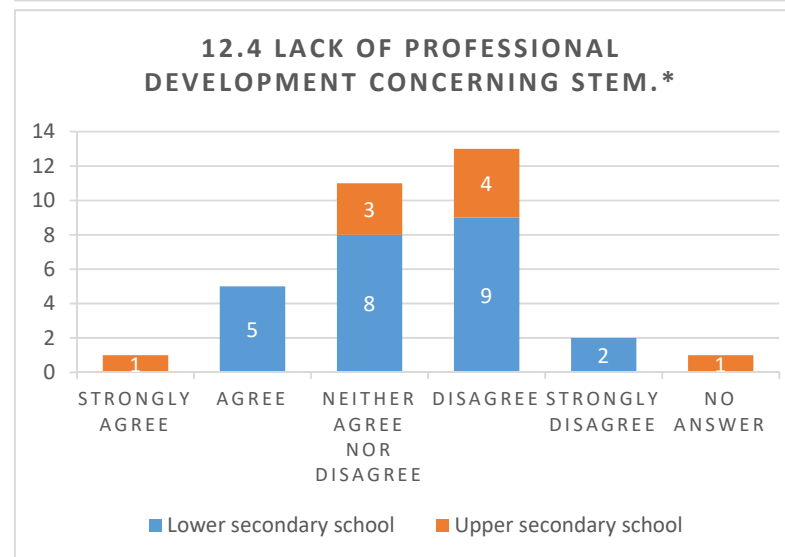
The results do not reflect clear patterns in opinions. The most noted challenges in applying emerging technologies were regarded the **possibilities of using augmented or virtual reality technologies** (33% of respondents agreed or strongly agreed while 21% disagreed or strongly disagreed), **ideas and solutions of virtual reality** (33% of respondents agreed or strongly agreed while 18% disagreed or strongly disagreed), **mixed reality** (27% of respondents agreed or strongly agreed while 15% disagreed or strongly disagreed), **augmented reality** (24% of respondents agreed or strongly agreed while 15% disagreed or strongly disagreed)

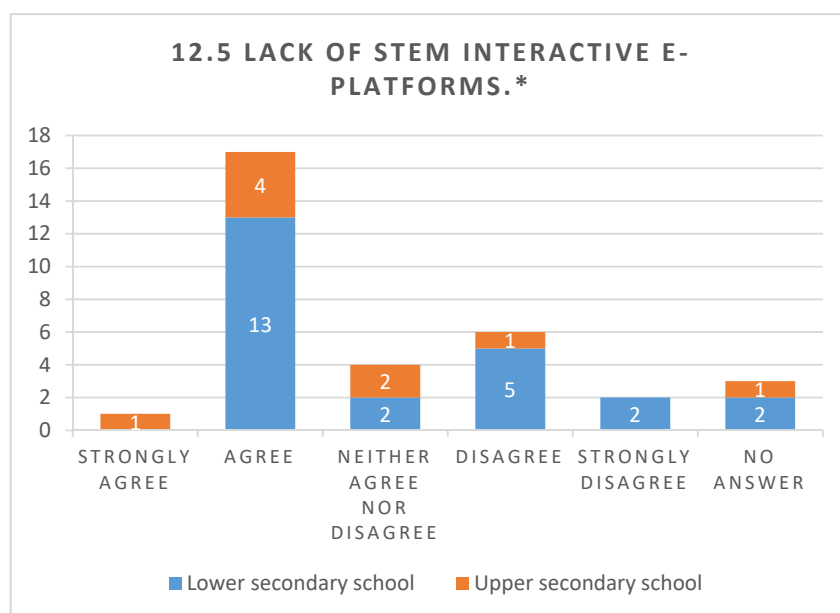
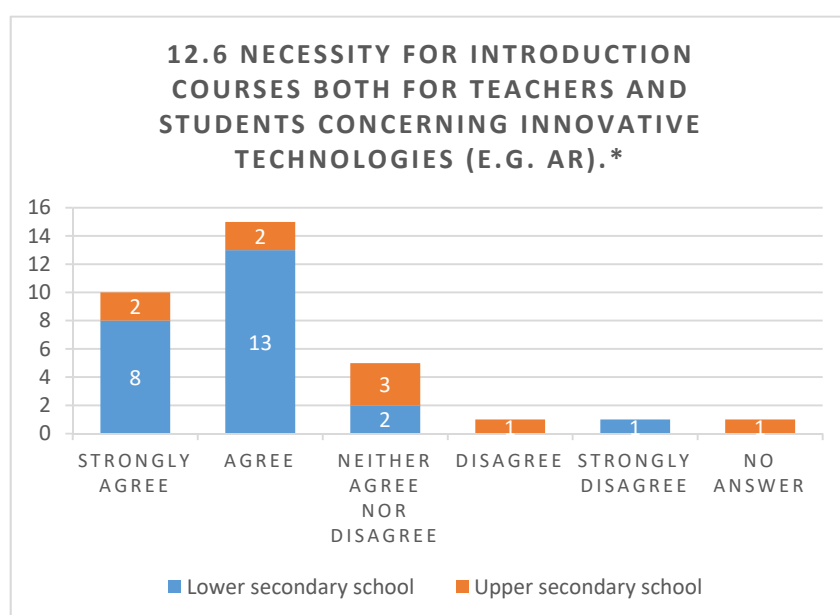
The results reflect that a clear majority of respondents do not find the **possibilities of using smartphones or tablets in STEM studies** a challenge in Estonia (12% of respondents agree or strongly agree while 60% disagreed or strongly disagreed).

Applying ideas and solutions of internet of things are also rather not regarded as a challenge (18% of respondents agreed or strongly agreed while 24% respondents disagreed or strongly disagreed).

However, considering previous answers regarding familiarity with these technologies, it must be noted that responses could differ due to respondents' varied level of awareness about these technologies.

12. What are the main challenges in your country in applying innovative emerging technologies in STEM studies? Please reply by selecting the level of agreement with the following statements.





The main challenges in applying innovative emerging technologies in STEM studies in Estonia are regarded to be the **lack of a single policy concerning STEM** (60% of respondents agree or strongly agree while 12% disagree or strongly disagree), **lack of a single framework or curriculum** (48% agree or strongly agree while 18% disagree or strongly disagree), **lack of STEM interactive e-platforms** (52% agree or strongly agree while 17% disagree or strongly disagree) and the **necessity for introduction courses both for teachers and students concerning innovative technologies** (74% agree or strongly agree while 17% disagree or strongly disagree).

Lack of familiarity with the STEM concept and **lack of professional development concerning STEM** were found to be a challenge by significantly smaller percent of respondents: respectively 27% and 18%

of respondents agreed or strongly agreed while 55% and 45% disagree or strongly disagree to these statements.

If you would like to describe challenges not listed in the previous question, do so here.

Altogether 5 people responded whose answers were categorized and will be given in the table below.

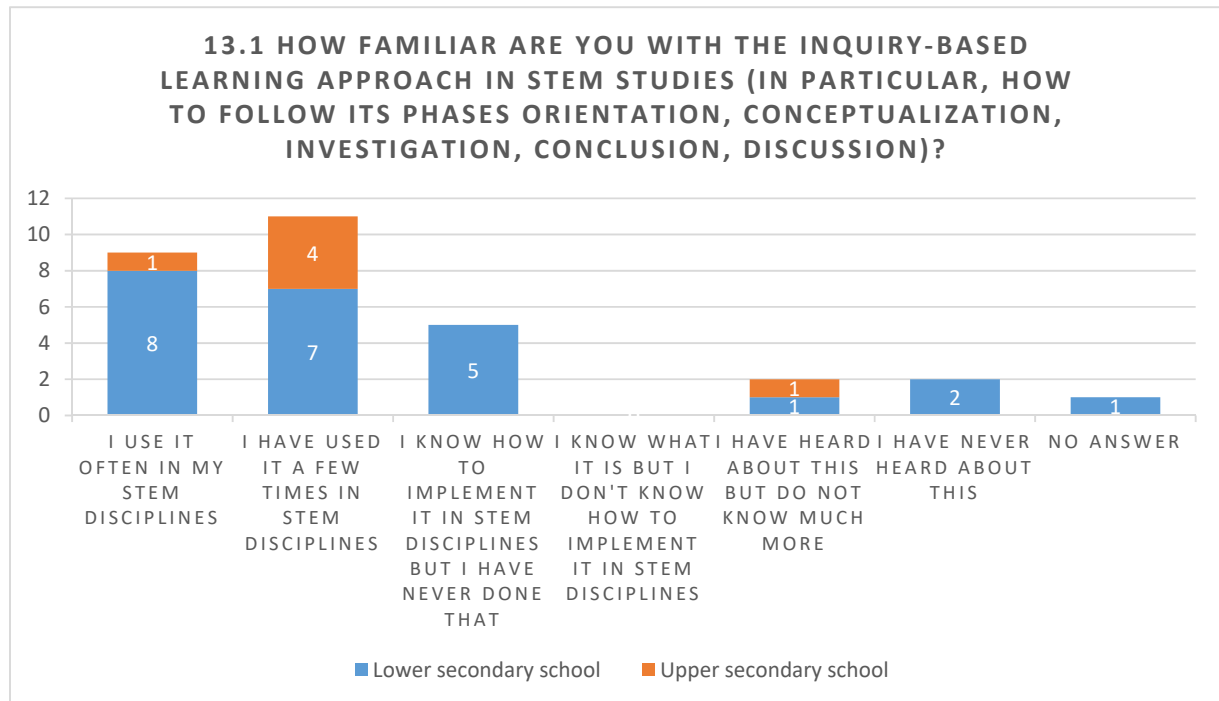
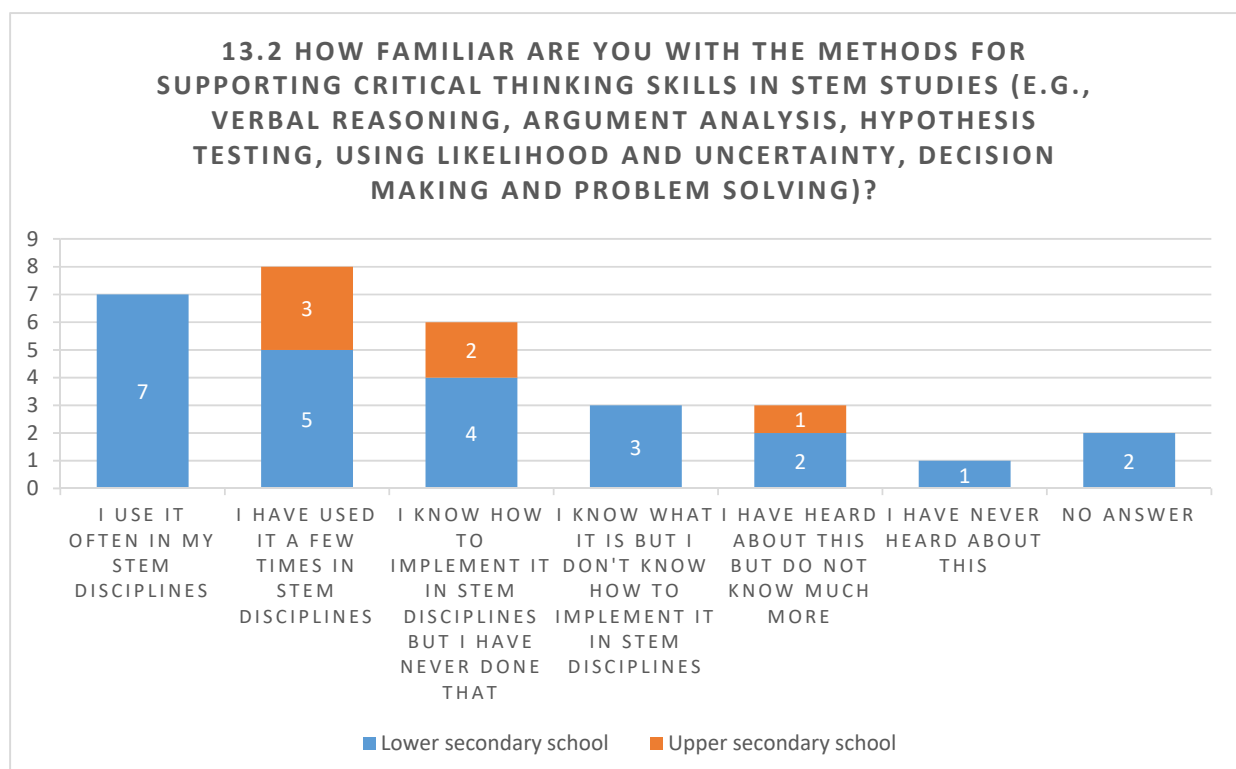
Category	Freq.
Constraints derived from the curriculum (not enough time for additional activities, curricula outdated etc.)	2
Lack of funding (e.g. lack of technological equipment in schools)	2
Relevance of existing technologies to the curricula	2
Lack in teachers' preparation/knowledge	1

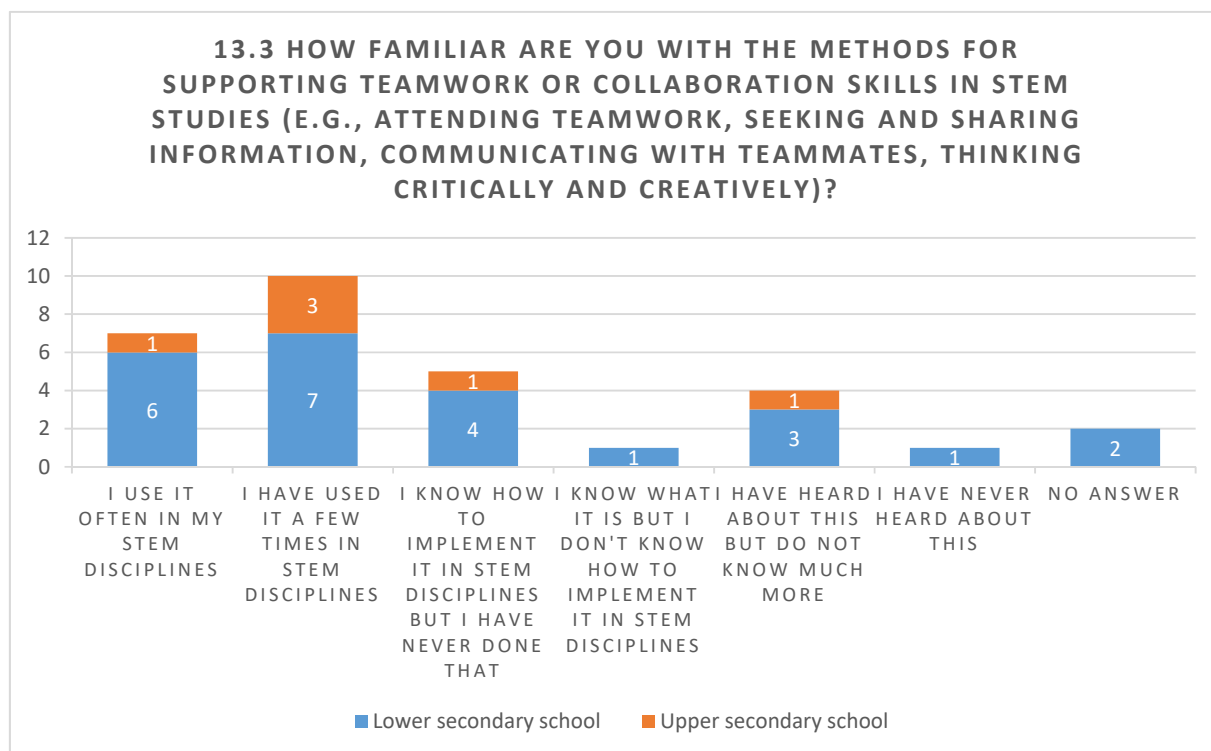
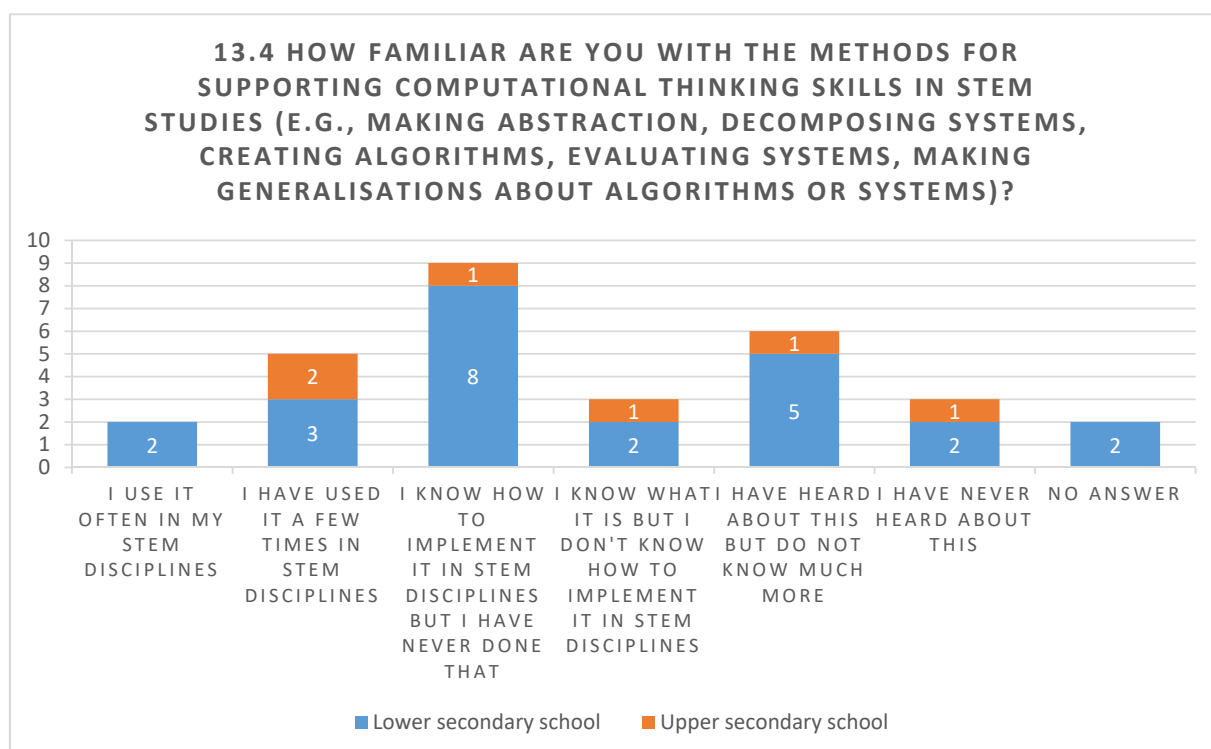
If you know then please describe one success story how STEM studies have been made attractive, and students are engaged and motivated. Think on a story that could be useful to learn in other countries as well. Please provide any additional material such as links to the materials about this story (e.g., descriptions, learning materials, guidelines, videos, photos). If you have some useful files to share, then please send these to your national contact mentioned in the beginning and end of the questionnaire.

Altogether 6 people responded whose answers will be given below.

- Using tablets has allowed to integrate various topics to natural science classes together with students which also support learning outcomes, but has been initiated by students themselves. Therefore, tablets add flexibility, as we can look up something during the class without much preparation.
- Go-Lab environment: <https://www.golabz.eu/>.
- Lego FLL yearly project, robotics challenges and competitions (Robomik), space project (Väätisa Klass+), Researchers' Night Festival (<http://www.teadlasteoo.ee/en>), TV show/students' science competition "Rakett 69" etc.
- Science theater (popular science experiments spanning through all natural sciences).
- IB DP Group 4 project: during the project, all students have to carry out a practical project within a week which requires applying knowledge in chemistry, biology and physics through inquiry.
- Using a welding simulator for offering vocational students to learn through practice While practicing with the simulator, the students are able to learn various welding techniques and receive instant feedback to their work.

13. How familiar are you with innovative pedagogies and contemporary learning approach used in EL-STEM project and what are the challenges in applying them? Please reply by selecting the level of familiarity with the following statements.

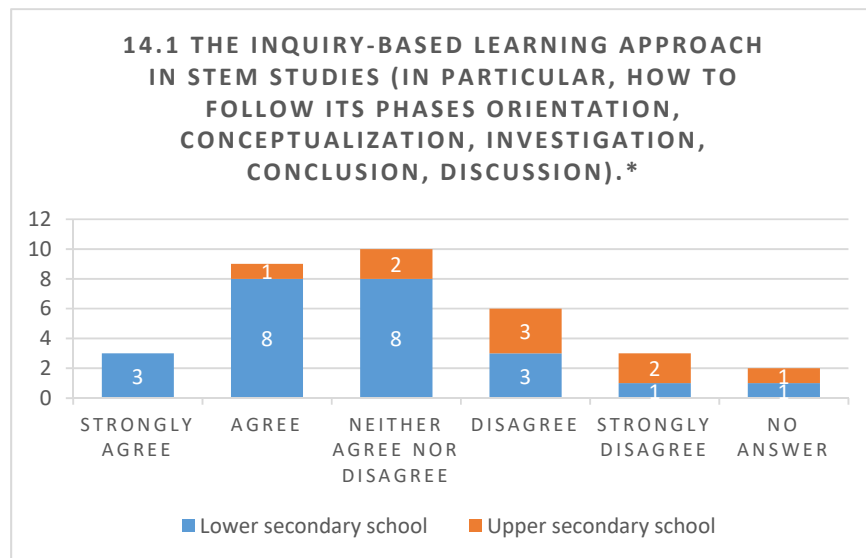
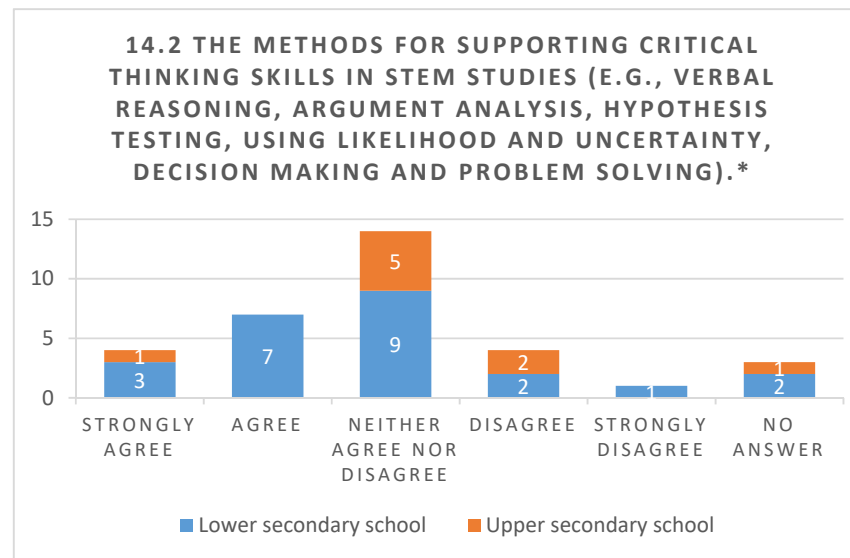
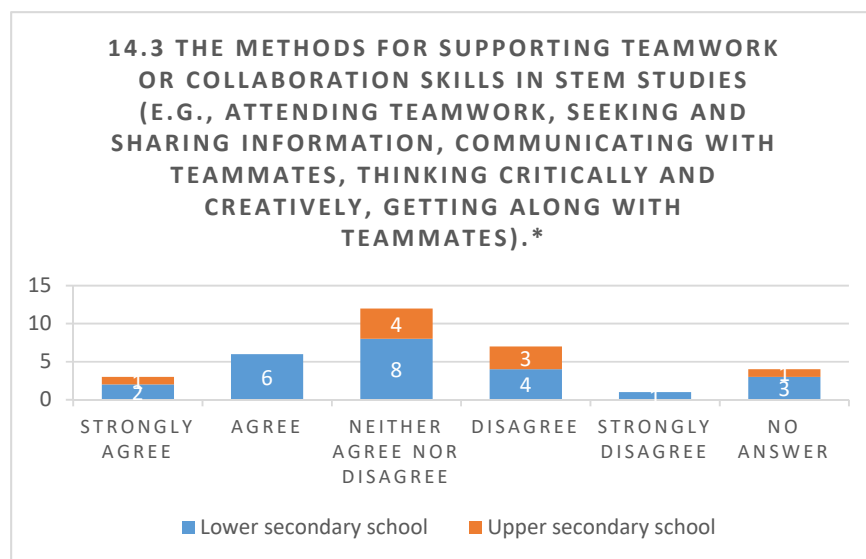
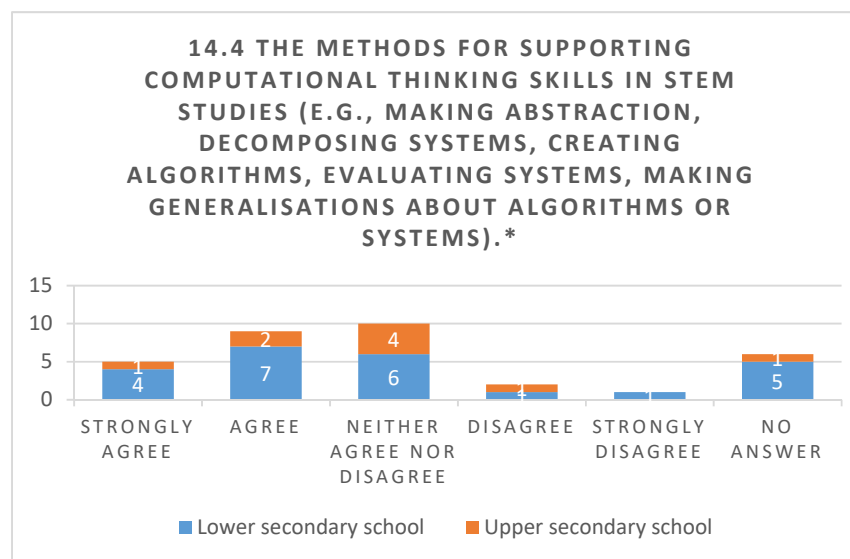


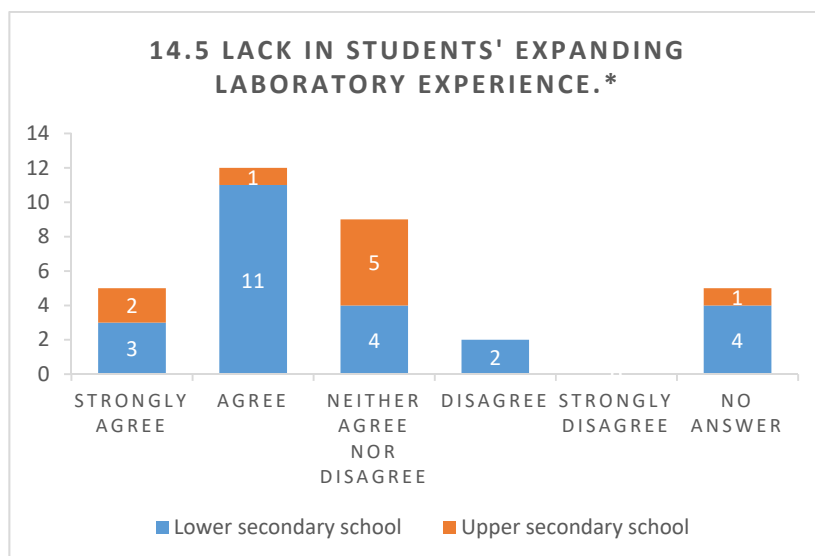


The results indicate that majority of respondents are familiar with the **methods of inquiry based learning approach in STEM studies** (67% of respondents have used it a few times or are using it often in STEM disciplines, 17% know how to implement it but have never done that), **methods for supporting critical thinking skills in STEM studies** (50% of respondents have used it a few times or are using it often in STEM disciplines, 20% know how to implement it but have never done that) and **teamwork or collaboration skills in STEM studies** (57% of respondents have used it a few times or are using it often in STEM disciplines, 17% know how to implement it but have never done that).

Fewer respondents are familiar with the **methods for supporting computational thinking skills in STEM studies** (23% of respondents have used it a few times or are using it often in STEM disciplines, while 30% of respondents know how to implement it in STEM disciplines, but have never done that).

14. What are the main challenges in your country in applying innovative pedagogies and contemporary learning approach in STEM studies?
Please reply by selecting the level of agreement with the following statements.





Analysing the responses, the most often recognized **challenge** in applying innovative pedagogies and contemporary learning approach in STEM studies in Estonia is regarded the **lack in students' expanding laboratory experience** (45% of respondents agree or strongly agree while 6% disagree or strongly disagree). Another challenges identified are the methods for **supporting computational thinking skills in STEM studies** (42% agree or strongly agree while 9% disagree or strongly disagree) and the **methods for supporting critical thinking skills in STEM studies** (33% agree or strongly agree while 15% disagree or strongly disagree).

Responses are divided for aspects of **inquiry-based learning approach** (36% agree or strongly agree while 27% disagree or strongly disagree) and the **methods for supporting teamwork or collaboration skills** (27% agree strongly agree while 24% disagree or strongly disagree) in STEM studies.

If you would like to describe challenges not listed in the previous question, do so here.

Altogether 4 people responded, whose answers were categorized and will be given in the table below.

Category	Freq.
Little opportunity to collaborate with other teachers (no suitable classrooms)	1
Lack of technological equipment	1
Students are not motivated to learn	1
Constraints derived from the curriculum (not enough time for additional activities, curricula outdated etc.)	1

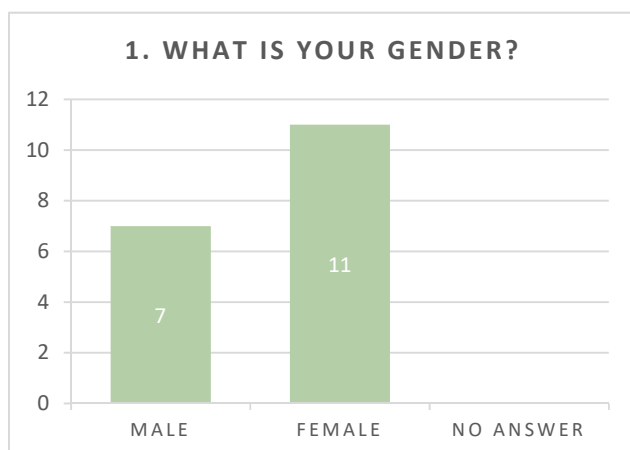
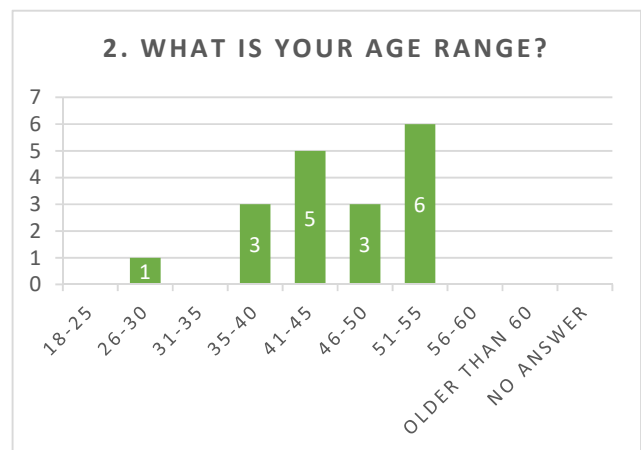
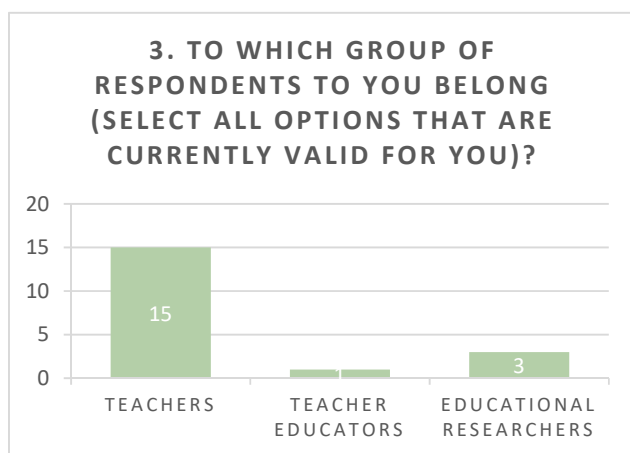
If you know then please describe one success story how innovative pedagogies or contemporary learning approach have been successfully used in STEM studies. Think on a story that could be useful to learn in other countries as well. Please provide any additional material such as links to the materials about this story (e.g., descriptions, learning materials, guidelines, videos, photos). If you have some useful files to share, then please send these to your national contact mentioned in the beginning and end of the questionnaire.

- Use of inquiry based learning has brought natural science classes closer to real life.
- MultiCo project: <http://www.multico-project.eu/>
- Carrying out a training for both teachers and students, where they were taught to use Wolfram software.

5.2.2. Cyprus

Altogether **18 people** responded to the survey from Cyprus. An overview of the respondents' profile and responses will be given in the charts below.

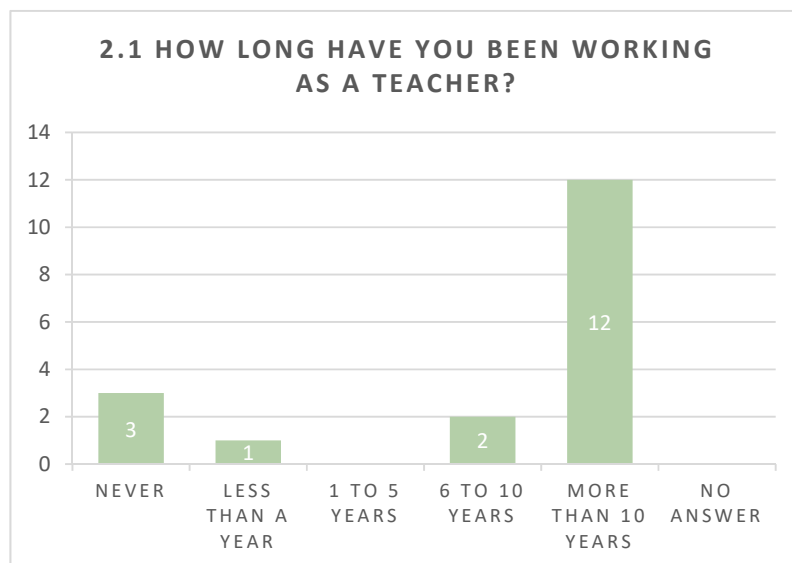
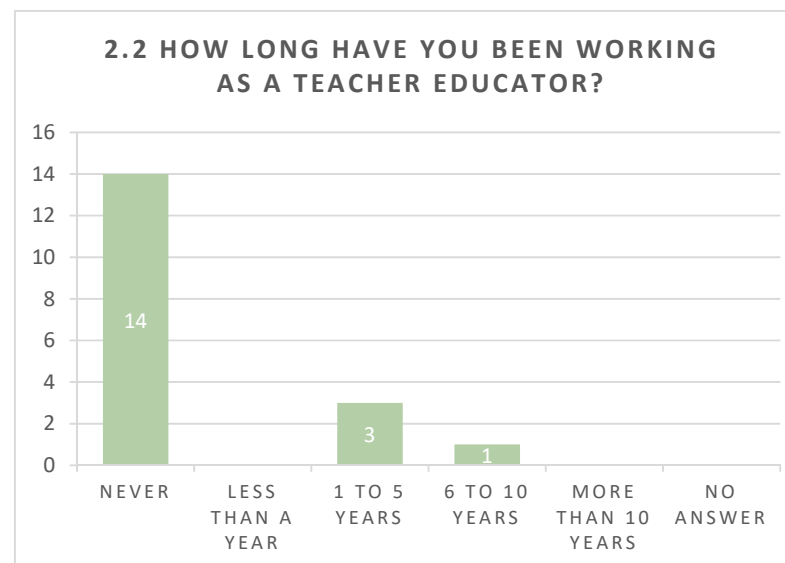
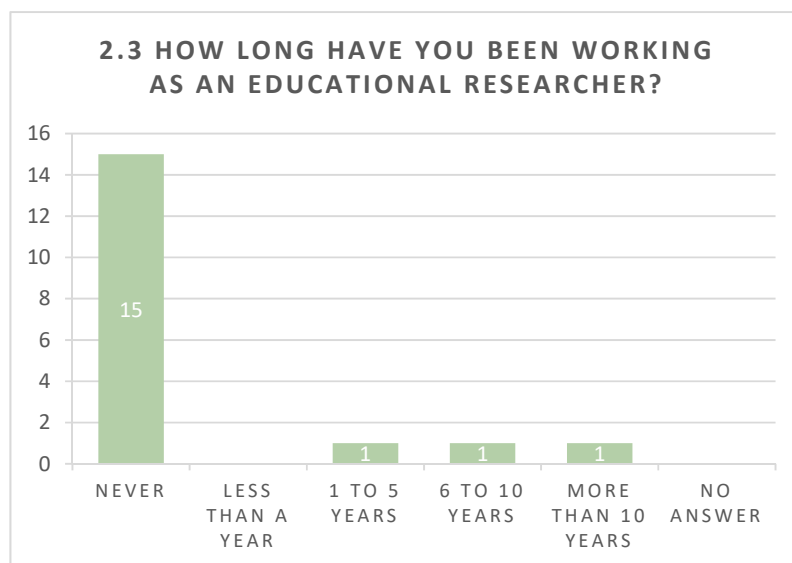
1. Background information



Majority of 18 respondents in Cyprus are **over 41 years old**. 33% of respondents are aged between 51-55 while 28% are aged between 41-45 and 17% between 46-50.

17% of respondents are aged 35-40 and 6% 26-30.

2. How long have you been working as a... (select an answer in case of all options)



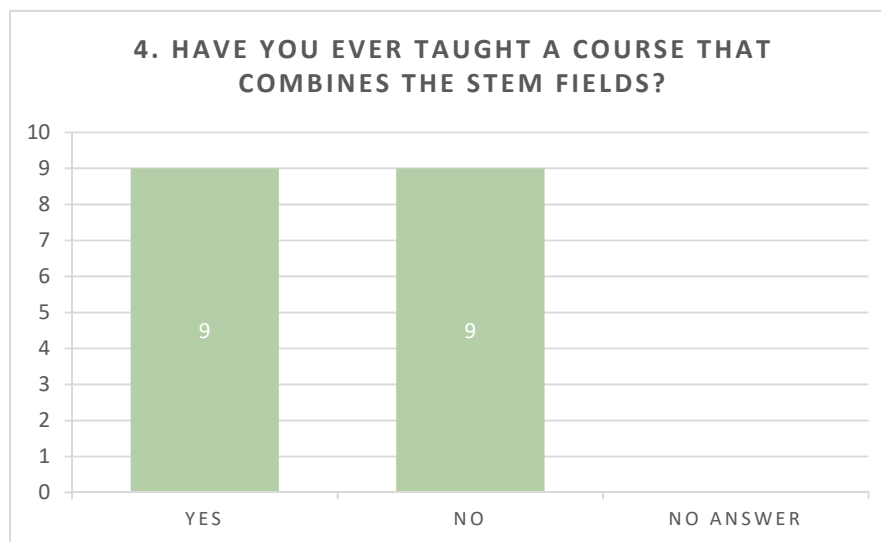
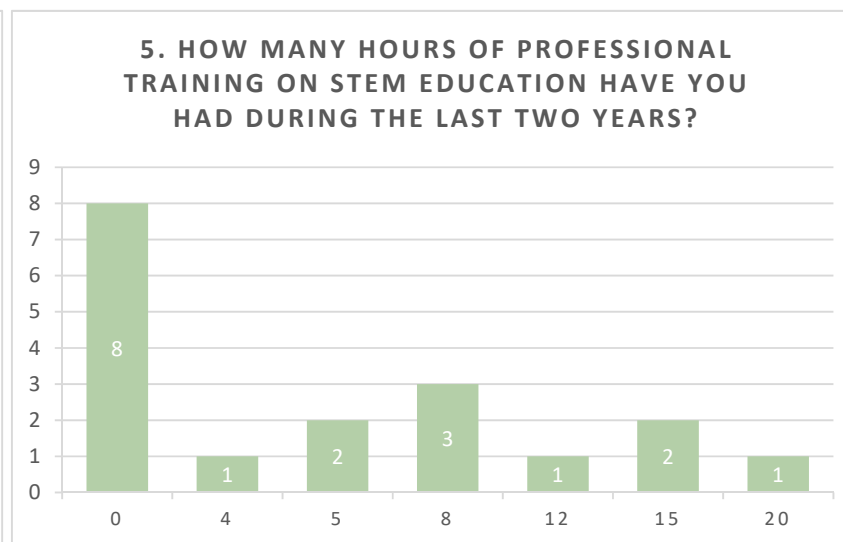
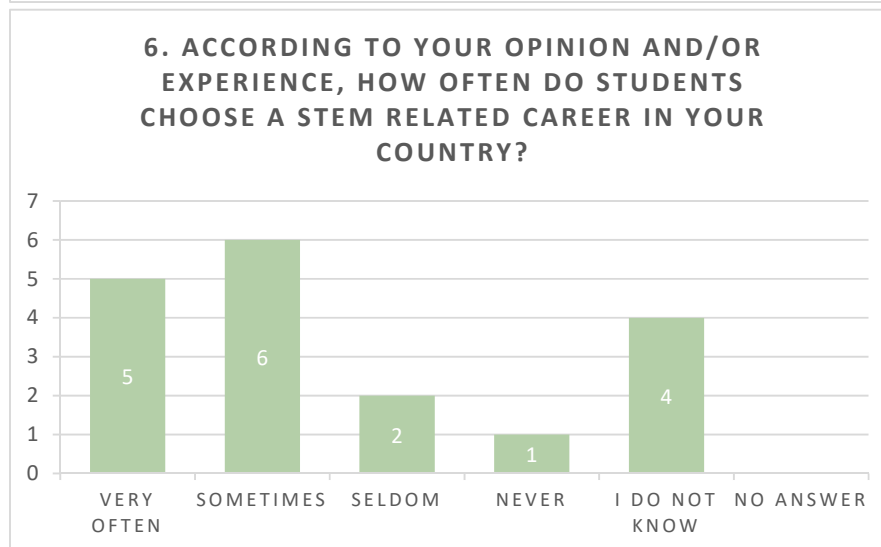
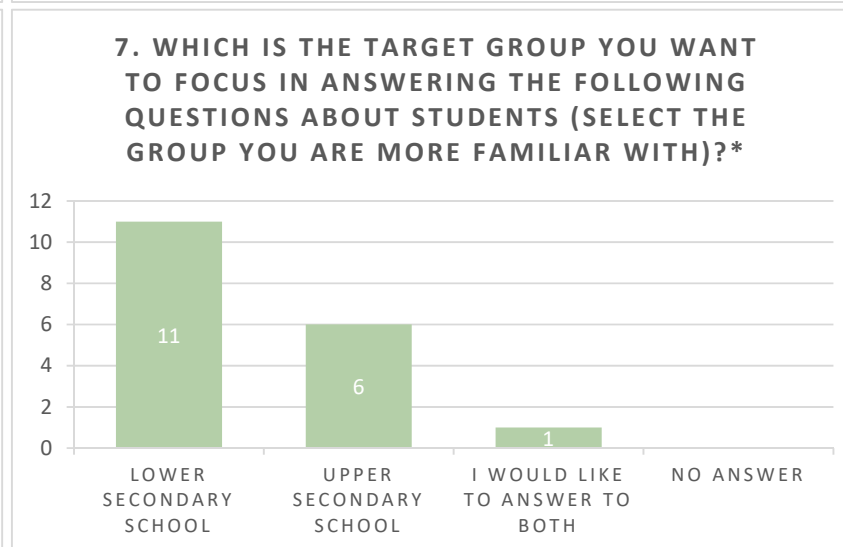
Clear majority of the respondents are working as **teachers** (83%) with over 10 years of experience (80%). Only 6% of respondents have indicated their experience with working as **teacher educator**, yet the length of this experience was marked to 1 to 5 years (75%) and to 6 to 10 years (25%). 17% have experience with working as **educational researcher**, with experiences varying between 1 to 5 years to more than 10 years.

3. How do you understand the concept of STEM (use up to 1000 characters)

Altogether, 17 people responded to the question. The answers were categorised and an overview of the responses will be given in the table below.

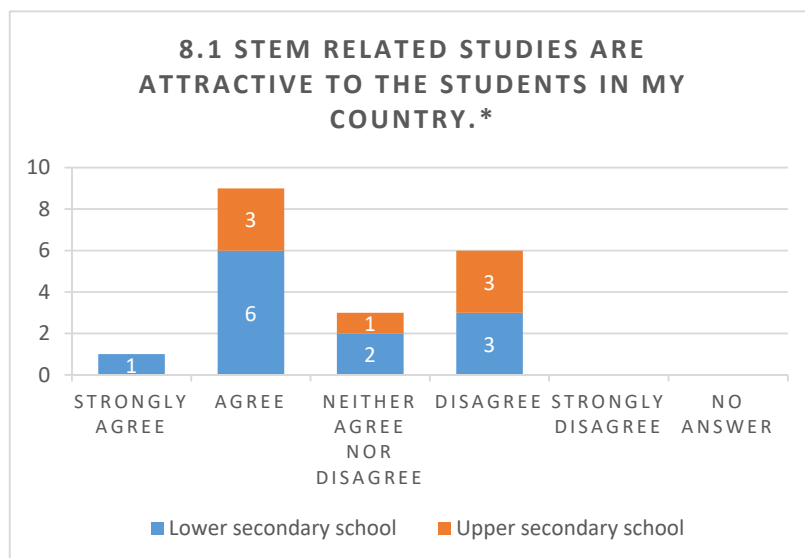
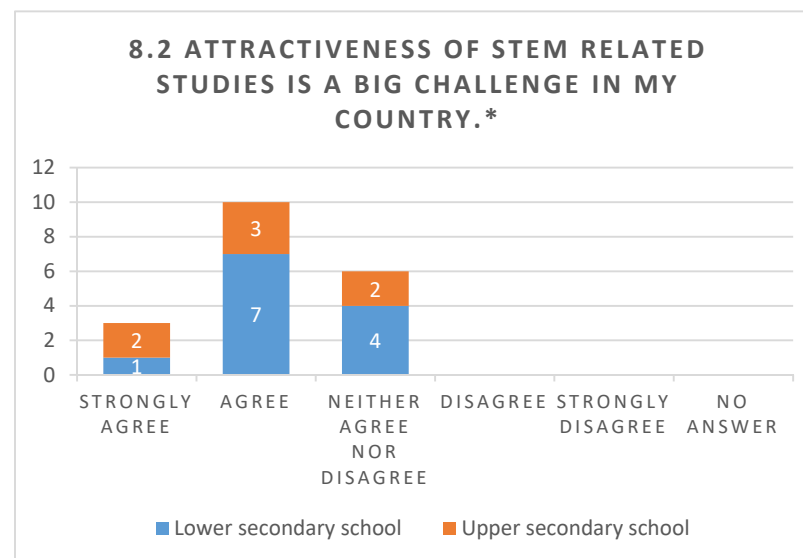
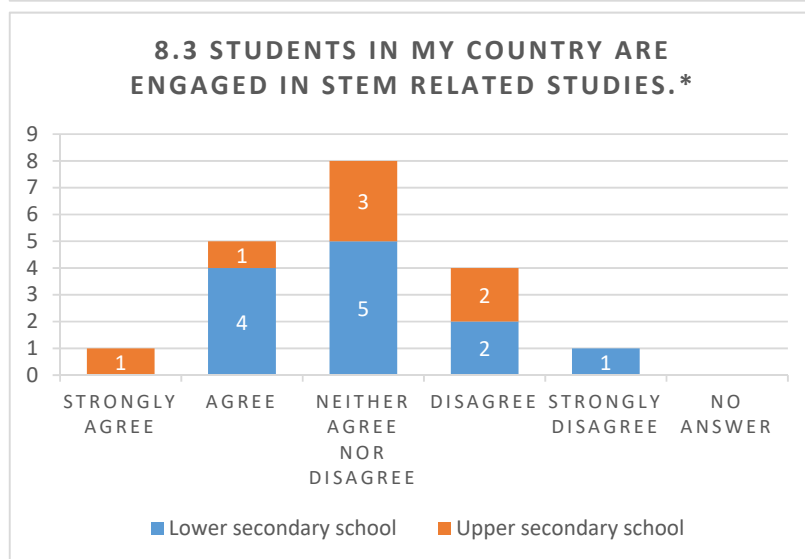
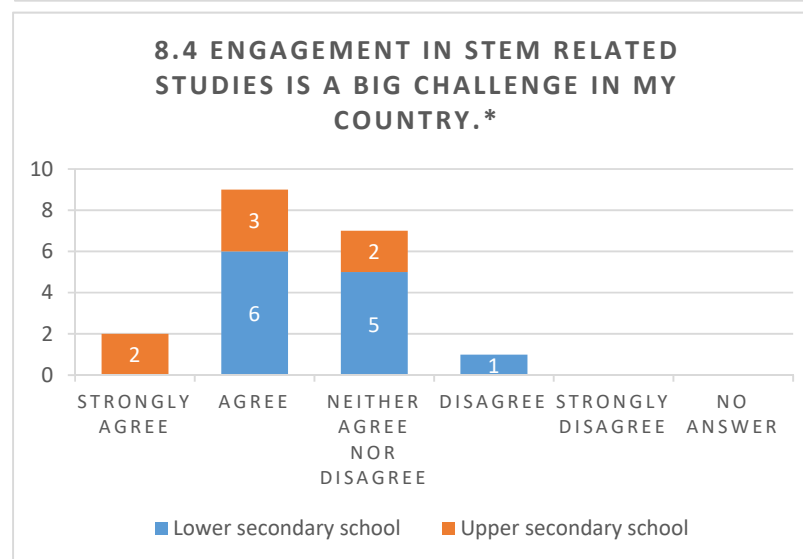
Category	Freq.
Incorrect explanation	6
I do not know	3
Science Technology Engineering Mathematics and the integration of these disciplines/use of research based learning method/use of applied approach	3
Science Technology Engineering Mathematics and the integration of these disciplines with applied approach, in order to foster understanding and connecting theoretical knowledge to practice and to develop computational, critical thinking, teamwork and collaboration skills.	3
Not replied to the question	2

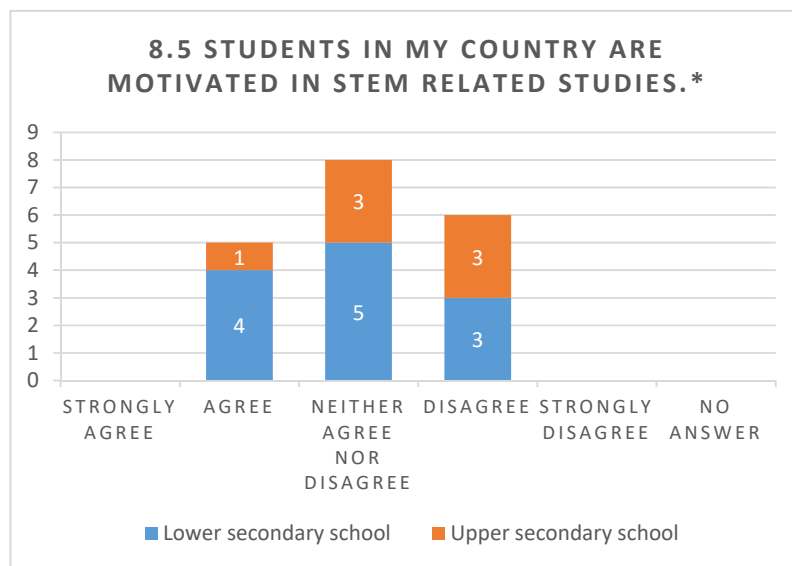
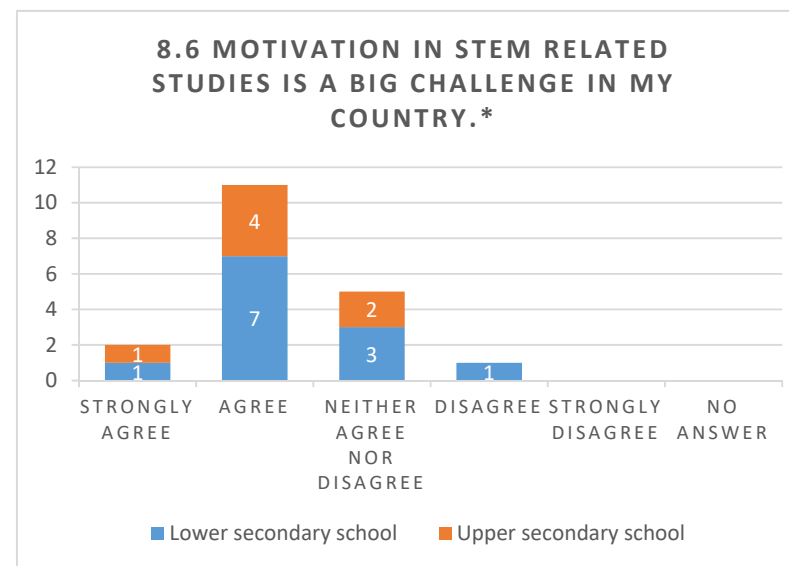
35% of responses were categorized into “**Incorrect explanation**” category, if the respondents had not given any terms or explanations that could be understood as internal part of the STEM concept (e.g. “way to motivate students to learn”; “how to teach mathematics to students in order to make them attractive and interesting to students”). Three respondents (18%) stated clearly they **do not know what STEM concept is**, 18% **explained the acronym and described one or two aspects of the concept** and equally another 18% of respondents **explained the acronym and added a further explanation to the concept**. The answers of two respondents (12%) were **not relevant to the question**.



*** Note:** There were two types of questions: Firstly, questions which asked about the respondents' familiarity and experience with specific technologies or methods (to which all participants responded only once). Secondly, questions which required answering in the context of lower or upper secondary school. As 1 participant responded the questions twice (from both lower and upper secondary school), 19 responses are counted in total for these questions. These questions will be marked with an asterisk (*).

8. What is the attractiveness of STEM studies and how engaged and motivated the students are in STEM studies in different countries? Please reply by selecting the level of agreement with the following statements.

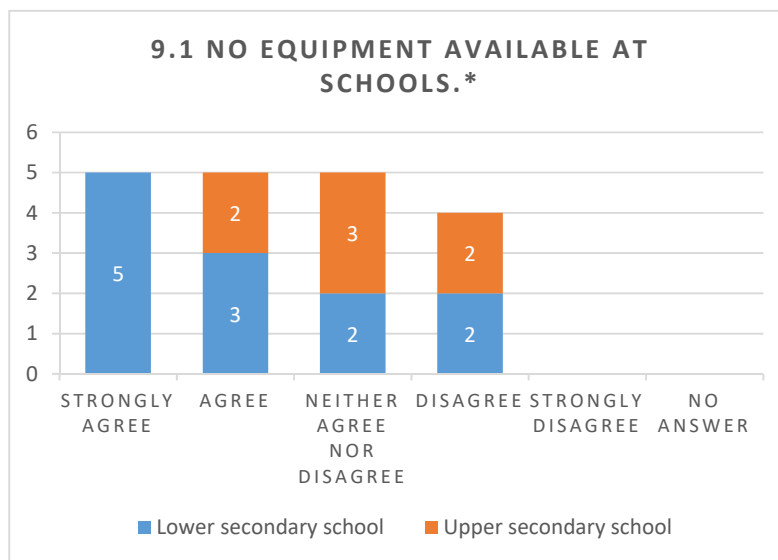
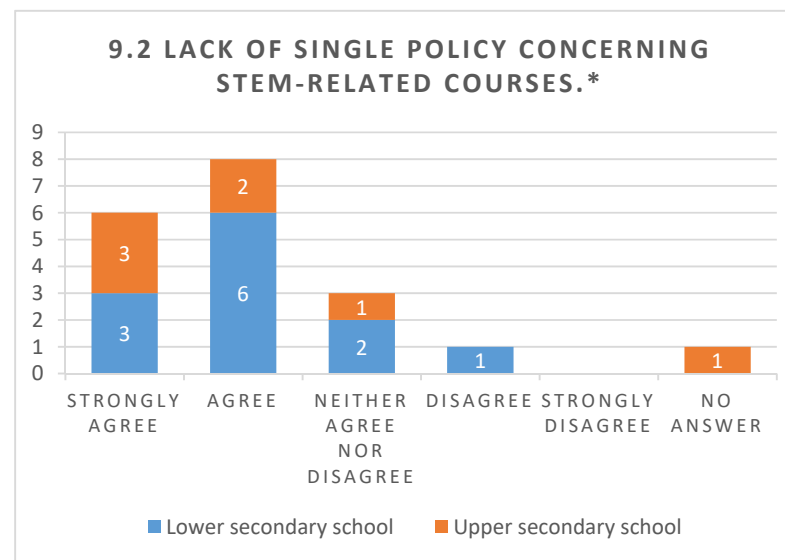
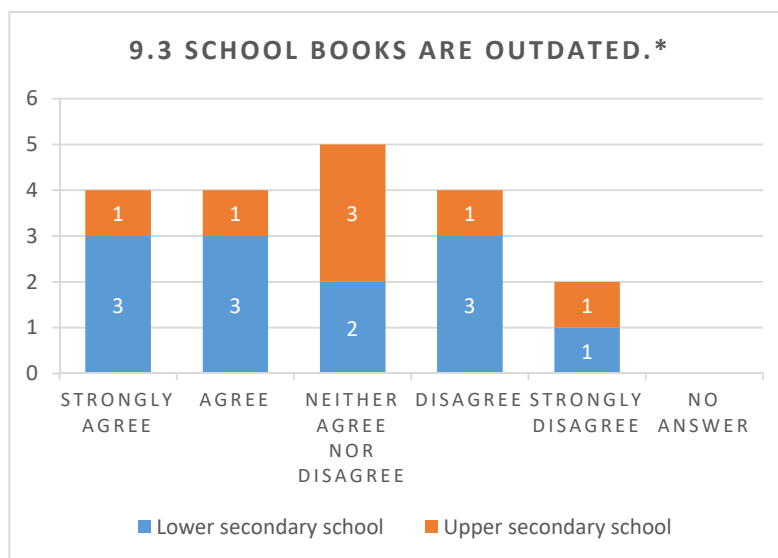
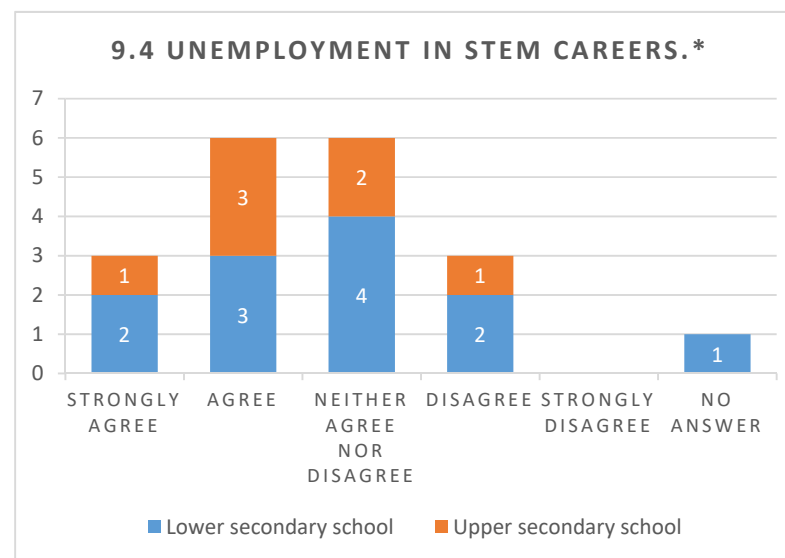




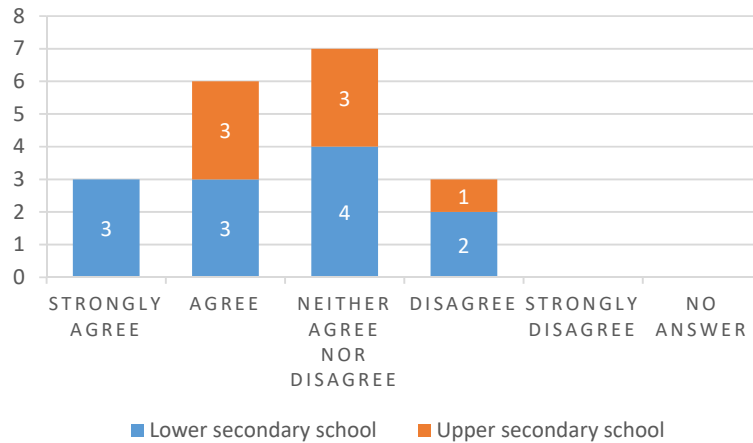
The responses indicate **contradictory results**: while approximately half of respondents agree that **STEM related studies are attractive in Cyprus** (53% of respondents agreed or strongly agreed while 32% disagreed or strongly disagreed), over half of respondents also agree that **attractiveness of STEM related studies is a challenge** (68% of respondents agreed or strongly agreed while 0% disagreed or strongly disagreed).

Slightly clearer patterns could be identified in the following statements: **students are engaged in STEM related studies in Cyprus** (32% of respondents agreed or strongly agreed while 26% disagreed or strongly disagreed), **engagement is a big challenge** (58% of respondents agreed or strongly agreed while 5% disagreed or strongly disagreed); **students in Cyprus are motivated in STEM related studies** (26% of respondents agreed or strongly agreed while 32% disagreed or strongly disagreed), **motivation in STEM related studies is a big challenge in Cyprus** (68% of respondents agreed or strongly agreed while 5% disagreed or strongly disagreed).

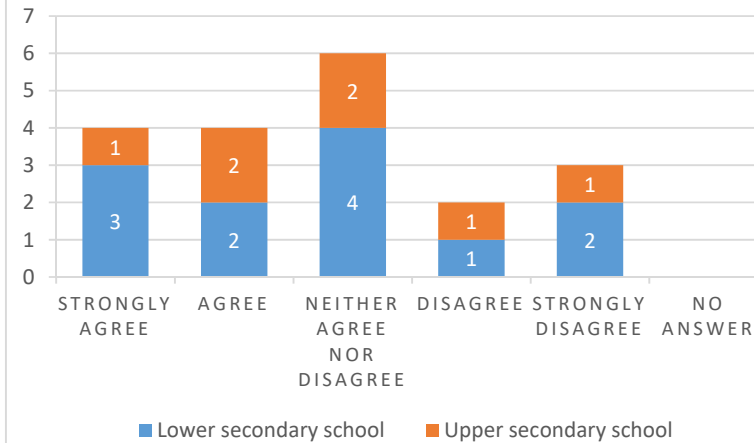
9. What are the main challenges in your country in making STEM studies attractive, to engage students more and to increase their motivation towards STEM studies and careers? Please reply by selecting the level of agreement with the following statements.



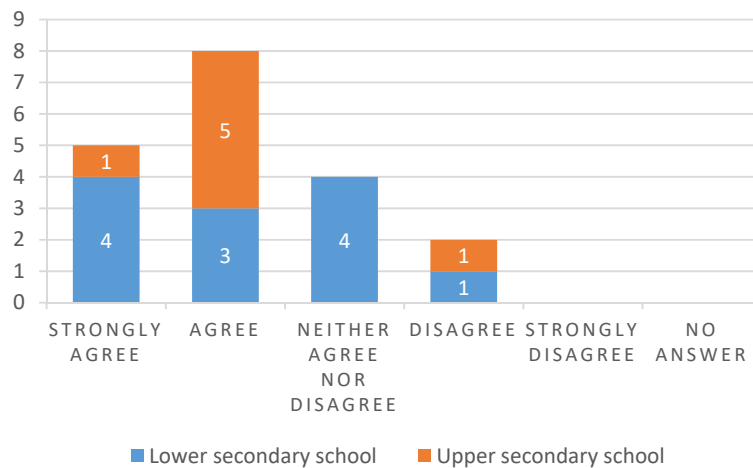
9.5 STEM EDUCATORS' PEDAGOGICAL APPROACHES.*



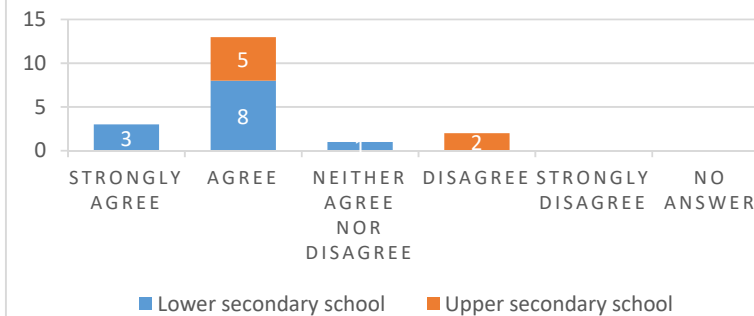
9.6 GENDER STEREOTYPES CONCERNING STEM STUDIES.*



9.7 LACK OF PROFESSIONAL DEVELOPMENT OPPORTUNITIES.*



9.8 THE SCHOOL COURSES/LESSONS/UNITS OF SCIENCE, TECHNOLOGY, ENGINEERING & MATH, AS WELL AS THEIR EDUCATIONAL MATERIAL, DO NOT BUILD LINKS TO TEACH THEM FROM AN INTEGRATED STEM PERSPECTIVE (HOW THESE SHOULD BE LINKED IN PRACTICE).*



The results indicate most statements above are considered challenges for increasing students' motivation and engagement towards STEM studies. Most respondents found that **school curriculum not building links between the disciplines** is a challenge (84% of respondents agreed or strongly agreed while 11% disagreed or strongly disagreed), followed by the **lack of single policy concerning STEM-related courses** (74% of respondents agreed or strongly agreed while 5% disagreed or strongly disagreed) and **options for professional development** (68% agreed or strongly agreed while 11% disagreed or strongly disagreed).

Approximately half of respondents find also the **availability of equipment at schools** (53% agreed or strongly agreed while 21% disagreed or strongly disagreed), **unemployment in STEM careers** (47% agreed or strongly agreed while 16% disagreed or strongly disagreed), **STEM educators' pedagogical approaches** (47% agreed or strongly agreed while 16% disagreed or strongly disagreed) and **school books are outdated** to be a challenge (42% agreed or strongly agreed while 32% disagreed or strongly disagreed), along with **gender stereotypes concerning STEM studies** (42% agree or strongly agreed while 26% disagreed or strongly disagreed).

If you would like to describe challenges not listed in the previous question, do so here.

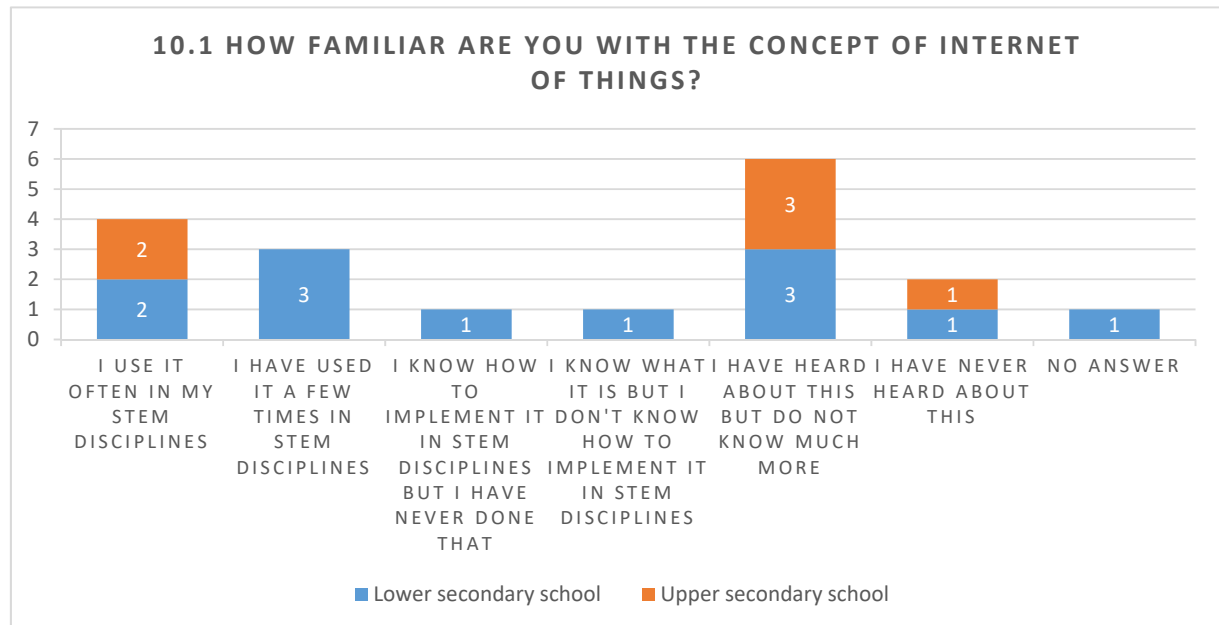
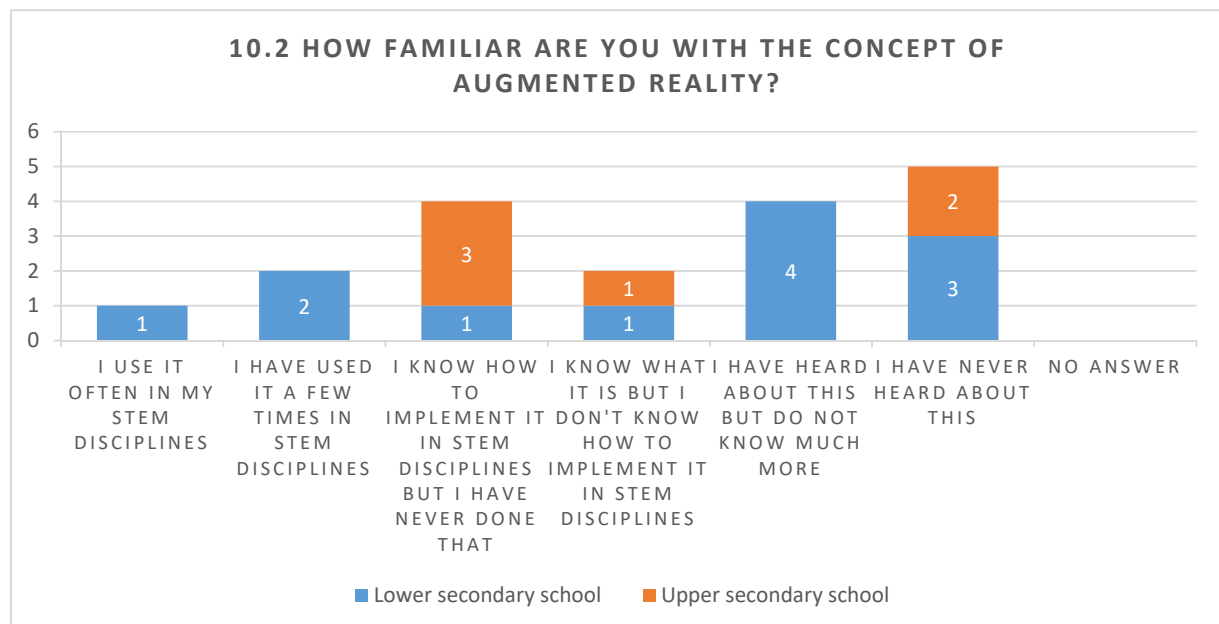
Altogether 4 people responded to the question, whose responses were categorized and will be given in the table below.

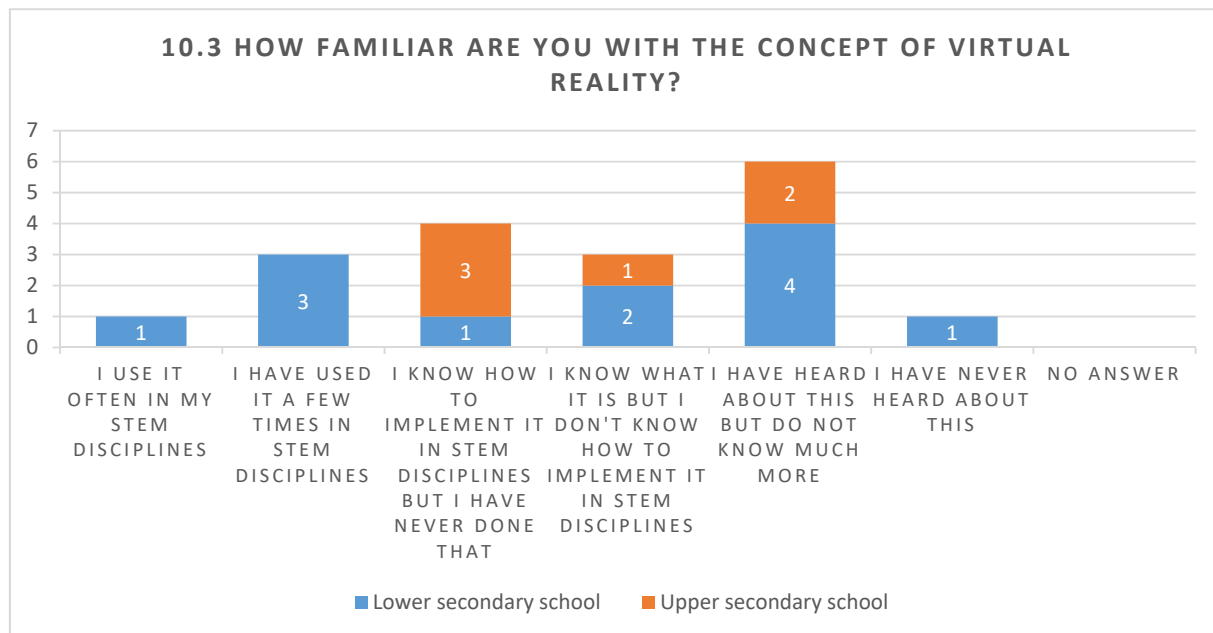
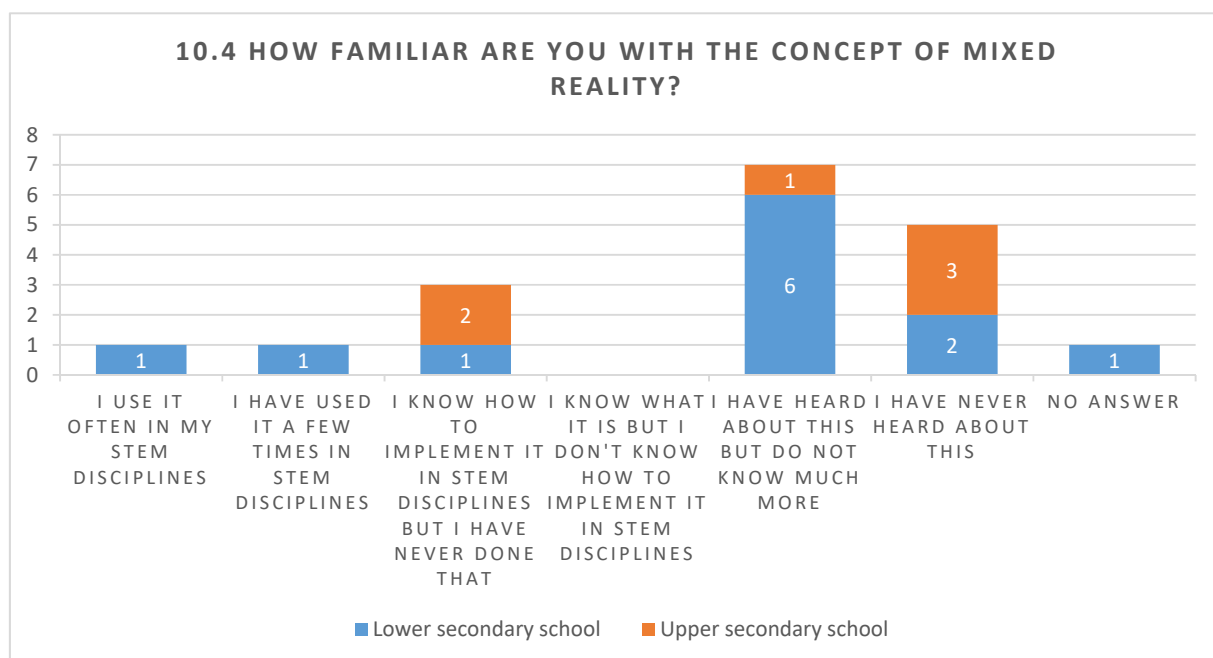
Category	Freq.
Constraints derived from the curriculum (not enough time for additional activities, curricula outdated etc.)	2
Little opportunity to collaborate with other teachers (no suitable classrooms, not enough time, overloaded with work, not interested in collaboration)	1
Lack of finances	1

If you know then please describe one success story how STEM studies have been made attractive, and students are engaged and motivated. Think on a story that could be useful to learn in other countries as well. Please provide any additional material such as links to the materials about this story (e.g., descriptions, learning materials, guidelines, videos, photos). If you have some useful files to share, then please send these to your national contact mentioned in the beginning and end of the questionnaire.

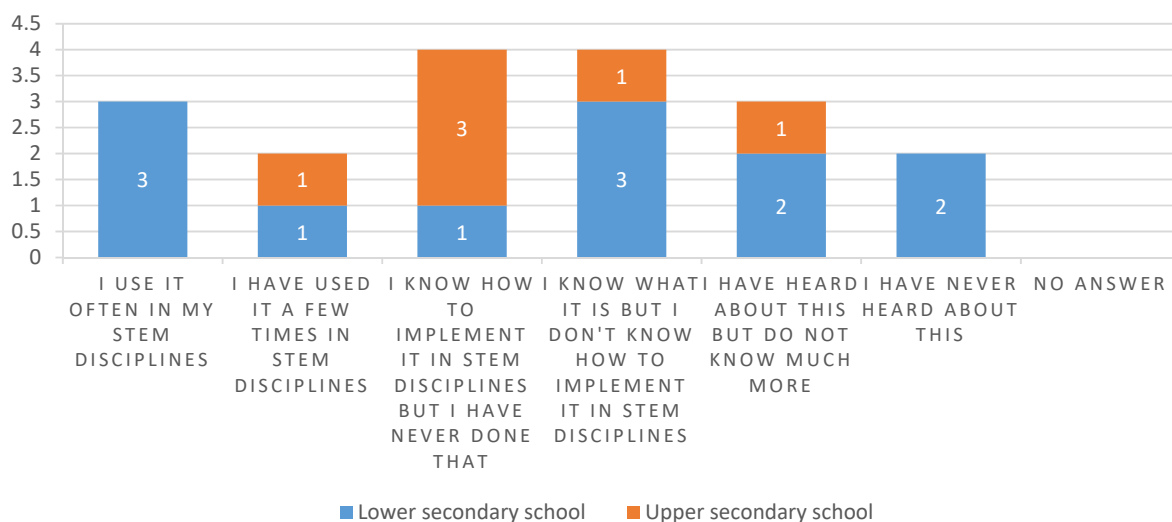
Altogether 1 respondent answered the question who found that the only case where STEM is promoted in general in Cyprus, is in the context of schools attending Erasmus projects.

10. How familiar are you with the following innovative emerging technologies? Please reply by selecting the level of familiarity with the following statements.

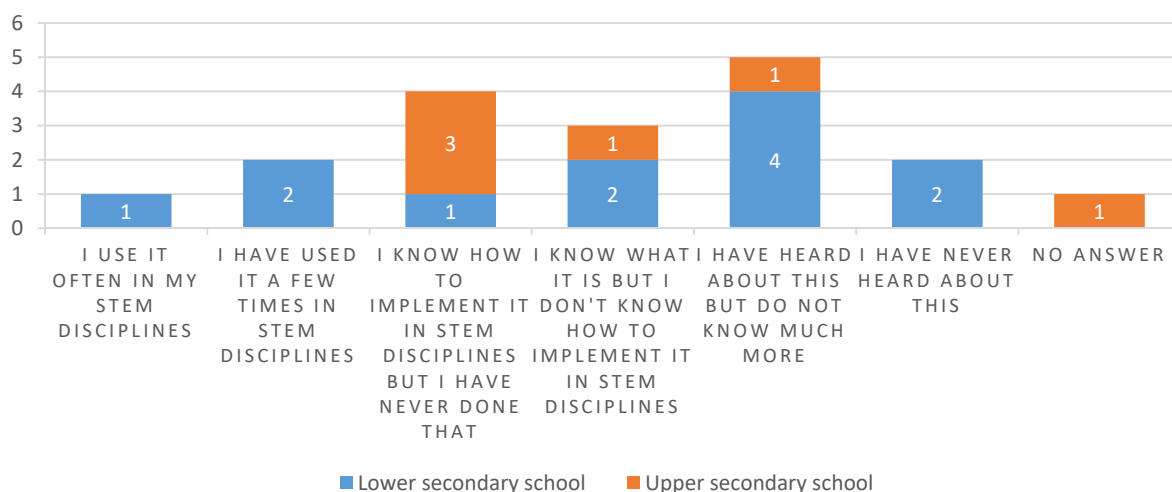




10.5 HOW FAMILIAR ARE YOU WITH THE POSSIBILITIES OF USING SMARTPHONES OR TABLETS IN STEM STUDIES?



10.6 HOW FAMILIAR ARE YOU WITH THE POSSIBILITIES OF USING AUGMENTED OR VIRTUAL REALITY TECHNOLOGIES (E.G., GLASSES, TABLETS, SMARTPHONES) IN STEM STUDIES?

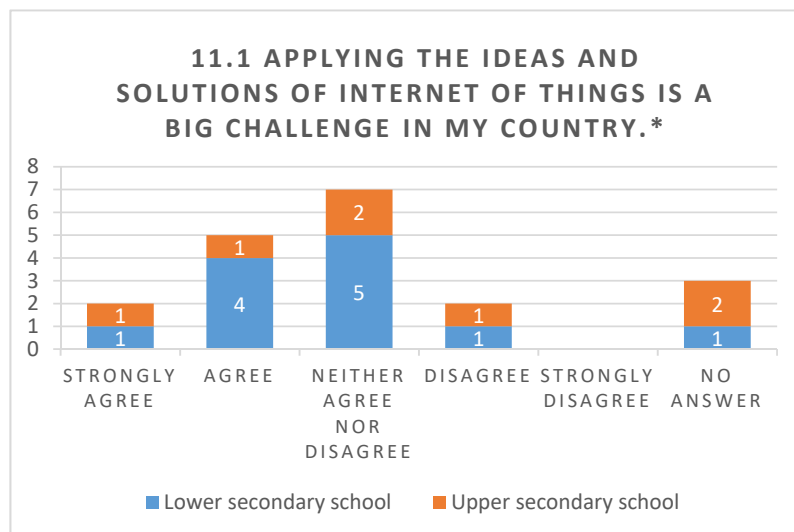
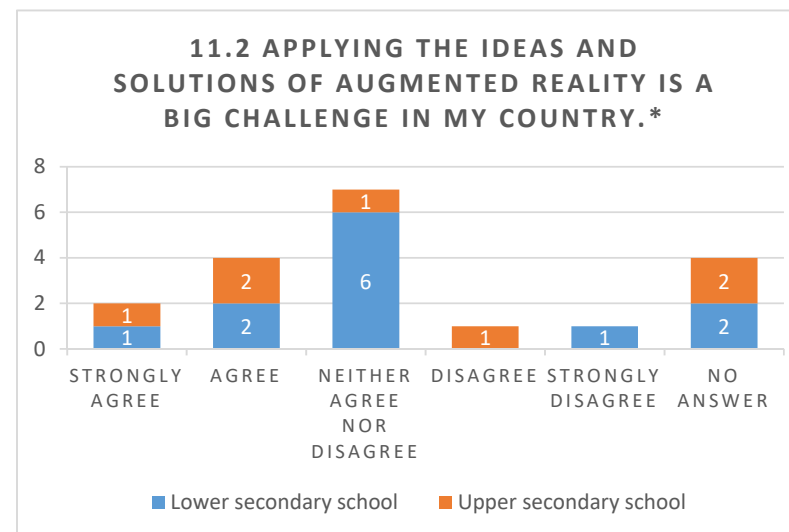
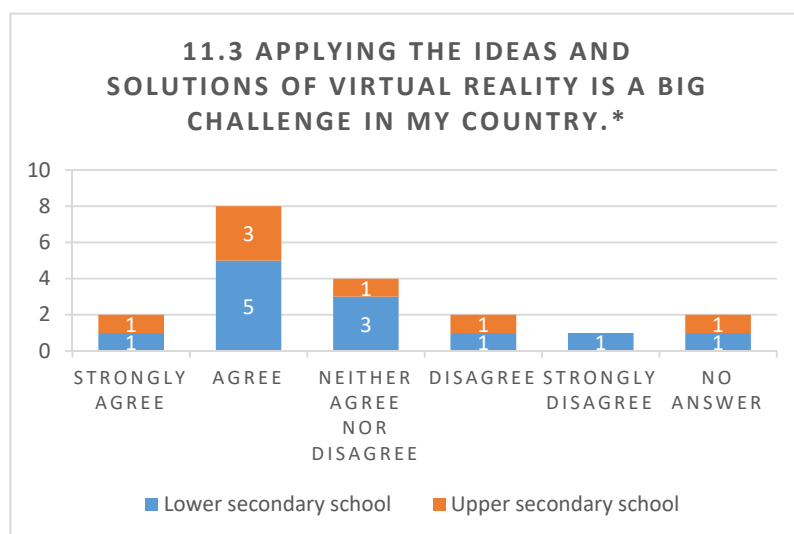
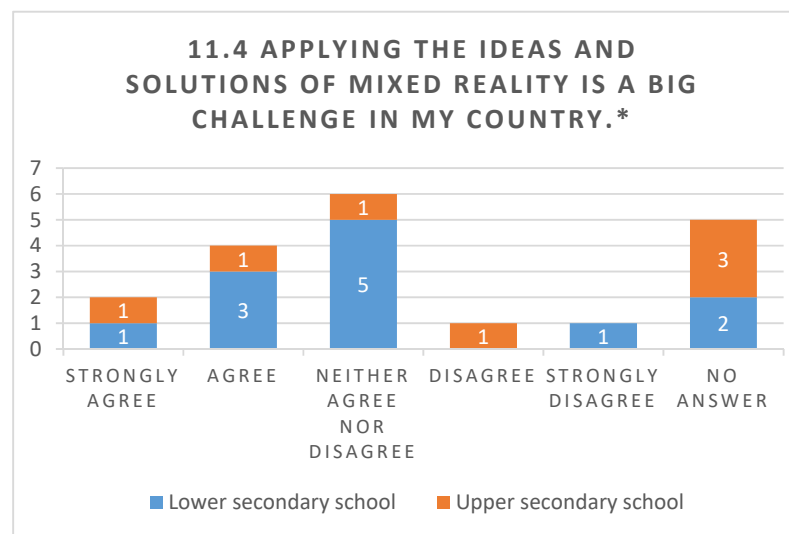


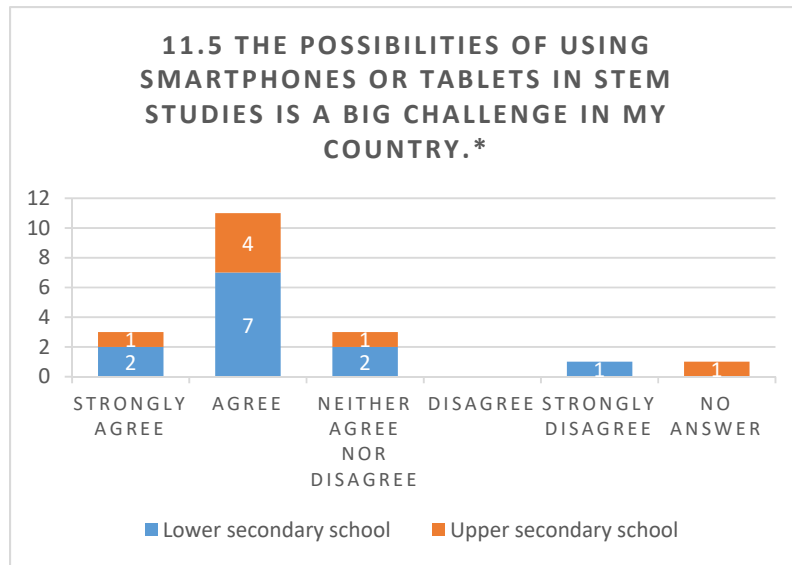
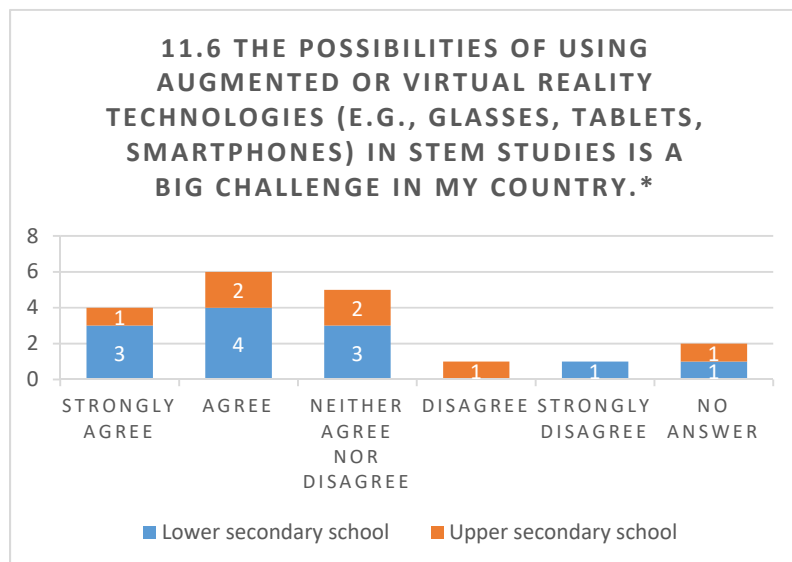
The results indicate that familiarity and use of the technologies listed above is often divided in half. The respondents are most familiar with the possibilities of **using smartphones or tablets for STEM studies** (28% of respondents have used it a few times or are using it often in STEM disciplines, 22% know how to implement it but have never done that), followed by the familiarity with the **concept of internet of things** (39% of respondents have used it a few times or are using it often in STEM disciplines, 6% know how to implement it but have never done that) and the **concept of virtual reality** (22% of respondents have used it a few times or are using it often in STEM disciplines, 22% know how to implement it but have never done that).

Respondents indicated less familiarity and use with the **concept of augmented reality** (17% of respondents have used it a few times or are using it often in STEM disciplines, 22% know how to implement it but have never done that), the **concept of mixed reality** (11% of respondents have used it a few times or are using it often in STEM disciplines, 17% know how to implement it but have never done that) and the **possibilities of using augmented or virtual reality technologies in STEM studies** (17% of respondents have used it a few times or are using it often in STEM disciplines, 22% know how to implement it but have never done that).

What should be noted in several cases is that even if respondent is aware of the technology and its possibilities to use in STEM disciplines, it is often not being used in their work. Also, nearly half of respondents reported that they have either only heard about the technology in question but does not know much more or has not heard about it at all.

11. What are the challenges in applying emerging technologies? Please reply by selecting the level of agreement with the following statements.

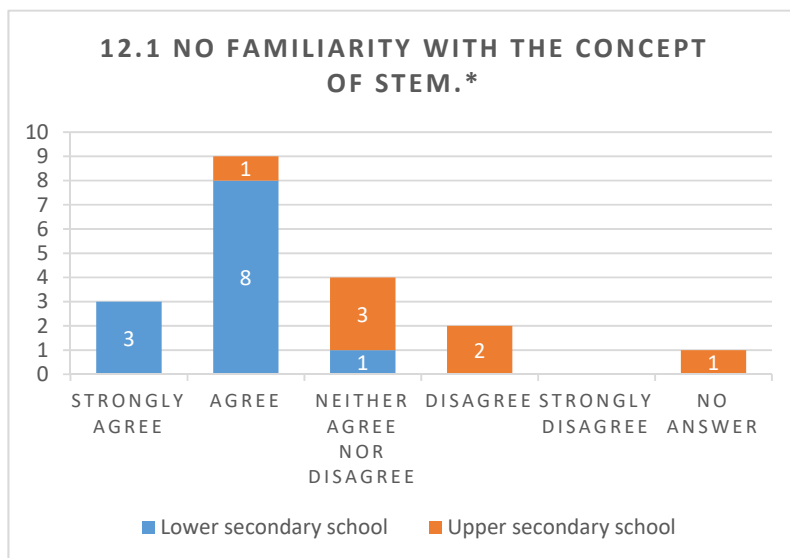
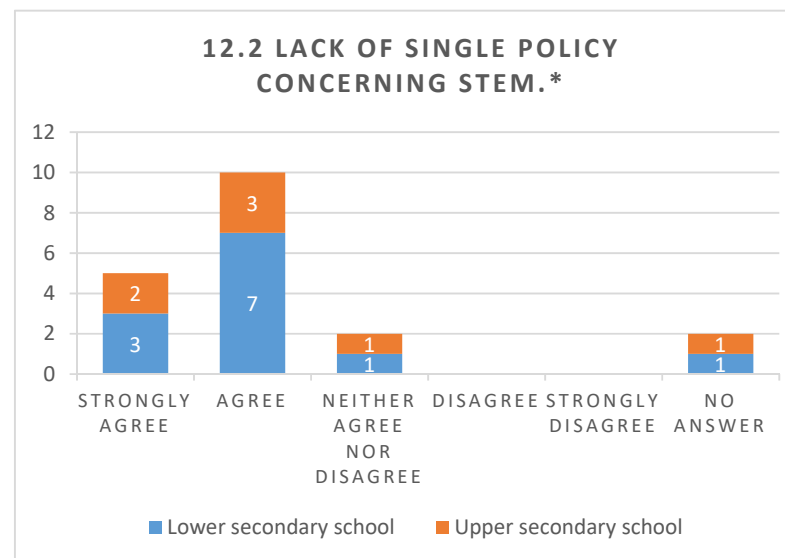
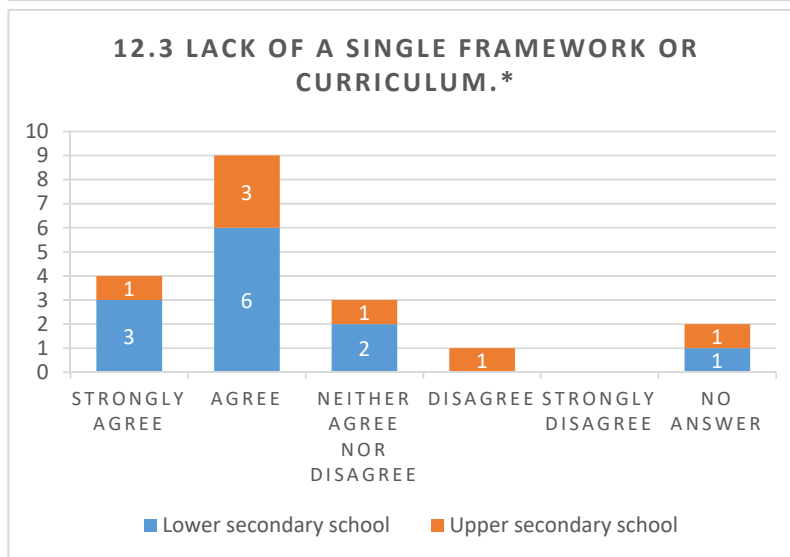
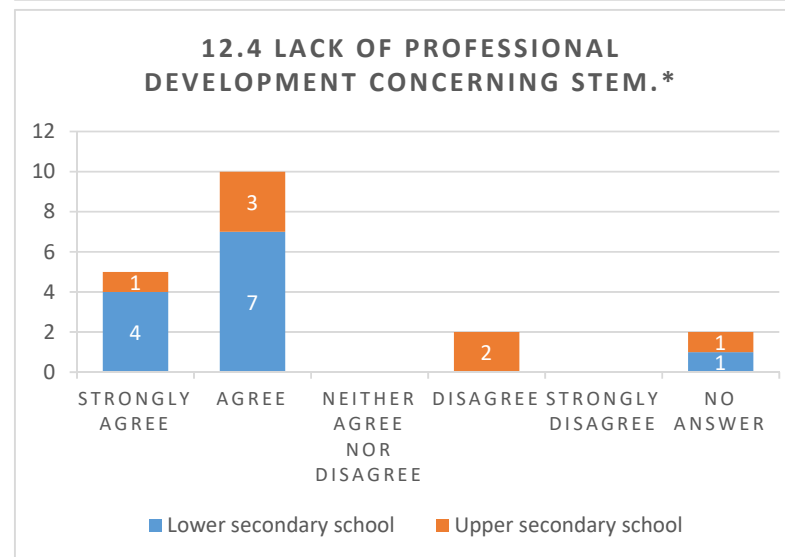


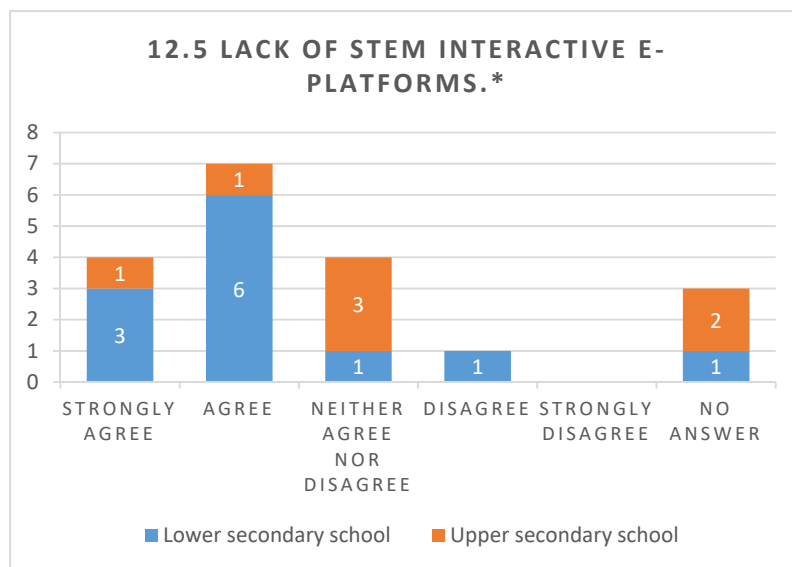
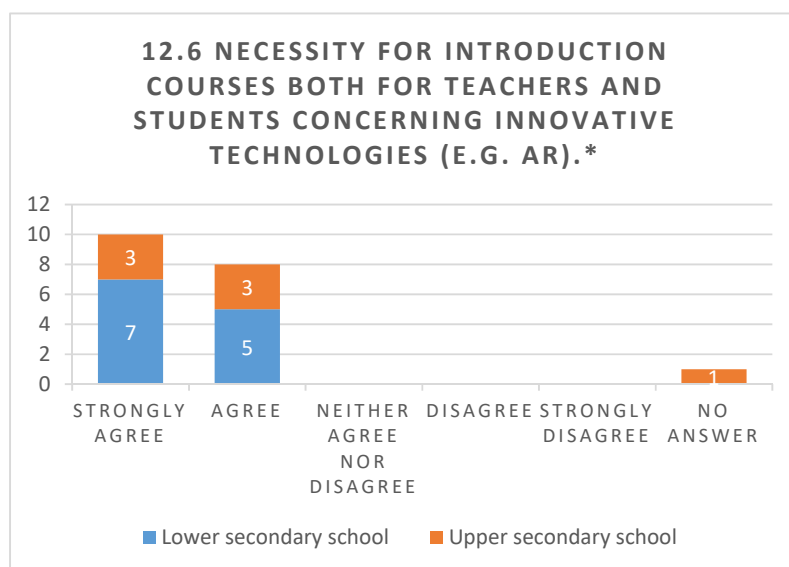


The results reflect that **using the technologies stated above are often found to be a challenge** in Cyprus. The most challenging aspects indicated are the **possibilities of using smartphones** (74% of respondents agreed or strongly agreed while 5% disagreed or strongly disagreed), the **possibilities of using augmented or virtual reality technologies** (53% of respondents agreed or strongly agreed while 11% disagreed or strongly disagreed) and applying the **ideas and solutions of virtual reality** (53% of respondents agreed or strongly agreed while 21% disagreed or strongly disagreed). These were followed by applying the **ideas and solutions of internet of things** (37% of respondents agreed or strongly agreed while 11% disagreed or strongly disagreed), **ideas and solutions of augmented reality** (32% of respondents agreed or strongly agreed while 11% disagreed or strongly disagreed), and **mixed reality** (32% of respondents agreed or strongly agreed while 11% disagreed or strongly disagreed).

However, it must be noted that responses could differ due to respondents' varied level of awareness about these technologies. For instance, as respondents' familiarity to internet of things and mixed reality was mapped low in previous question, in this question many have remained neutral regarding these technologies.

12. What are the main challenges in your country in applying innovative emerging technologies in STEM studies? Please reply by selecting the level of agreement with the following statements.





All of the statements above were found to be a challenge. The main challenges in applying innovative emerging technologies in STEM studies in Cyprus are regarded to be **necessity for introduction courses both for teachers and students concerning innovative technologies** (95% agree or strongly agree while 0% disagree or strongly disagree), **the lack of a single policy concerning STEM** (79% of respondents agree or strongly agree while 0% disagree or strongly disagree), **lack of professional development concerning STEM** (79% of respondents agree or strongly agree while 11% disagree or strongly disagree), **lack of a single framework or curriculum** (68% agree or strongly agree while 5% disagree or strongly disagree), **lack of familiarity with the STEM concept** (63% agree or strongly agree while 11% disagree or strongly disagree) and the **lack of STEM interactive e-platforms** (58% agree or strongly agree while 5% disagree or strongly disagree).

If you would like to describe challenges not listed in the previous question, do so here.

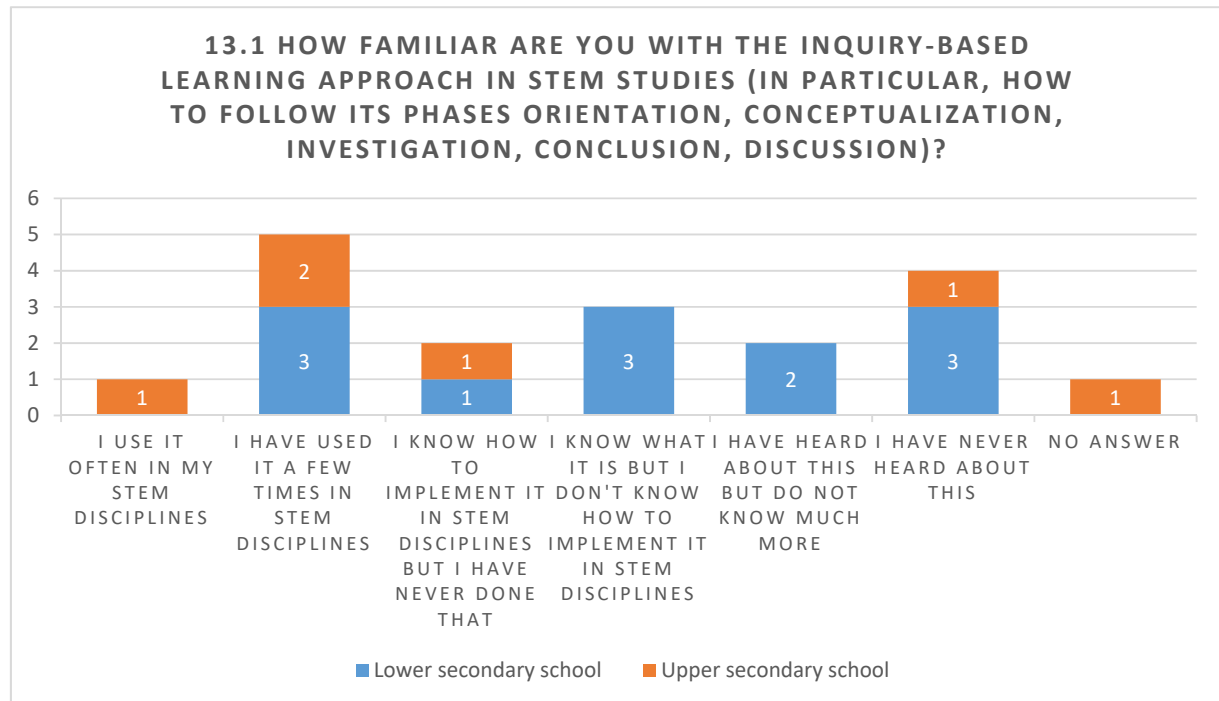
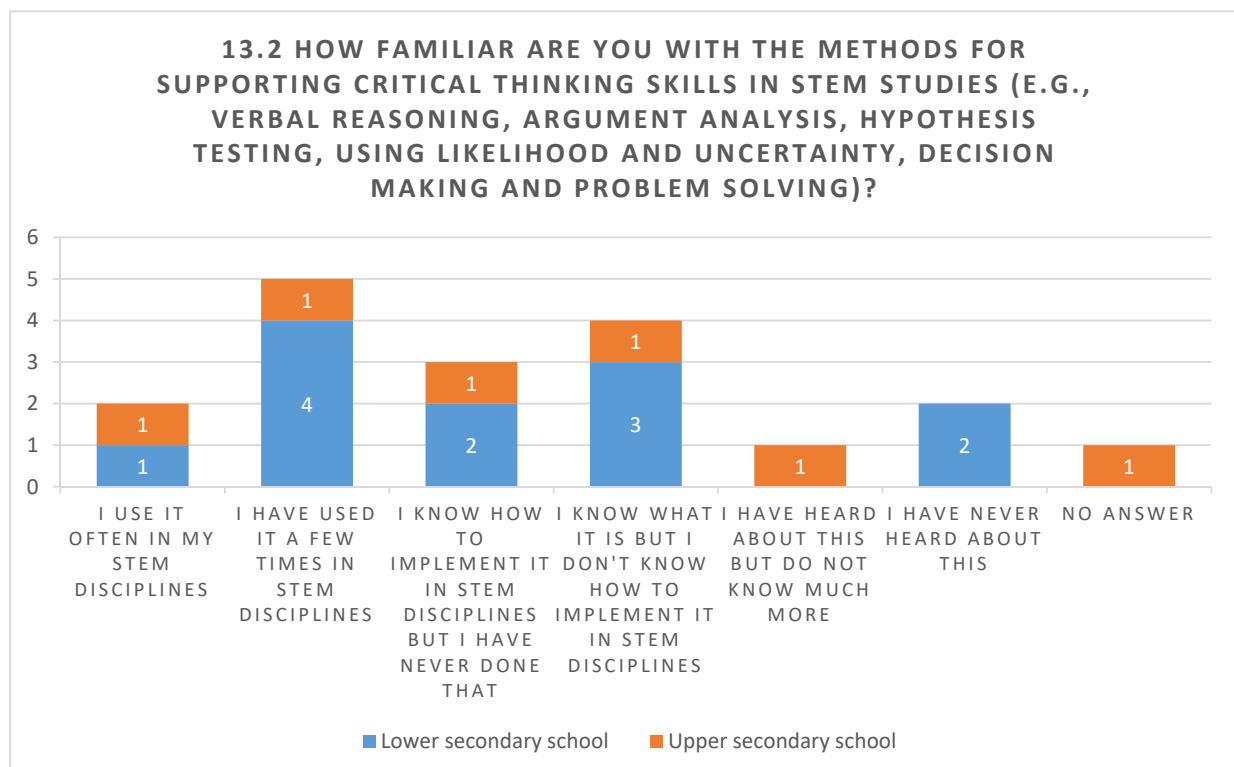
Altogether 1 person responded to the question whose answers were categorized and will be given in the table below.

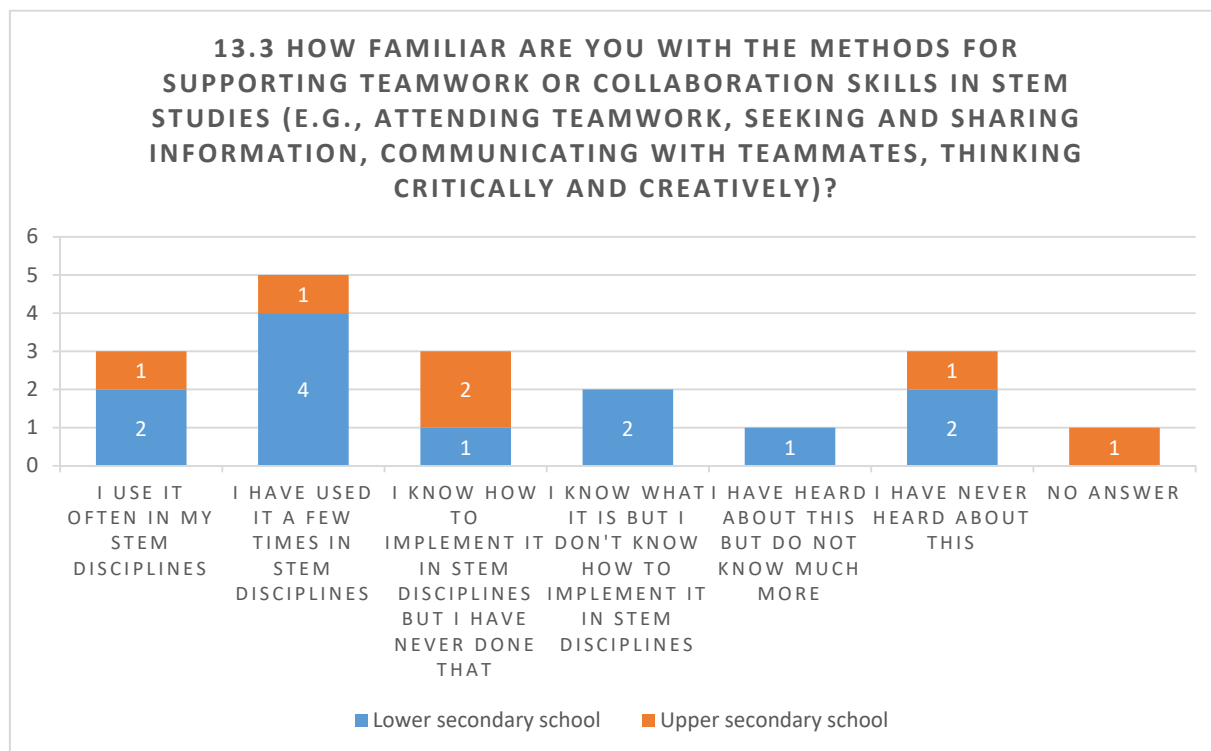
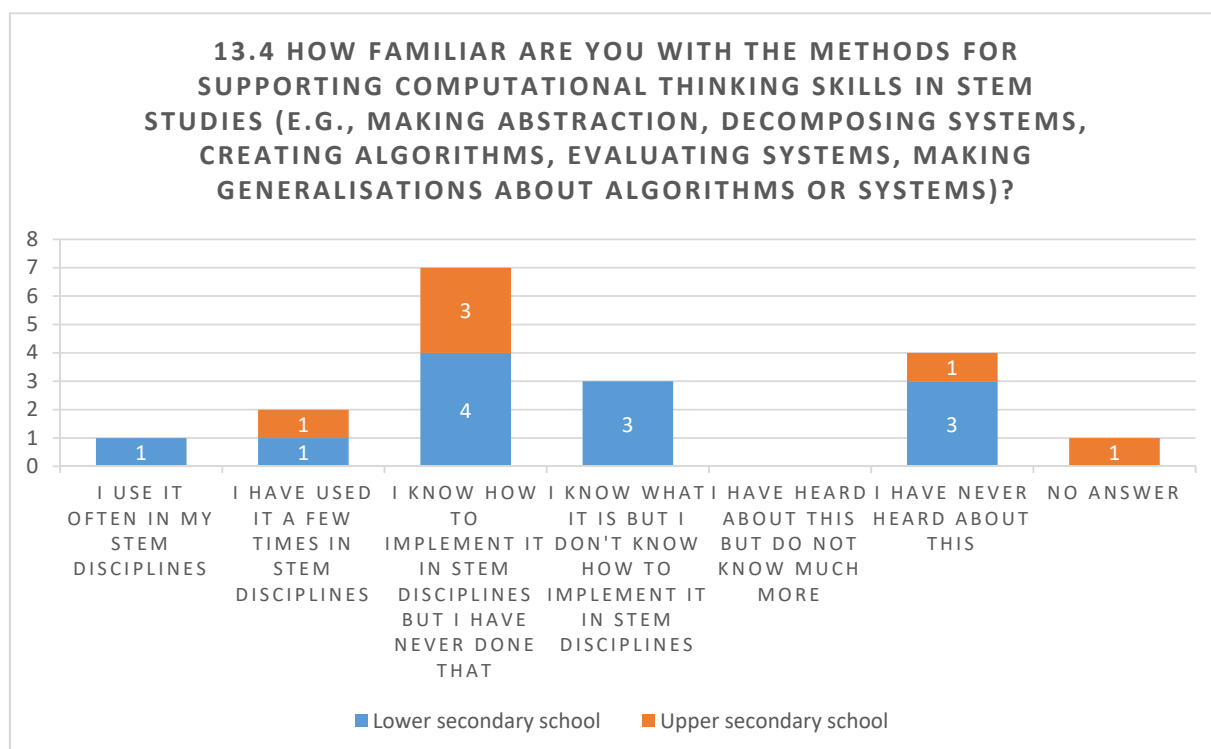
Category	Freq.
Lack of funding (e.g. lack of technological equipment in schools)	1
Lack in teachers' preparation/knowledge	1

If you know then please describe one success story how innovative emerging technologies have been successfully used in STEM studies. Think on a story that could be useful to learn in other countries as well. Please provide any additional material such as links to the materials about this story (e.g., descriptions, learning materials, guidelines, videos, photos). If you have some useful files to share, then please send these to your national contact mentioned in the beginning and end of the questionnaire.

No responses were received.

13. How familiar are you with innovative pedagogies and contemporary learning approach used in EL-STEM project and what are the challenges in applying them? Please reply by selecting the level of familiarity with the following statements.



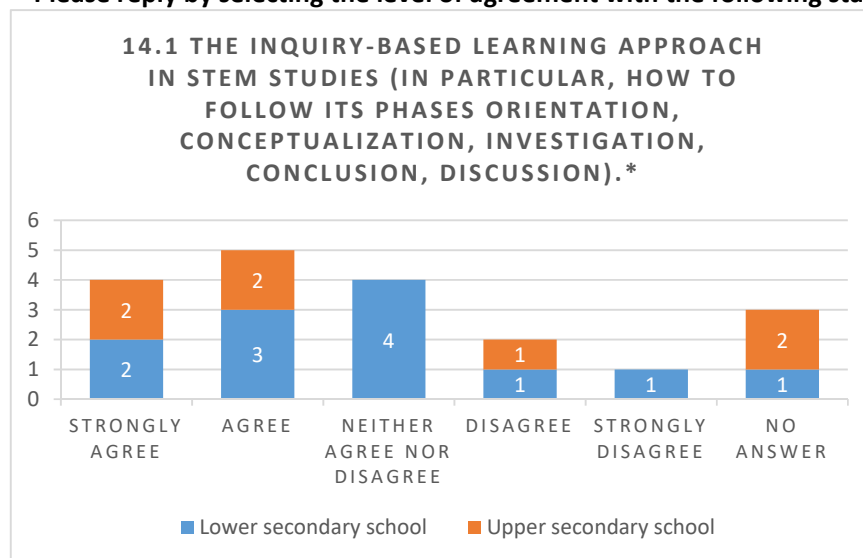
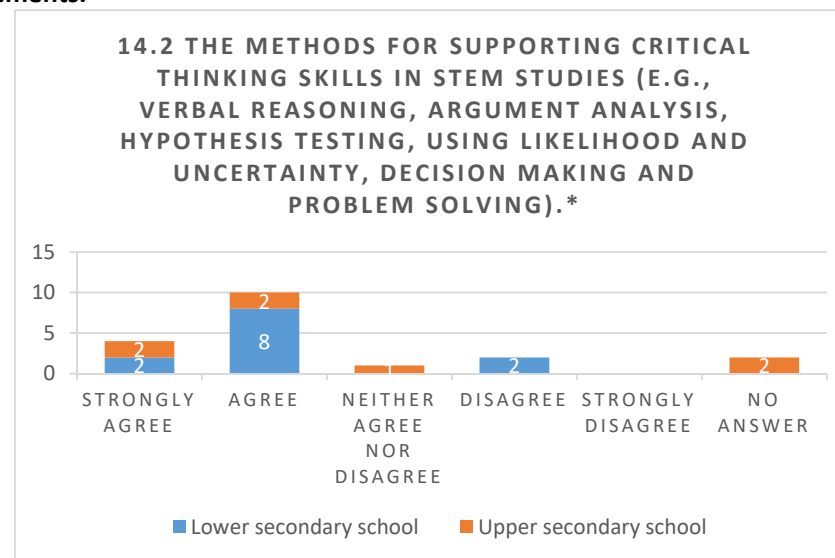
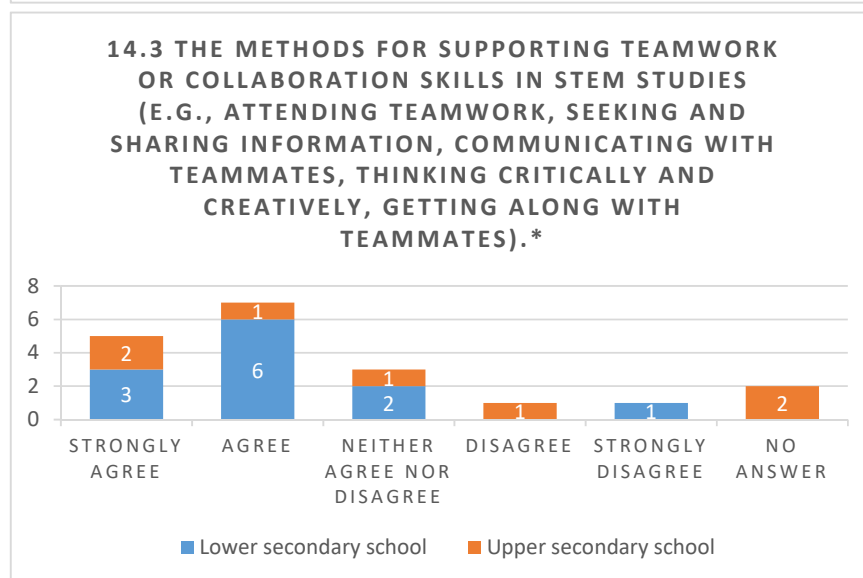
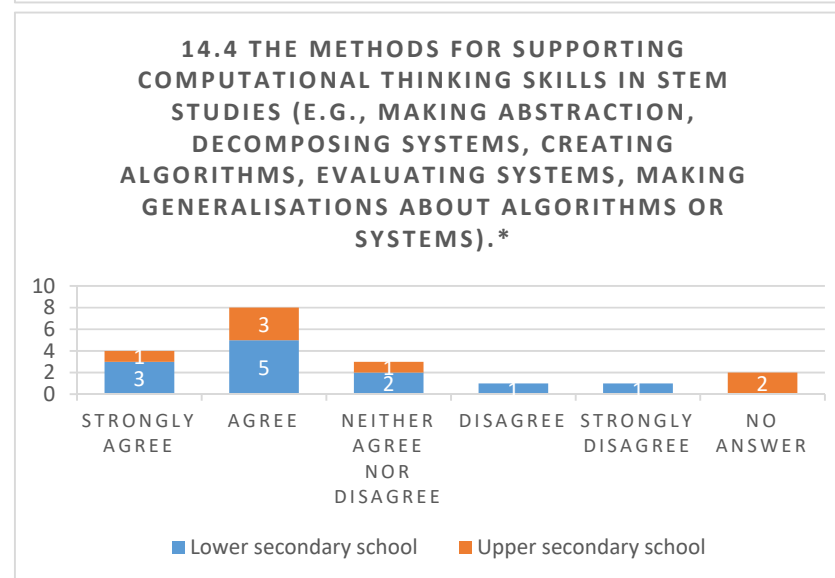


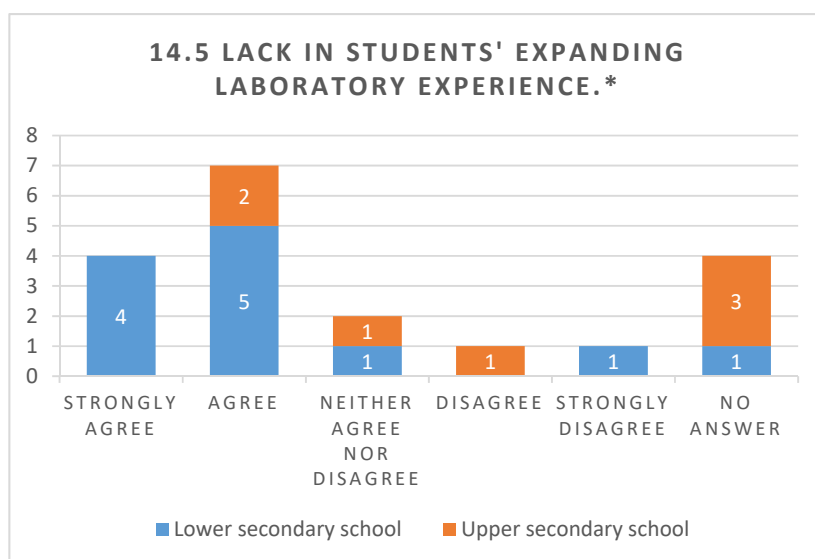
The results indicate that the familiarity with various methods is varied. Most familiarity and use was recognized with the methods for supporting **teamwork or collaboration skills in STEM studies** (44% of respondents have used it a few times or are using it often in STEM disciplines, 17% know how to implement it but have never done that), followed by the **methods for supporting critical thinking skills in STEM studies** (39% of respondents have used it a few times or are using it often in STEM disciplines, 17% know how to implement it but have never done that).

What is notable is that while 17% of respondents have used **methods for supporting computational thinking skills in STEM studies** a few times or are using it often in STEM disciplines, 39% of respondents know how to implement it in STEM disciplines, but have never done that.

Less familiarity was indicated with **the methods of inquiry based learning approach in STEM studies** (33% of respondents have used it a few times or are using it often in STEM disciplines, 11% know how to implement it but have never done that).

14. What are the main challenges in your country in applying innovative pedagogies and contemporary learning approach in STEM studies?
Please reply by selecting the level of agreement with the following statements.





It reflects from the results that all of the statements above are rather considered as challenges in Cyprus. The most often recognized challenge in applying innovative pedagogies and contemporary learning approach in STEM studies in Cyprus is regarded the **methods for supporting critical thinking skills in STEM studies** (74% agree or strongly agree while 11% disagree or strongly disagree). Another challenges identified are the **methods for supporting computational thinking skills in STEM studies** (63% agree or strongly agree while 11% disagree or strongly disagree) and the **methods for supporting teamwork or collaboration skills** (63% agree strongly agree while 11% disagree or strongly disagree), **lack in students' expanding laboratory experience** (58% of respondents agree or strongly agree while 11% disagree or strongly disagree) and **inquiry-based learning approach** (47% agree or strongly agree while 16% disagree or strongly disagree) in STEM studies.

If you would like to describe challenges not listed in the previous question, do so here.

Altogether 1 people responded to the question, whose answer was categorized and will be given in the table below.

Category	Freq.
Lack in teachers' preparation/knowledge	1

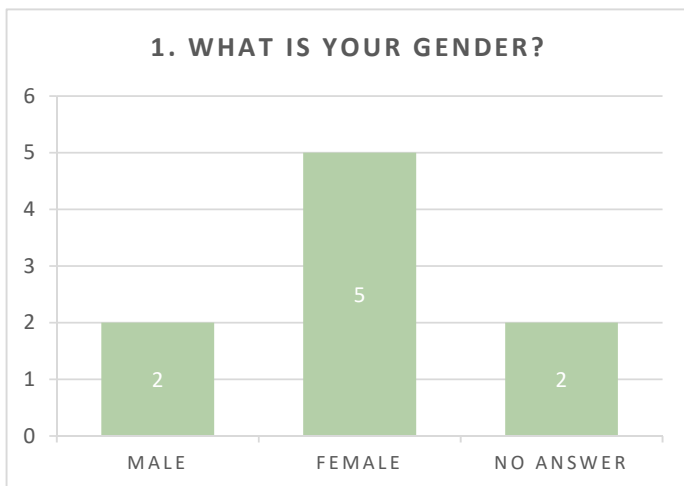
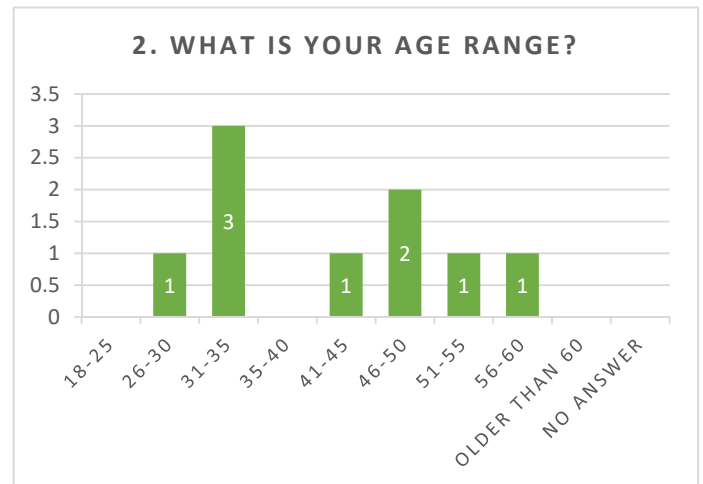
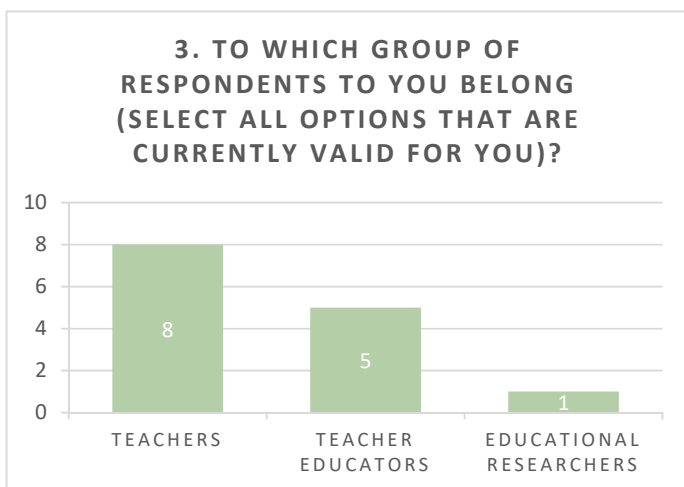
If you know then please describe one success story how innovative pedagogies or contemporary learning approach have been successfully used in STEM studies. Think on a story that could be useful to learn in other countries as well. Please provide any additional material such as links to the materials about this story (e.g., descriptions, learning materials, guidelines, videos, photos). If you have some useful files to share, then please send these to your national contact mentioned in the beginning and end of the questionnaire.

No responses were received.

5.2.3. Finland

Altogether **9 people** responded to the survey from Finland. An overview of the respondents' profile and responses will be given in the charts below.

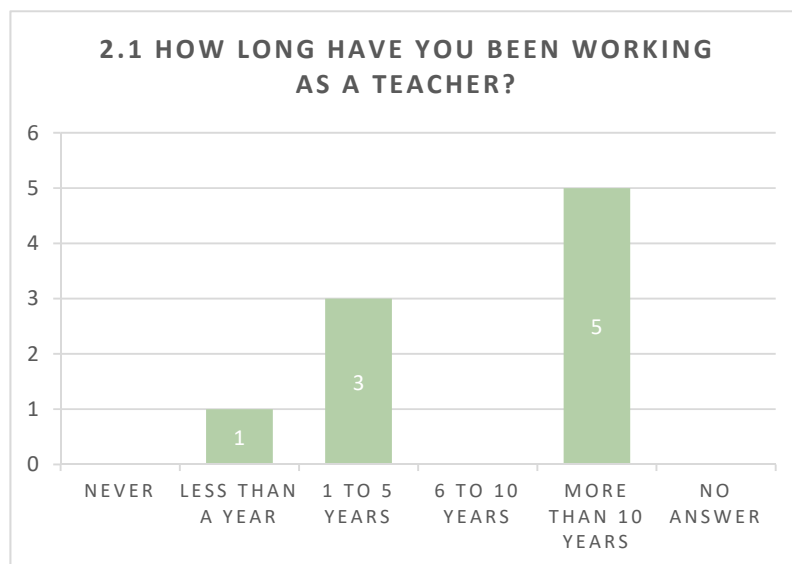
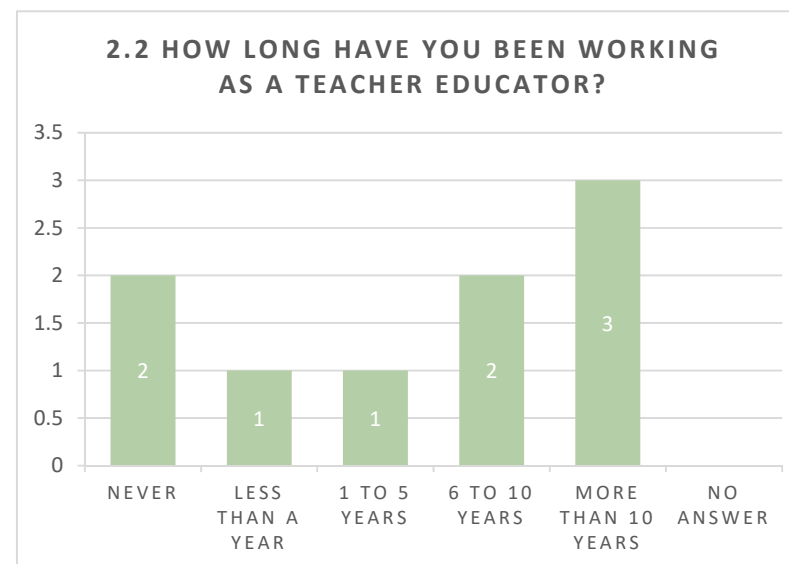
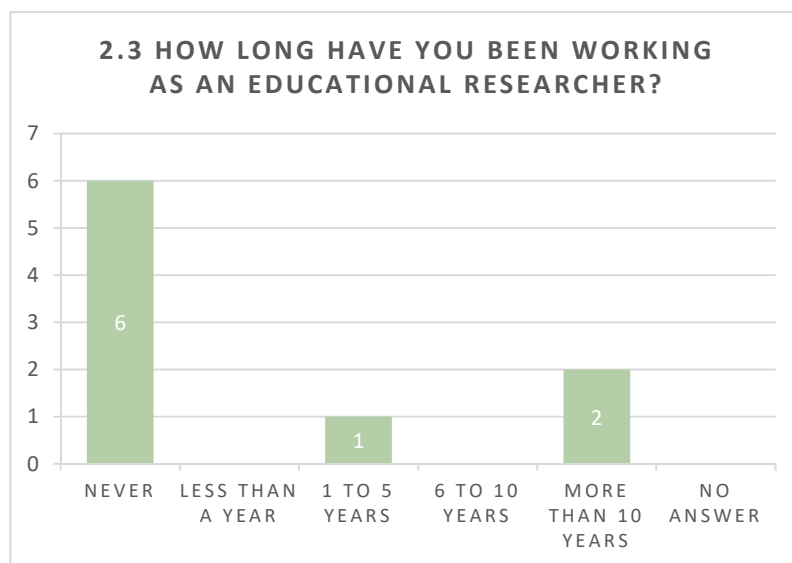
1. Background information



Out of 9 respondents in Finland, 33% are **aged between 31-35**, and 22% between 46-50. Other participants' ages vary from 26 to 60.

Majority of the respondents are working as **teachers** (89%) with over 10 years of experience (56%).

2. How long have you been working as a... (select an answer in case of all options)



Approximately half of respondents are working as **teacher educators** with experiences varying from less than a year to more than 10 years.

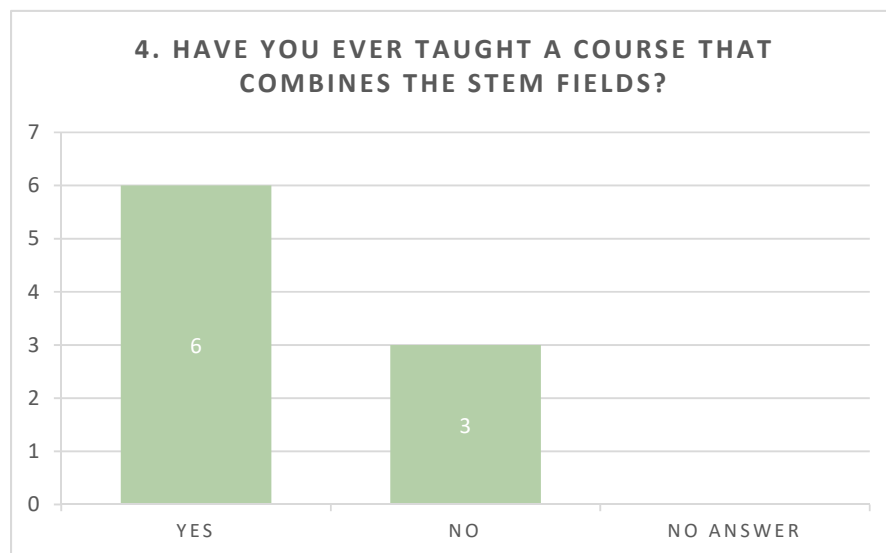
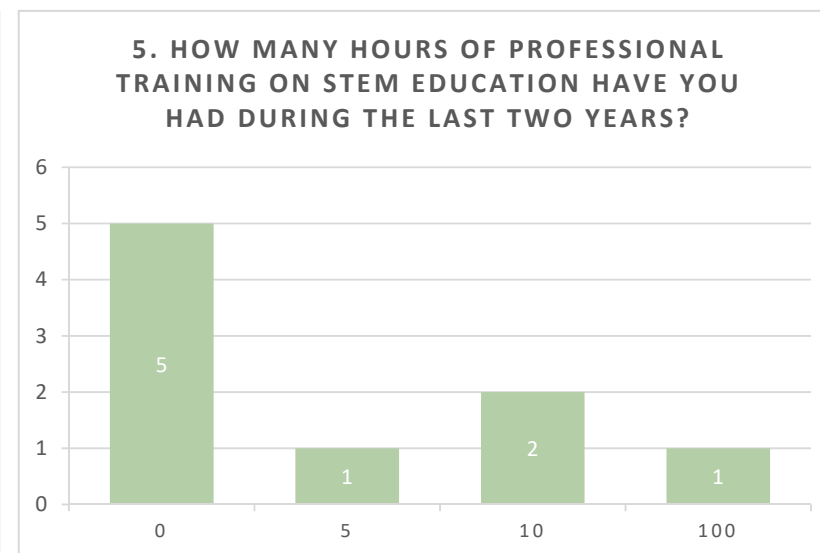
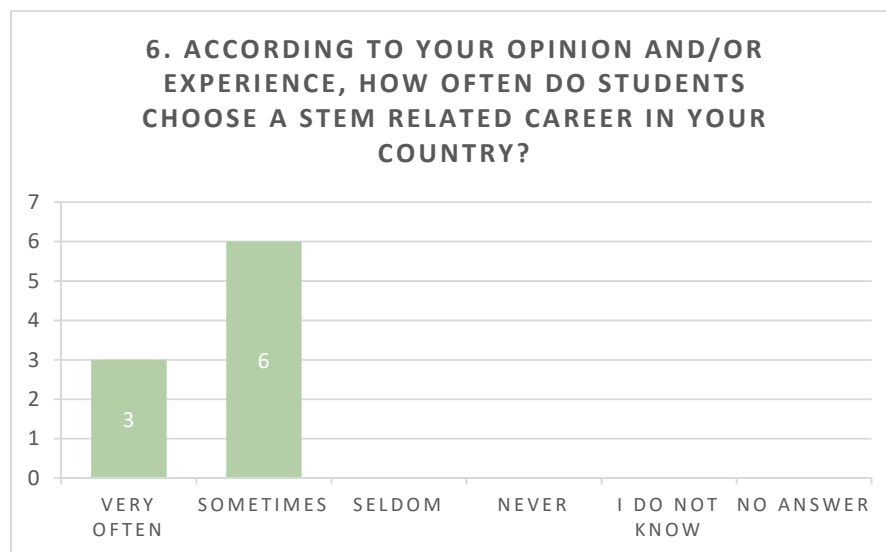
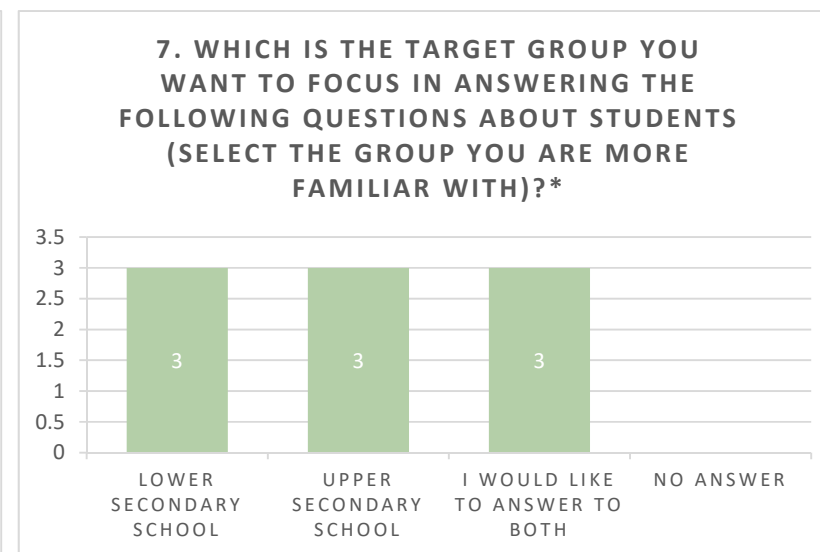
Only 11% of respondents have indicated their experience with working as **educational researcher**, yet the length of this experience was marked to 1 to 5 years (33%) and to more than 10 years (67%).

3. How do you understand the concept of STEM (use up to 1000 characters)?

Altogether, 9 people responded to the question in Finland. The answers were categorised and an overview of the responses will be given in the table below.

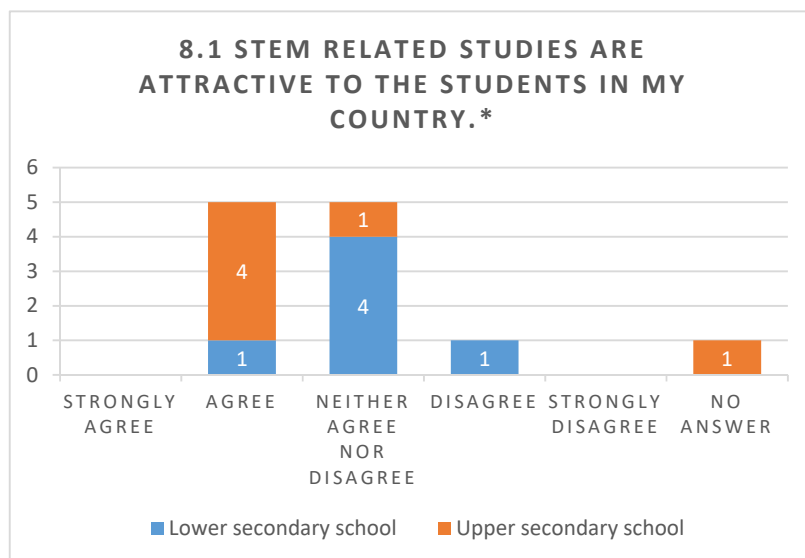
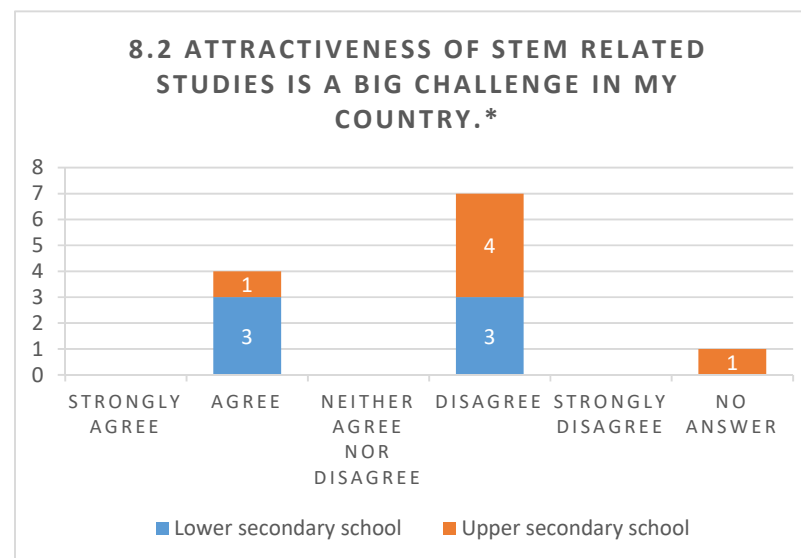
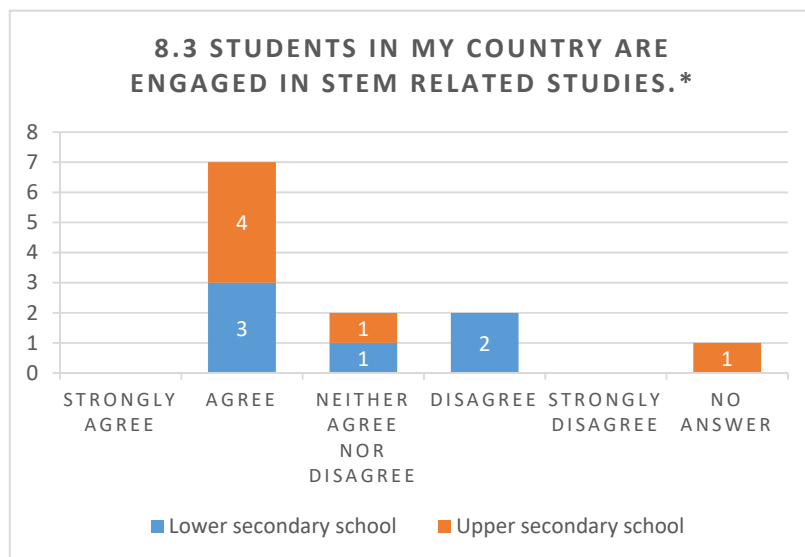
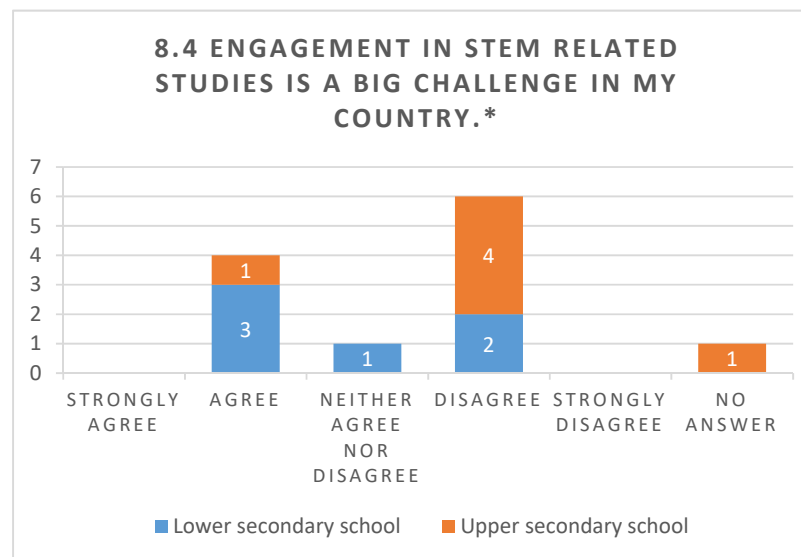
Category	Freq.
Science Technology Engineering Mathematics and the integration of these disciplines/use of research based learning method/use of applied approach	4
Science Technology Engineering Mathematics	3
Science Technology Engineering Mathematics and the integration of these disciplines with applied approach, in order to foster understanding and connecting theoretical knowledge to practice and to develop computational, critical thinking, teamwork and collaboration skills.	1
Not replied to the question	1

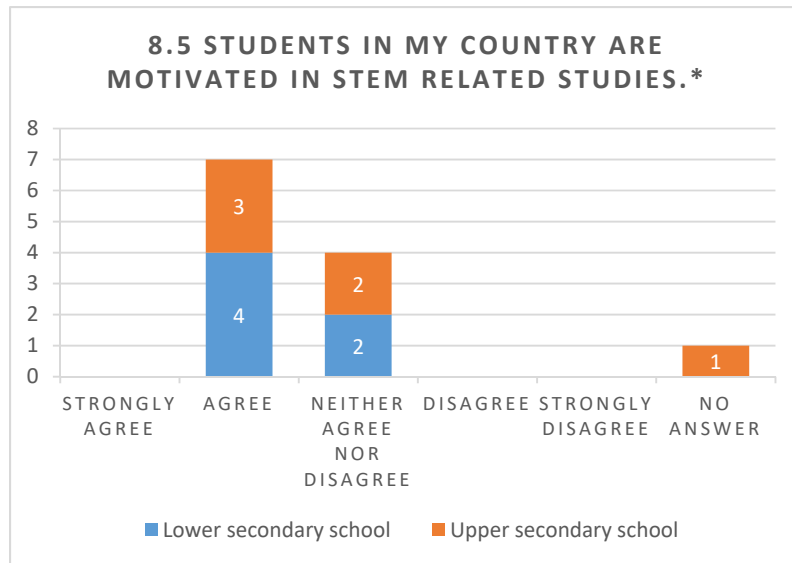
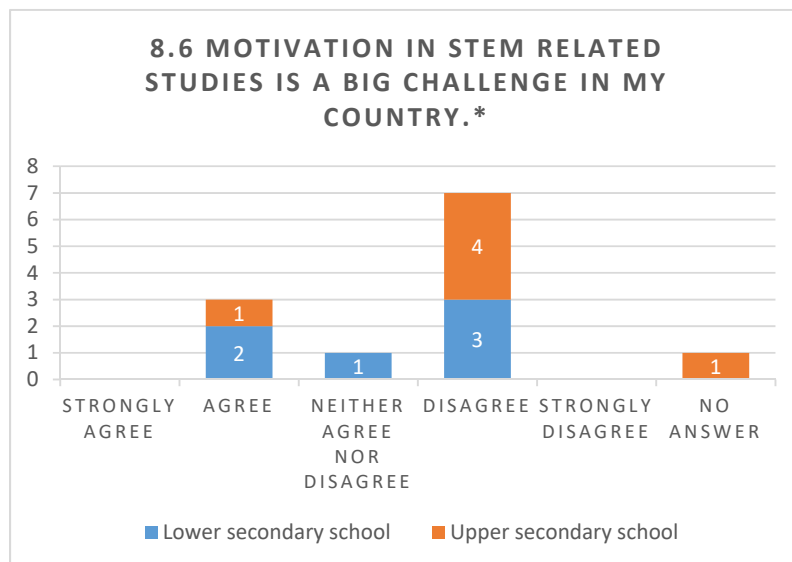
Nearly half of respondents (45%) described their understanding of the concept by **explaining the acronym and describing one or two aspects of the concept**, 33% **wrote only the names of disciplines which compose the STEM acronym** and equally one person (11%) **explained the acronym and added a further explanation to the concept** as well as **not replied the question**.



*** Note:** There were two types of questions: Firstly, questions which asked about the respondents' familiarity and experience with specific technologies or methods (to which all participants responded only once). Secondly, questions which required answering in the context of lower or upper secondary school. As 3 participants responded the questions twice (from both lower and upper secondary school), 12 responses are counted in total for these questions. These questions will be marked with an asterisk (*).

8. What is the attractiveness of STEM studies and how engaged and motivated the students are in STEM studies in different countries? Please reply by selecting the level of agreement with the following statements.

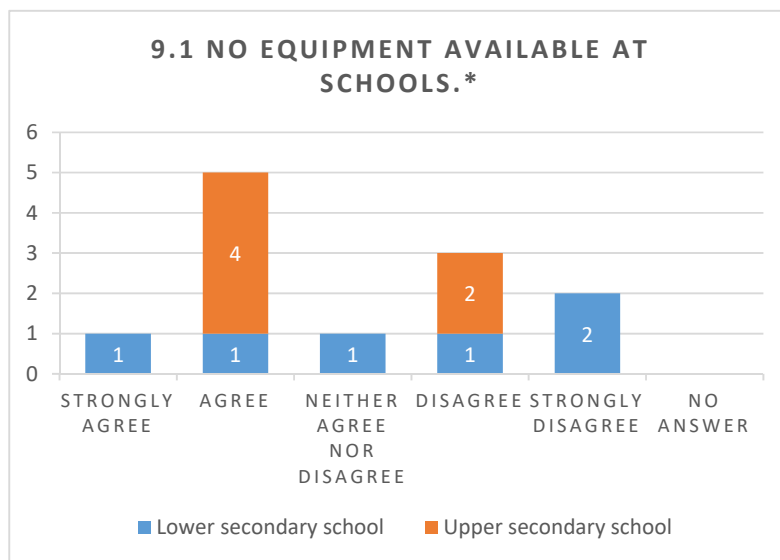
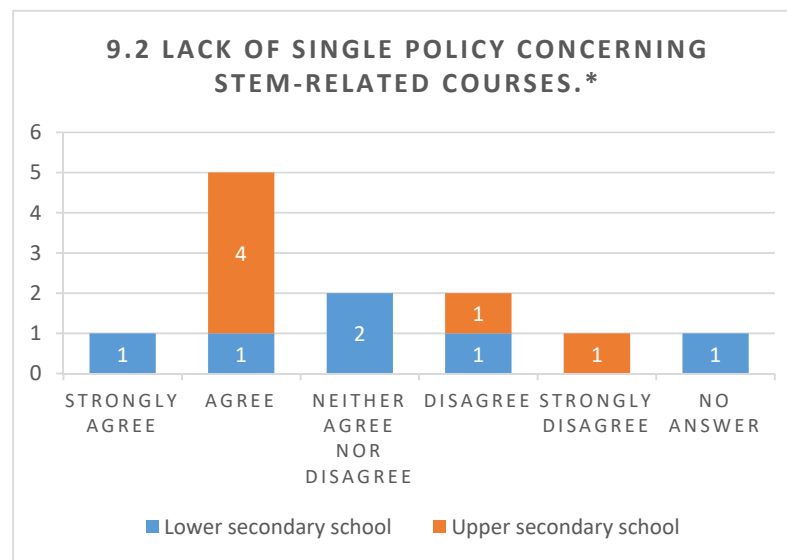
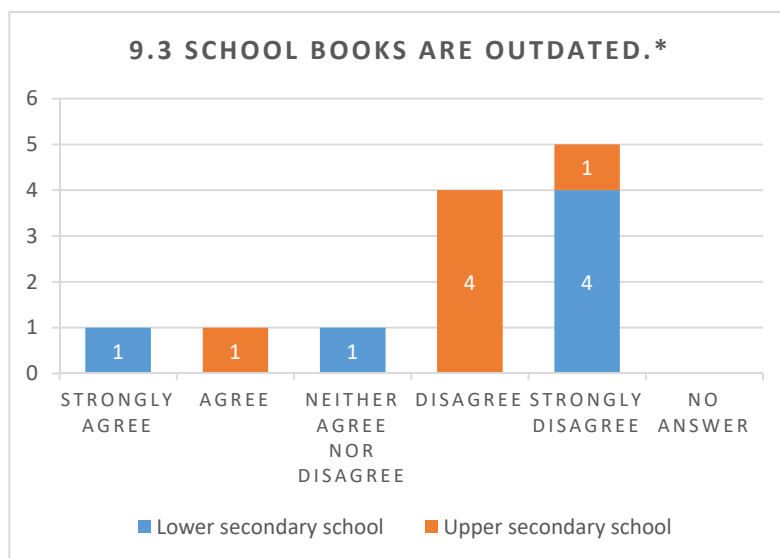
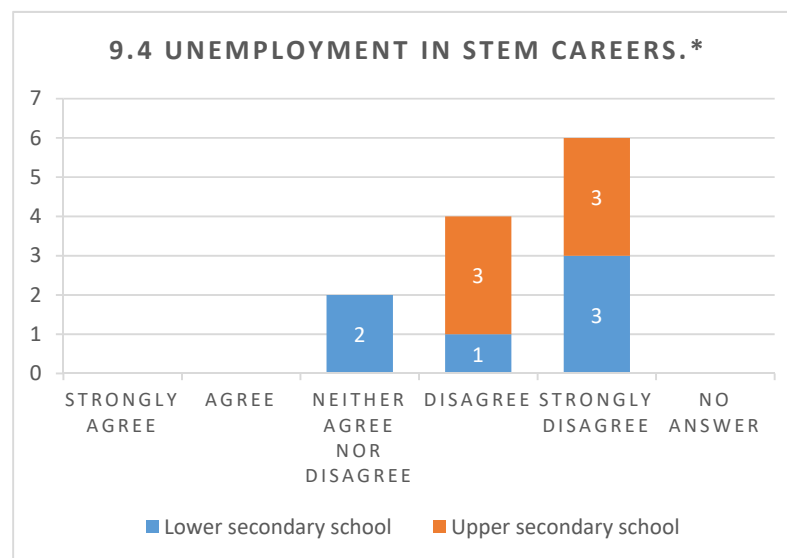




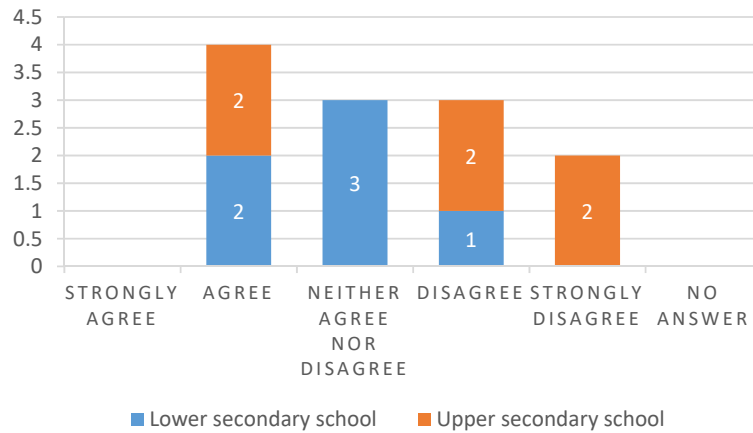
While nearly half of respondents agree that **STEM related studies are attractive to the students** in Finland (41% of respondents agreed or strongly agreed while 8% disagreed or strongly disagreed) over half of respondents do not find **attractiveness of STEM related studies to be a challenge** (33% of respondents agreed or strongly agreed while 58% disagreed or strongly disagreed).

Similar ratios reflect also in the following statements: while over half of respondents found that **students are engaged in STEM related studies in Finland** (58% of respondents agreed or strongly agreed while 17% disagree or strongly disagree), half of respondents also did not find **engagement to be a big challenge** (33% of respondents agreed or strongly agreed while 50% disagree or strongly disagree); while over half of respondents find that **students in Finland are motivated in STEM related studies** (58% of respondents agreed or strongly agreed while 0% disagree or strongly disagree), over half do not find **motivation in STEM related studies to be a big challenge in Finland** (58% of respondents agreed or strongly agreed while 58% disagree or strongly disagree).

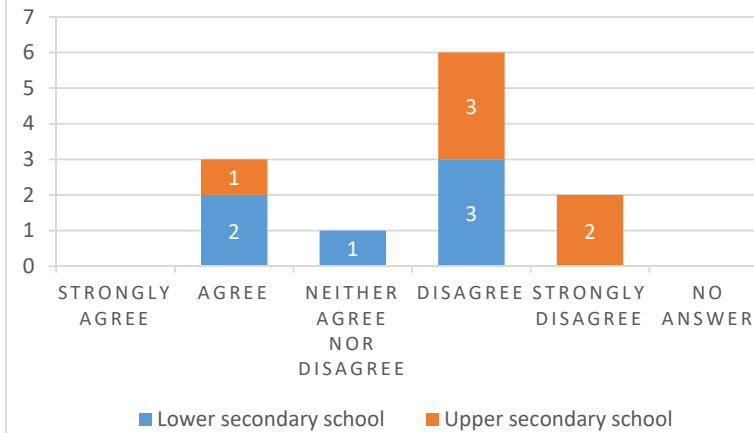
9. What are the main challenges in your country in making STEM studies attractive, to engage students more and to increase their motivation towards STEM studies and careers? Please reply by selecting the level of agreement with the following statements.



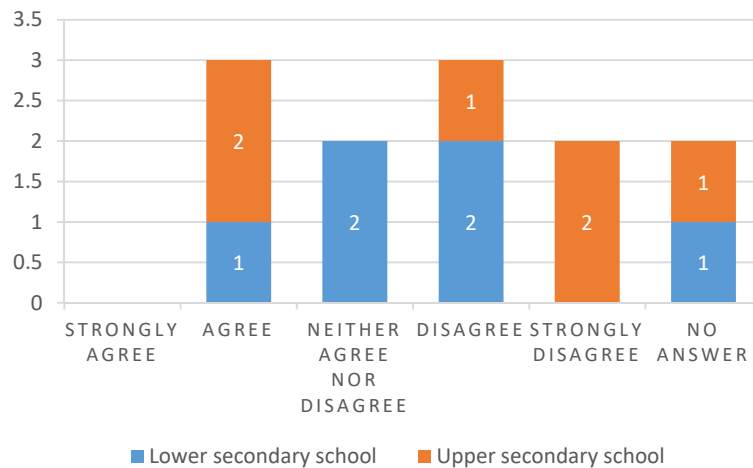
9.5 STEM EDUCATORS' PEDAGOGICAL APPROACHES.*



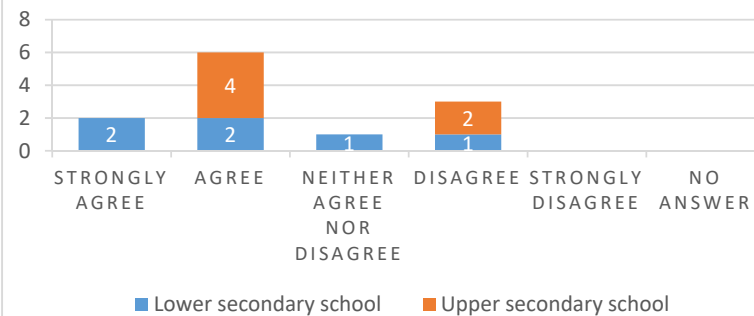
9.6 GENDER STEREOTYPES CONCERNING STEM STUDIES.*



9.7 LACK OF PROFESSIONAL DEVELOPMENT OPPORTUNITIES.*



9.8 THE SCHOOL COURSES/LESSONS/UNITS OF SCIENCE, TECHNOLOGY, ENGINEERING & MATH, AS WELL AS THEIR EDUCATIONAL MATERIAL, DO NOT BUILD LINKS TO TEACH THEM FROM AN INTEGRATED STEM PERSPECTIVE (HOW THESE SHOULD BE LINKED IN PRACTICE).*



The results indicate three main challenges for increasing students' motivation and engagement towards STEM studies: **school curriculum does not build links between the disciplines** (67% of respondents agreed or strongly agreed while 25% disagreed or strongly disagreed) and **lack of single policy concerning STEM-related courses** (50% of respondents agreed or strongly agreed while 25% disagreed or strongly disagreed).

Responses are more divided with the **availability of equipment at schools** (50% of respondents agreed or strongly agreed while 42% disagreed or strongly disagreed).

STEM educators' pedagogical approaches were found to be less challenging (33% of respondents agreed or strongly agreed while 41% disagreed or strongly disagreed) along with **gender stereotypes concerning STEM studies** (25% of respondents agreed or strongly agreed while 67% disagreed or strongly disagreed), **options for professional development** (25% of respondents agreed or strongly agreed while 42% disagreed or strongly disagreed), **school books are outdated** (17% of respondents agreed or strongly agreed while 75% disagreed or strongly disagreed).

Unemployment in STEM careers was regarded not a challenge at all (0% of respondents agreed or strongly agreed while 83% disagreed or strongly disagreed).

Additional challenges mentioned by 1 respondent was lack in teachers' preparation or knowledge.

If you would like to describe challenges not listed in the previous question, do so here.

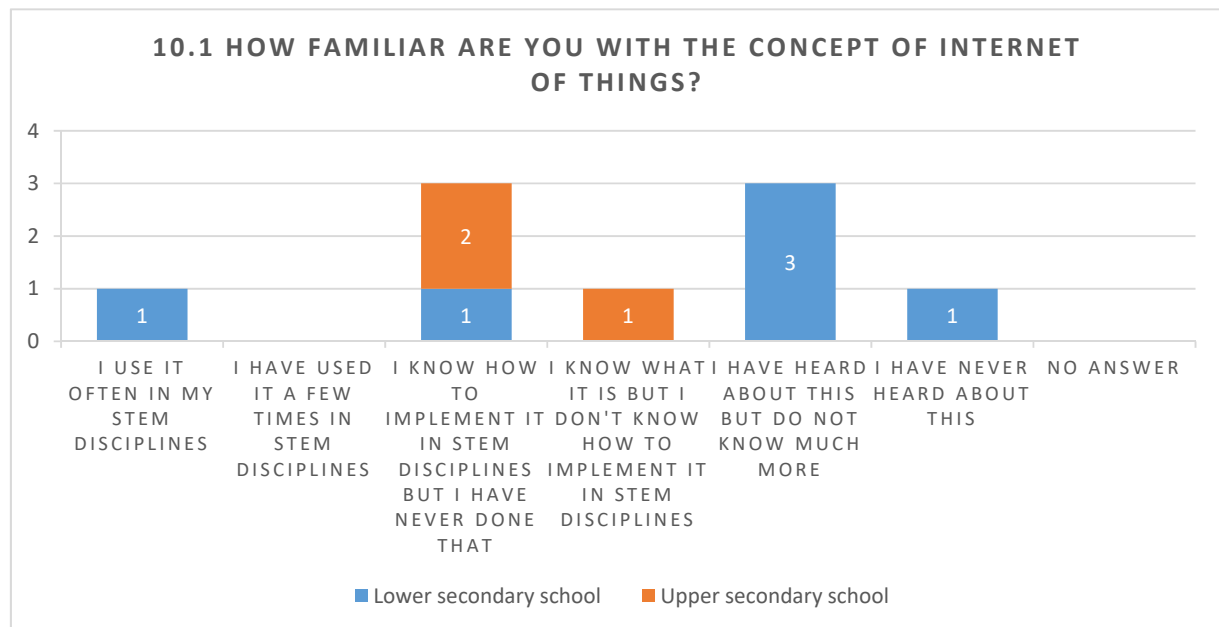
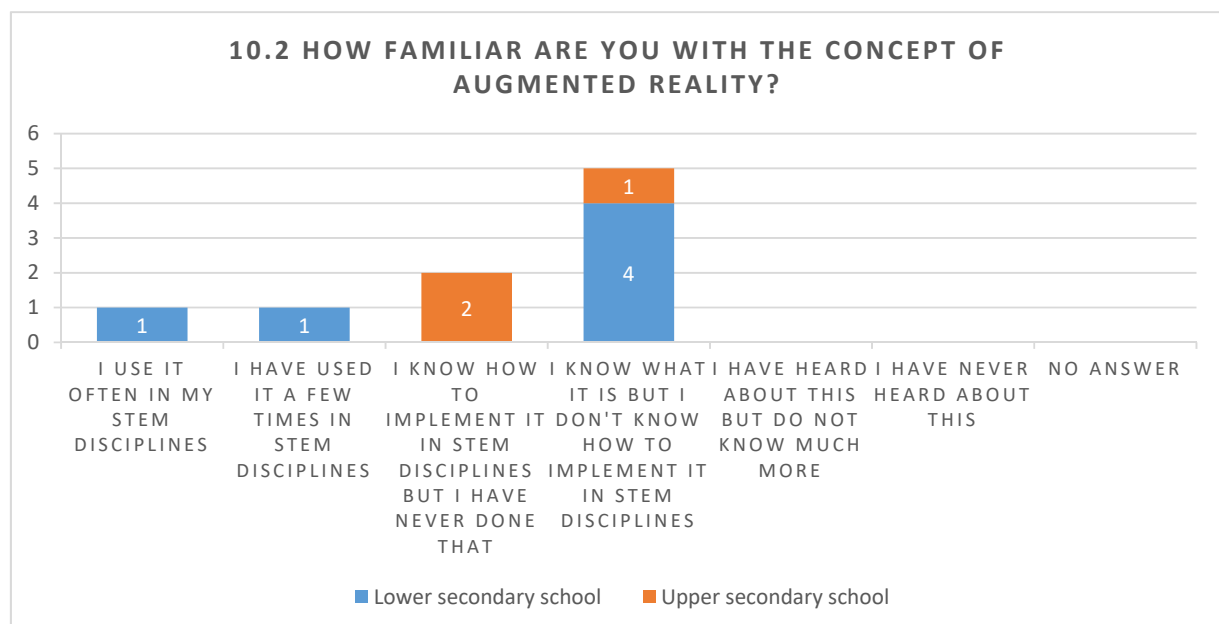
Altogether 1 person responded to the question whose answer was categorised will be given in the table below.

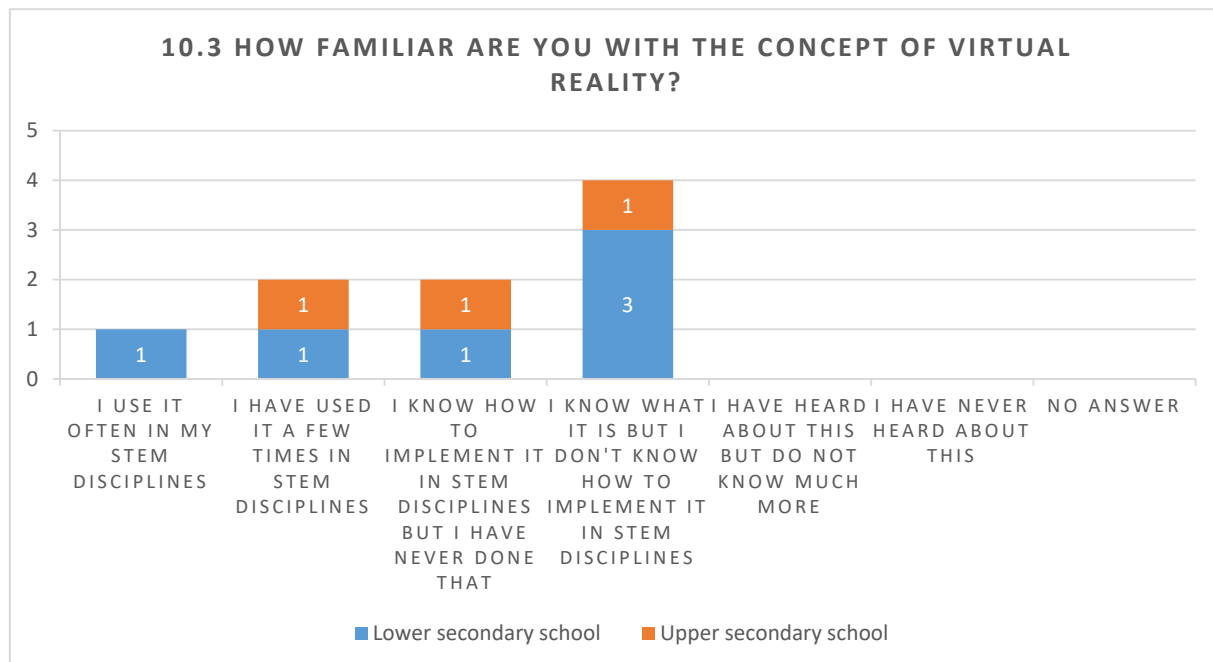
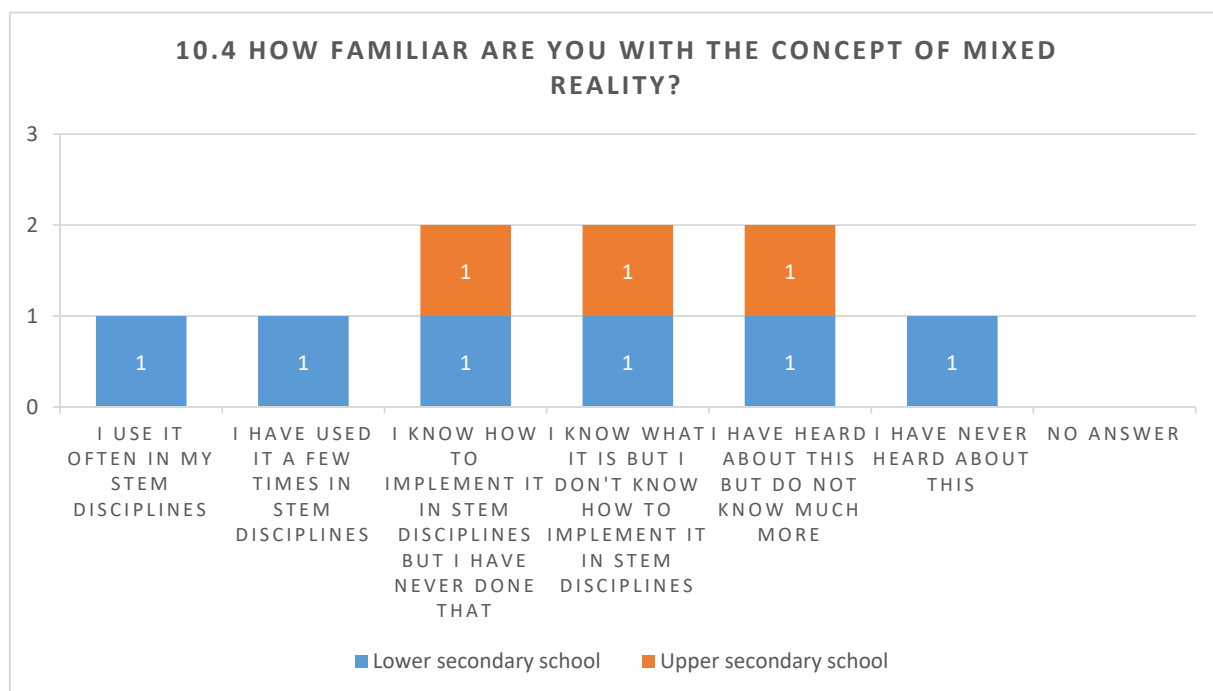
Category	Freq.
Lack in teachers' preparation/knowledge	1

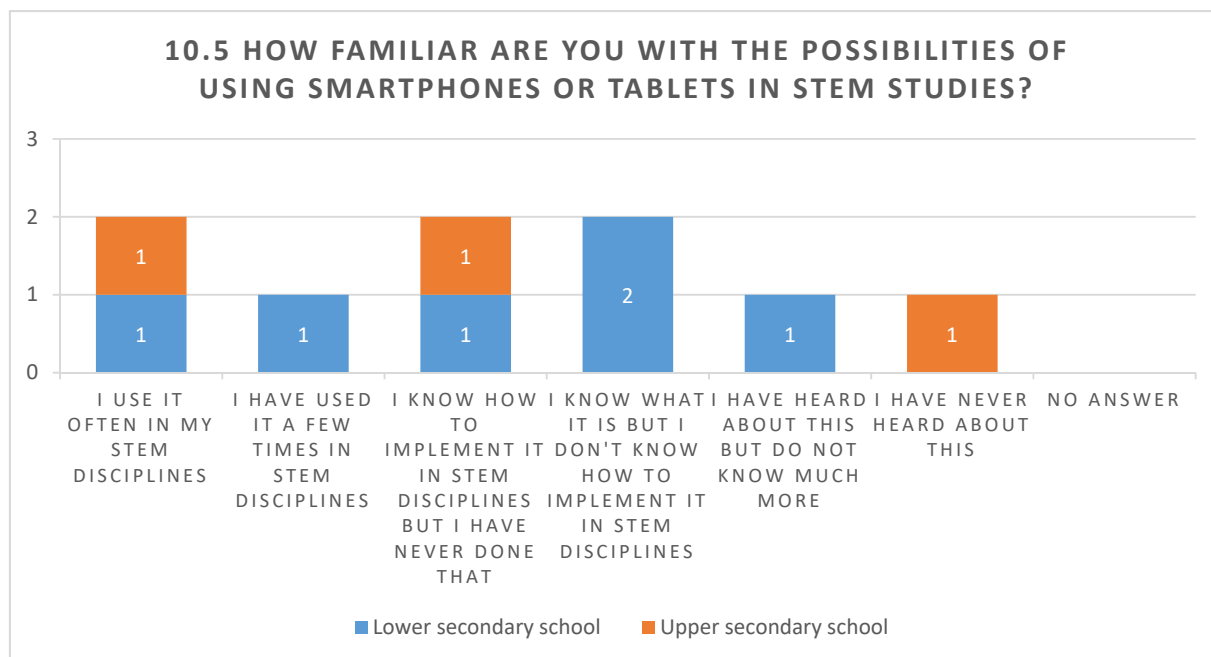
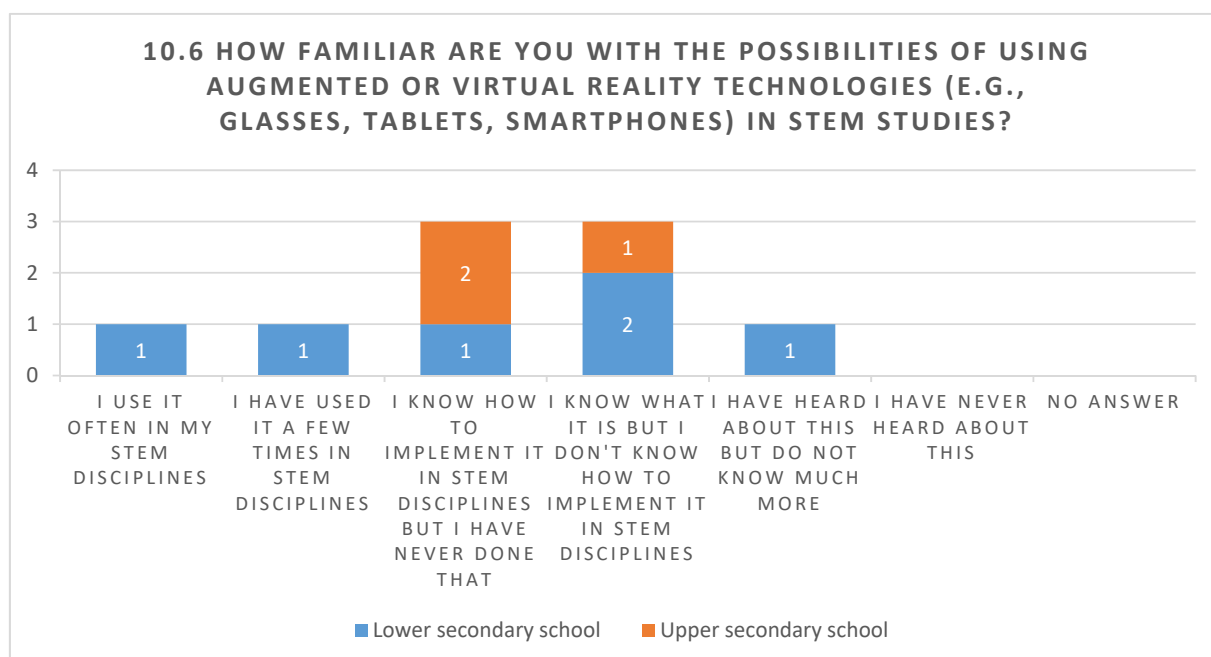
If you know then please describe one success story how innovative emerging technologies have been successfully used in STEM studies. Think on a story that could be useful to learn in other countries as well. Please provide any additional material such as links to the materials about this story (e.g., descriptions, learning materials, guidelines, videos, photos). If you have some useful files to share, then please send these to your national contact mentioned in the beginning and end of the questionnaire.

No responses were received.

10. How familiar are you with the following innovative emerging technologies? Please reply by selecting the level of familiarity with the following statements.





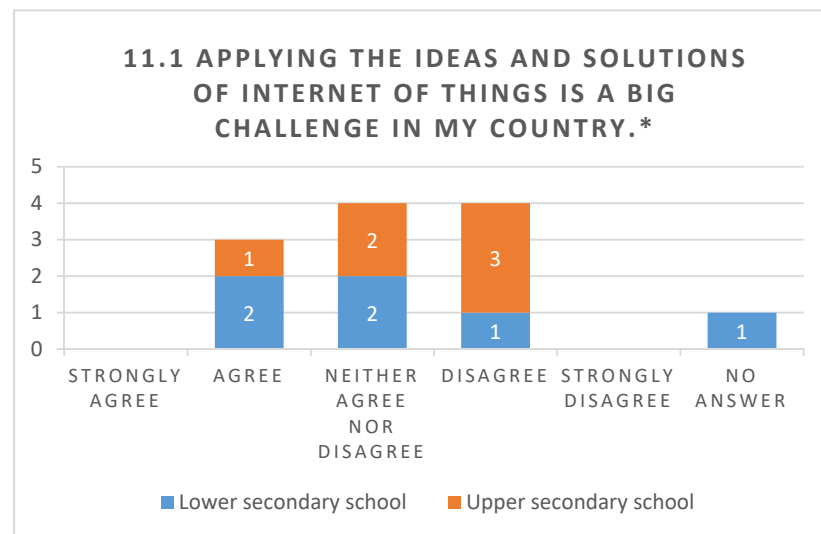
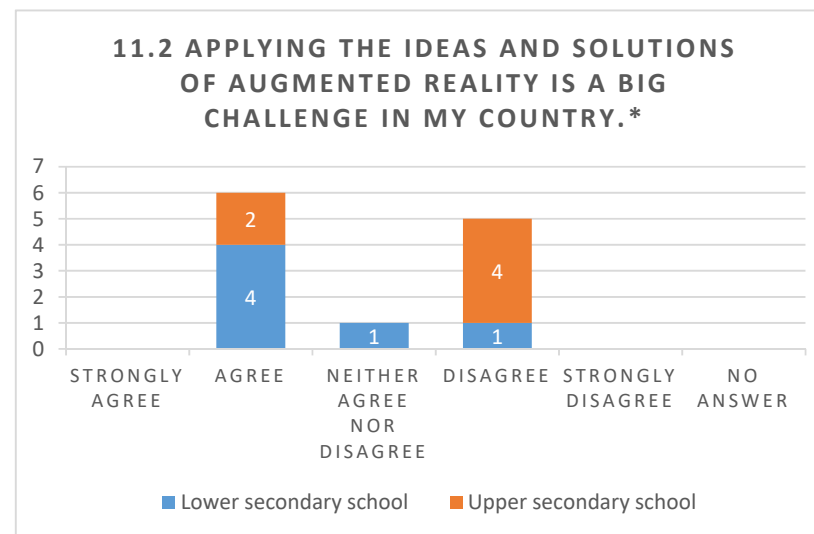
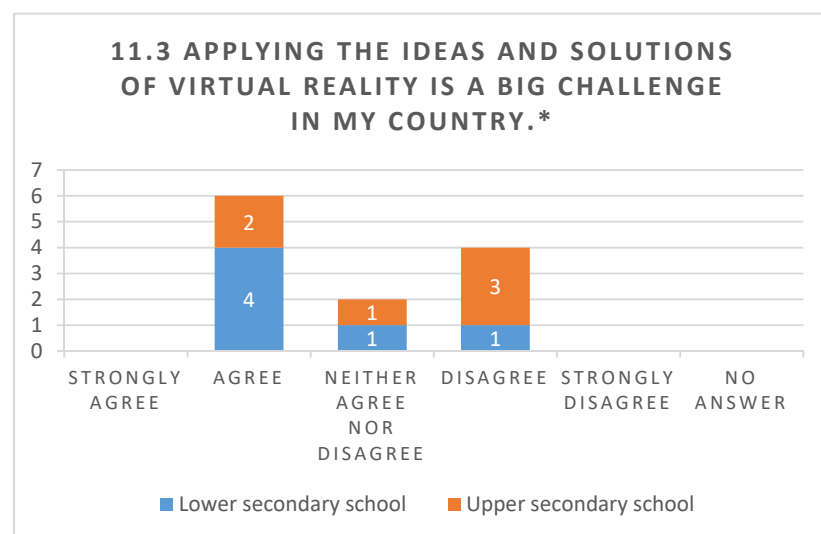
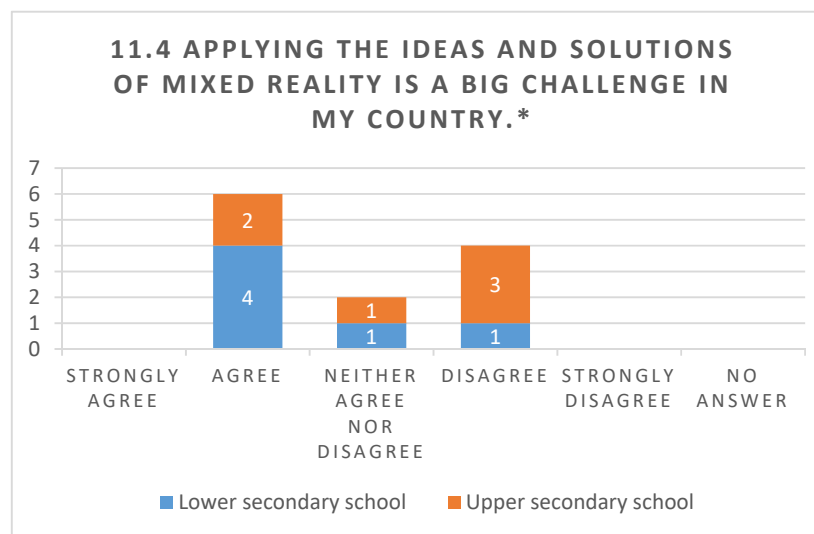


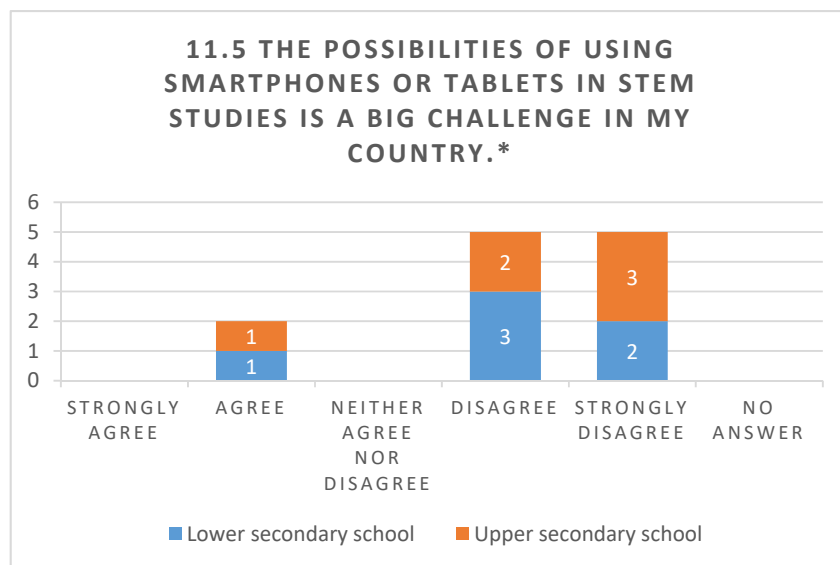
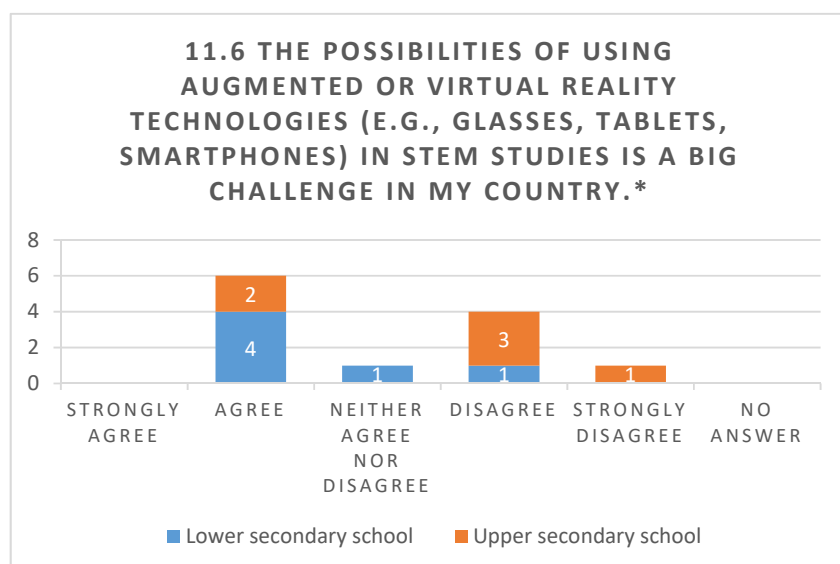
The results indicate that respondents are most familiar with and have most used the **concept of virtual reality** (33% of respondents have used it a few times or are using it often in STEM disciplines, 22% know how to implement it but have never done that), the possibilities of **using smartphones or tablets for STEM studies** (33% of respondents have used it a few times or are using it often in STEM disciplines, 22% know how to implement it but have never done that), and the **possibilities of using augmented or**

virtual reality technologies in STEM studies (22% of respondents have used it a few times or are using it often in STEM disciplines, 33% know how to implement it but have never done that).

Respondents are less familiar with the **concept of mixed reality** (22% of respondents have used it a few times or are using it often in STEM disciplines, 22% know how to implement it but have never done that) the **concept of augmented reality** (22% of respondents have used it a few times or are using it often in STEM disciplines, 22% know how to implement it but have never done that) and the **concept of internet of things** (11% of respondents have used it a few times or are using it often in STEM disciplines, 33% know how to implement it but have never done that).

11. What are the challenges in applying emerging technologies? Please reply by selecting the level of agreement with the following statements.





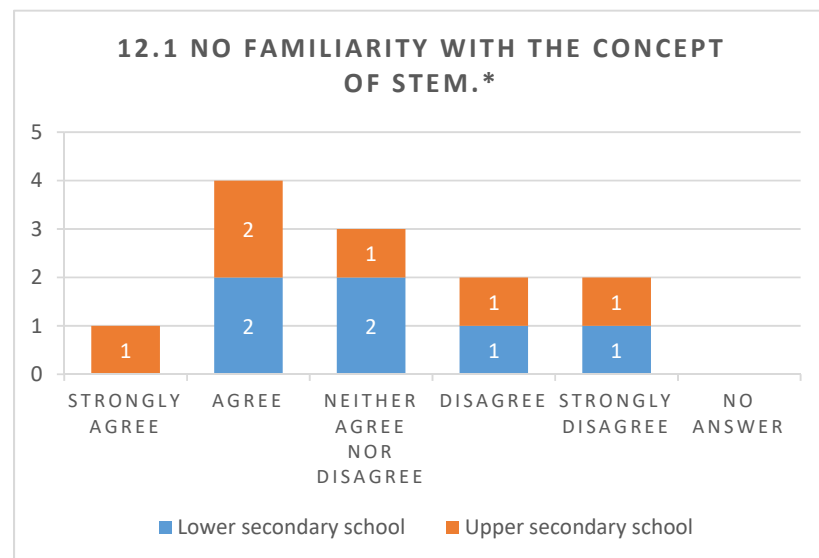
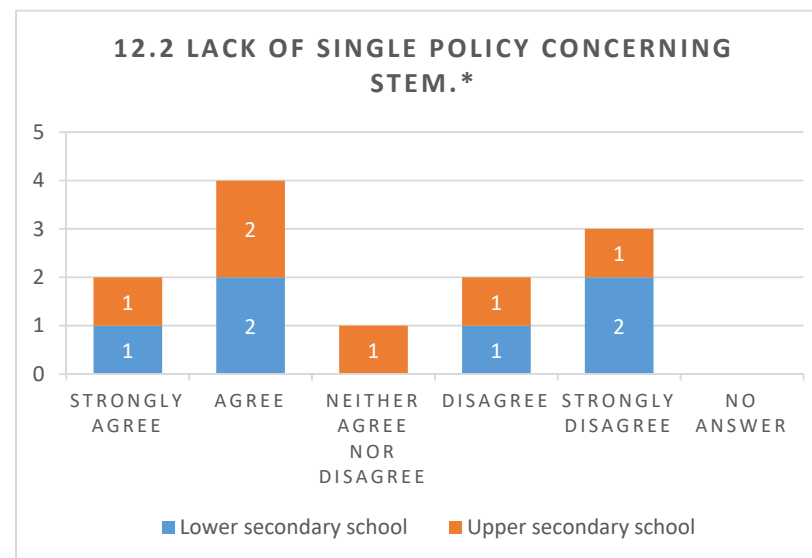
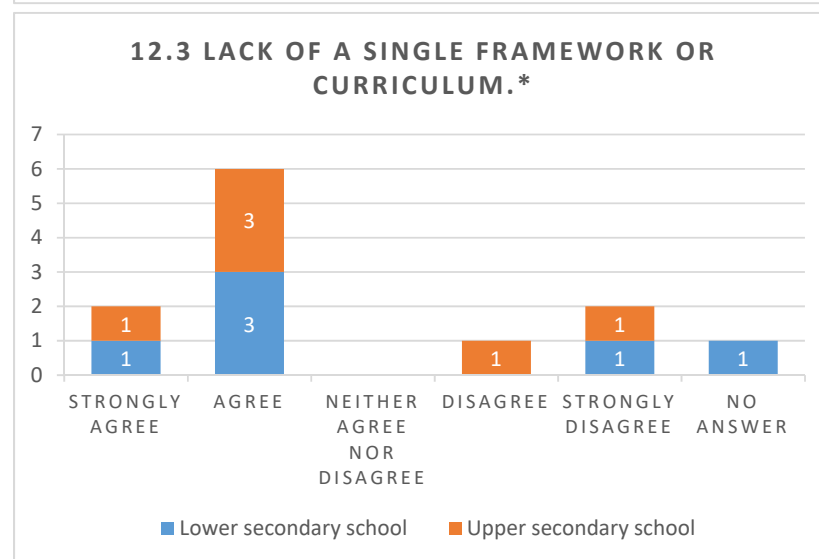
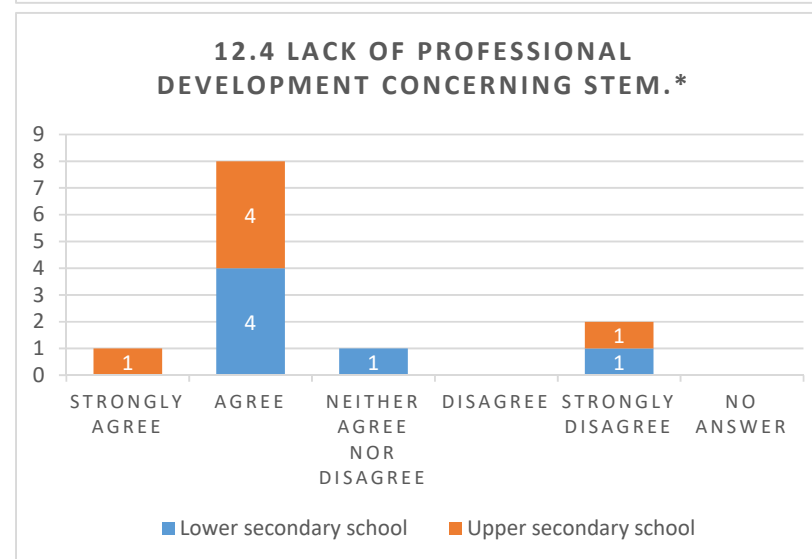
The results reflect contradictory opinions. The most noted challenges in applying emerging technologies were regarded **ideas and solutions of virtual reality** (50% of respondents agreed or strongly agreed while 33% disagreed or strongly disagreed), **mixed reality** (50% of respondents agreed or strongly agreed while 33% disagreed or strongly disagreed).

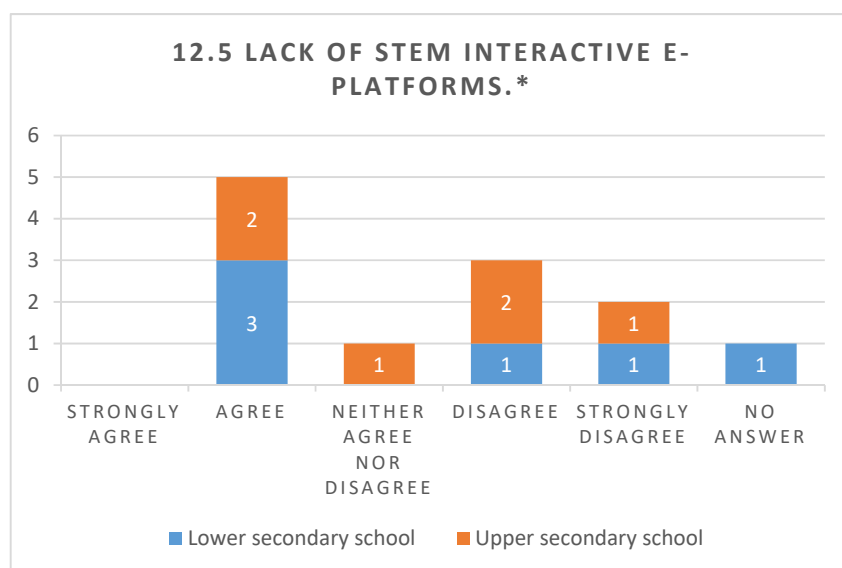
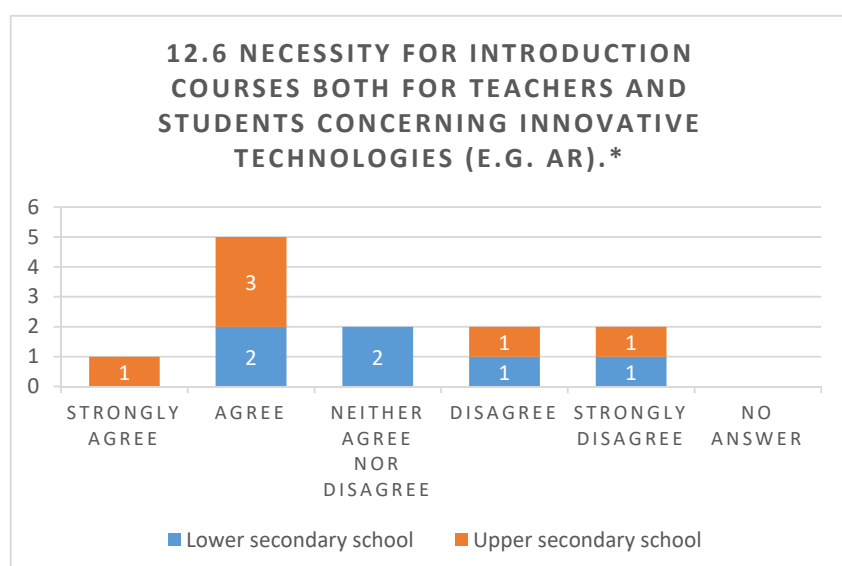
Opinions were divided with applying the ideas and solutions of **augmented reality** (50% of respondents agreed or strongly agreed while 42% disagreed or strongly disagreed) and the **possibilities of using augmented or virtual reality technologies** (50% of respondents agreed or strongly agreed while 42% disagreed or strongly disagreed).

Applying the **ideas and solutions of internet of things** was found to be less a challenge (25% agreed or strongly agreed while 33% disagreed or strongly disagreed), along with **the possibilities of using smartphones** (16% agreed or strongly agreed while 83% disagreed or strongly disagreed).

However, considering previous answers regarding familiarity with these technologies, it must be noted that responses could differ due to respondents' varied level of awareness about these technologies. For instance, as respondents' familiarity to internet of things was mapped low in previous question, in this question many have remained neutral regarding these technologies.

12. What are the main challenges in your country in applying innovative emerging technologies in STEM studies? Please reply by selecting the level of agreement with the following statements.





Two main challenges in applying innovative emerging technologies in STEM studies that were identified in Finland are the **lack of professional development concerning STEM** (75% of respondents agree or strongly agree while 17% disagree or strongly disagree) and the **lack of a single framework or curriculum** (67% of respondents agree or strongly agree while 25% disagree or strongly disagree).

In terms of other challenges in applying innovative emerging technologies in STEM studies, opinions were divided: **lack of familiarity with the STEM concept** (42% of respondents agree or strongly agree while 33% disagree or strongly disagree), the **lack of a single policy concerning STEM** (50% of respondents agree or strongly agree while 42% disagree or strongly disagree), **necessity for introduction courses both for teachers and students concerning innovative technologies** (50% of respondents agree or strongly agree while 33% disagree or strongly disagree) and the **lack of STEM interactive e-platforms** (42% of respondents agree or strongly agree while 42% disagree or strongly disagree).

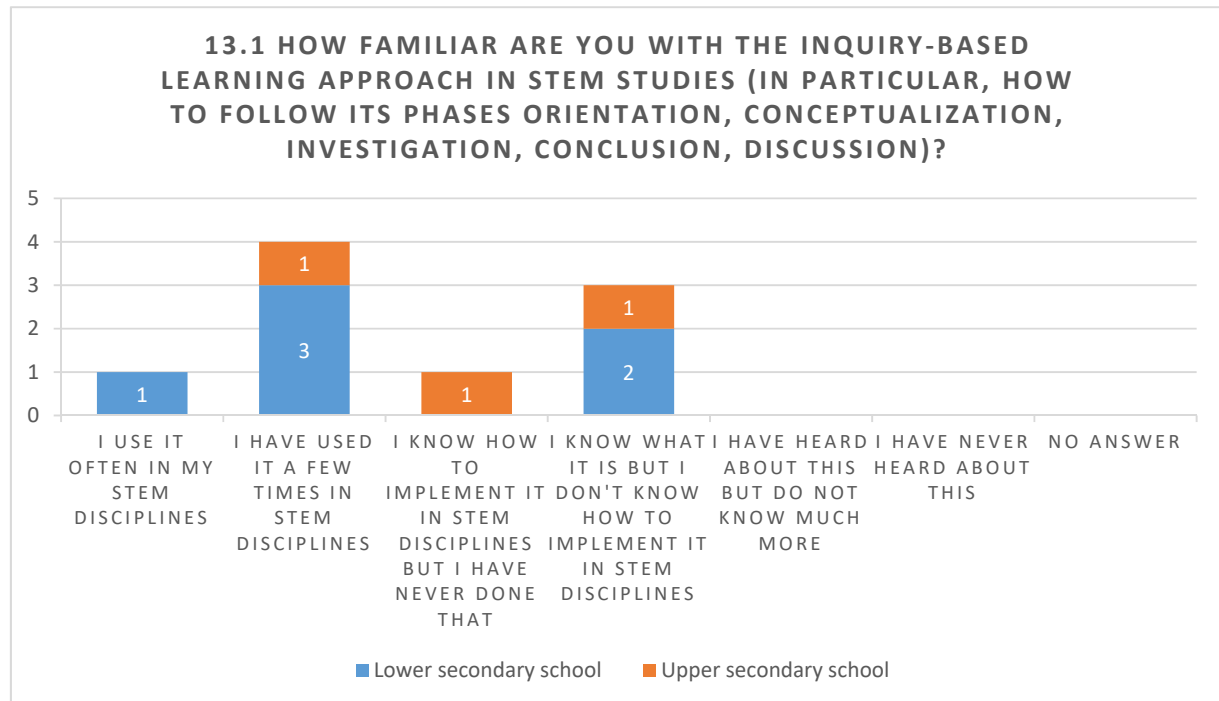
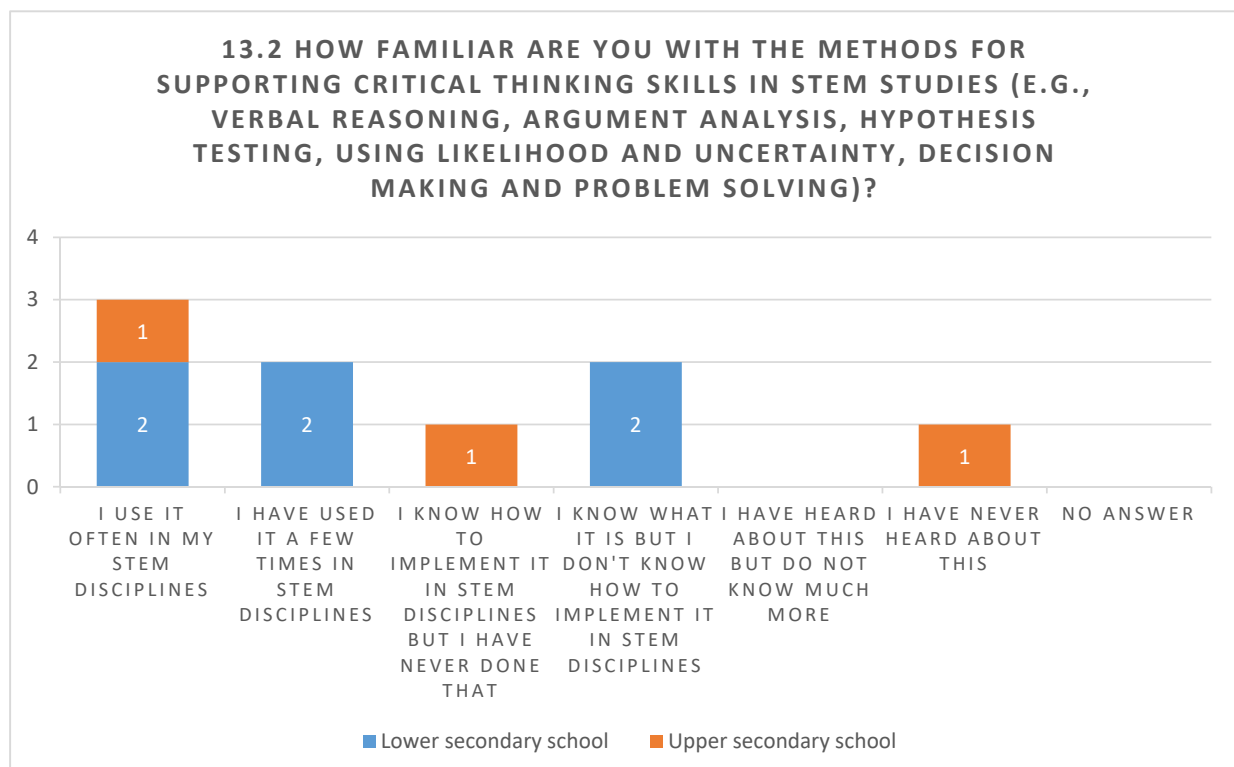
If you would like to describe challenges not listed in the previous question, do so here.

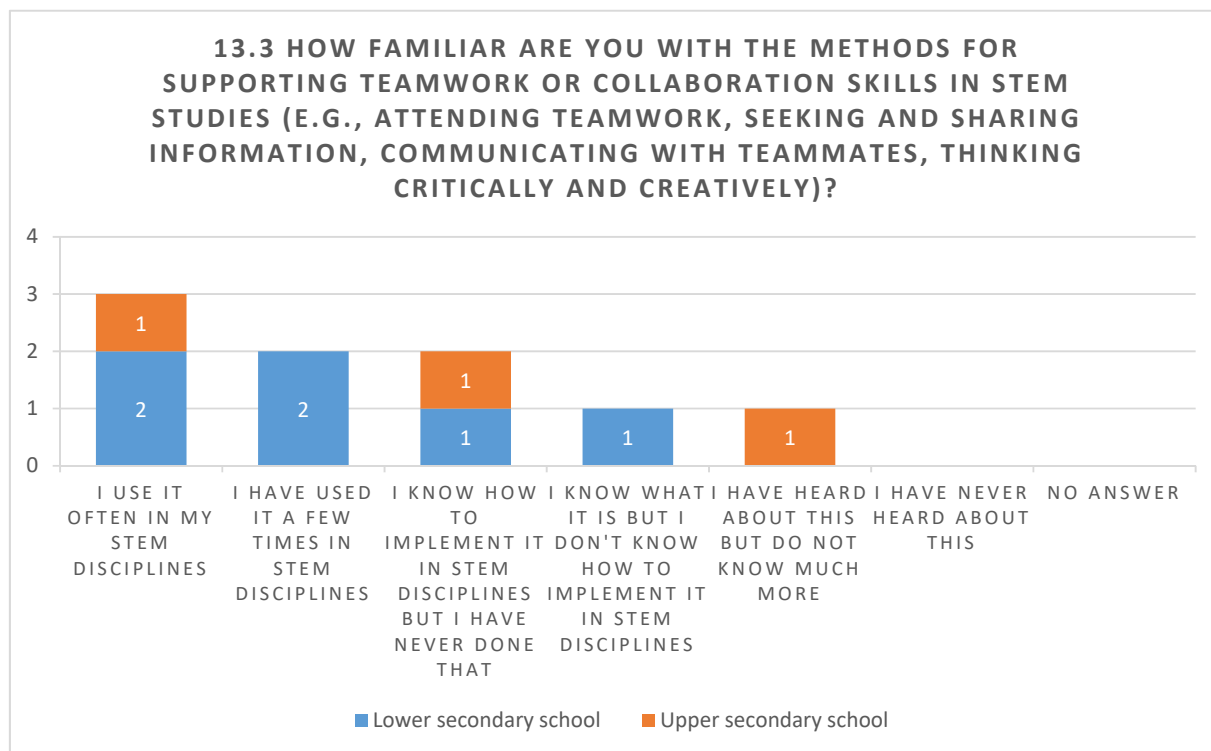
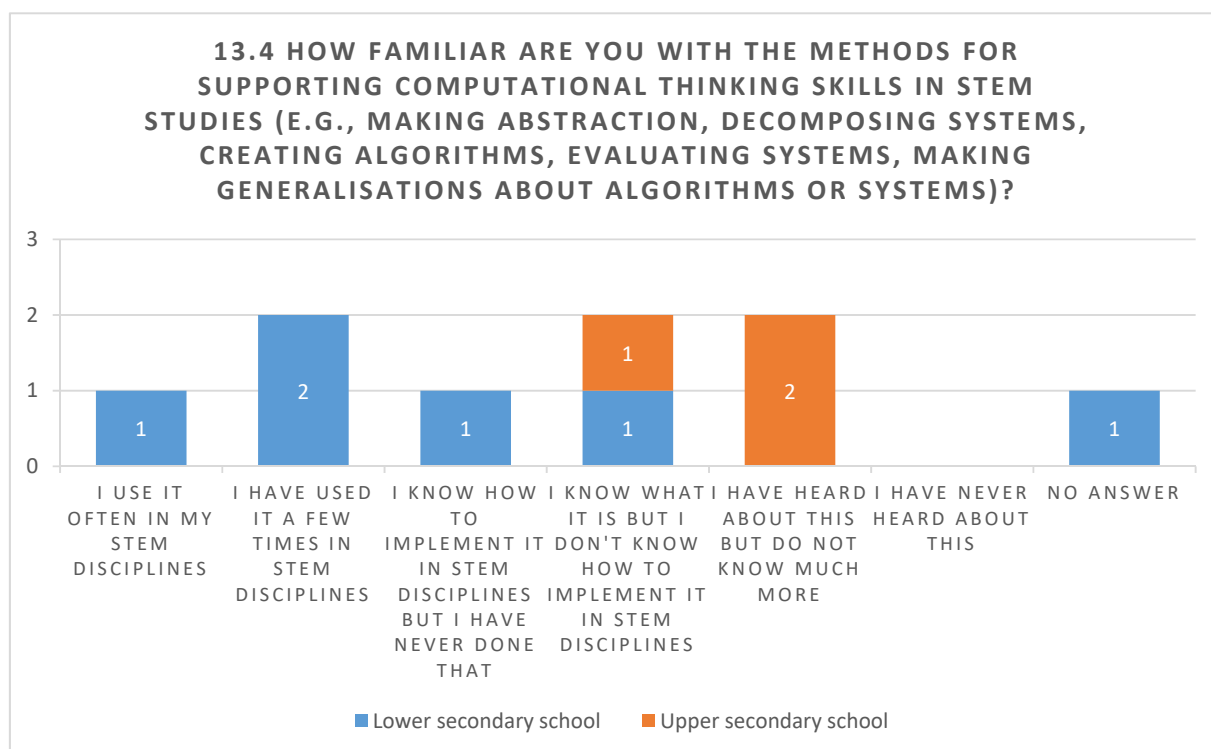
No responses were received.

If you know then please describe one success story how innovative emerging technologies have been successfully used in STEM studies. Think on a story that could be useful to learn in other countries as well. Please provide any additional material such as links to the materials about this story (e.g., descriptions, learning materials, guidelines, videos, photos). If you have some useful files to share then please send these to your national contact mentioned in the beginning and end of the questionnaire.

No responses were received.

13. How familiar are you with innovative pedagogies and contemporary learning approach used in EL-STEM project and what are the challenges in applying them? Please reply by selecting the level of familiarity with the following statements.

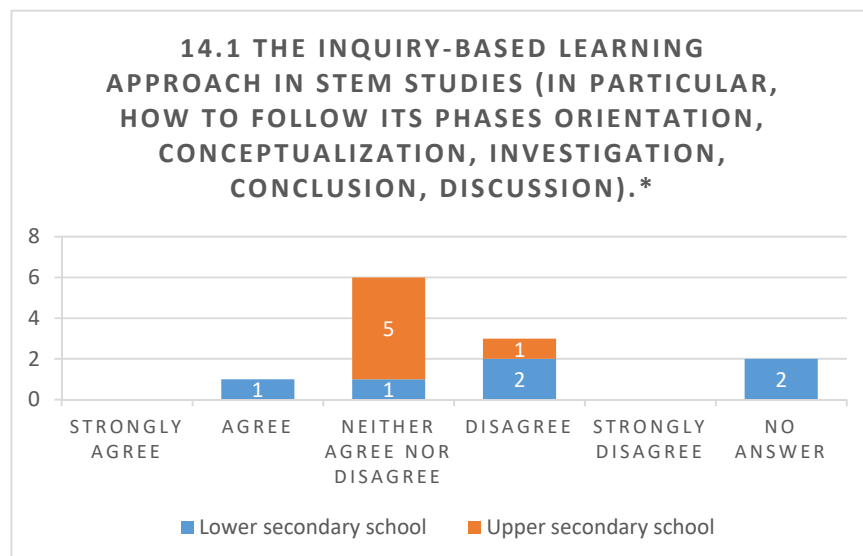
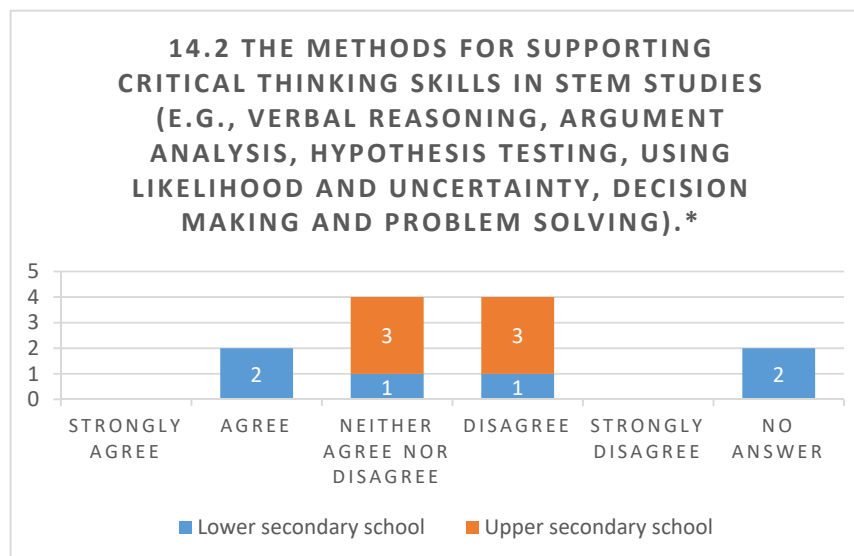
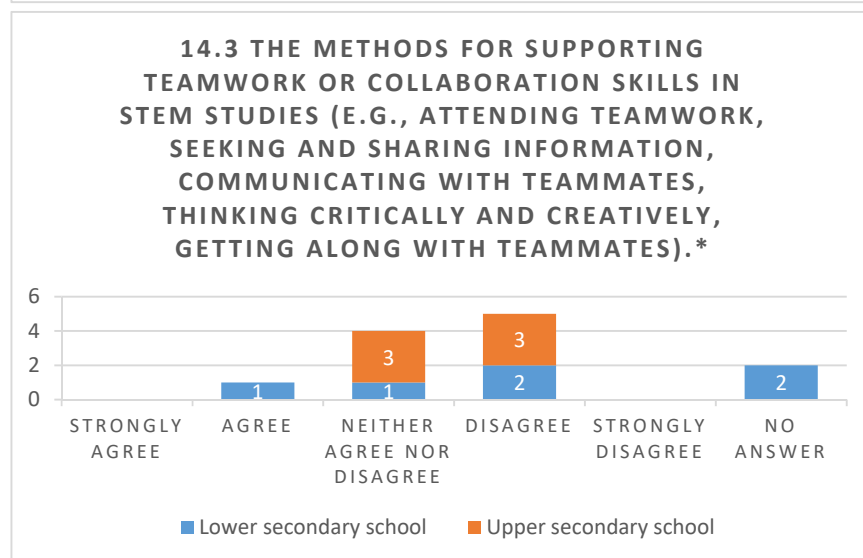
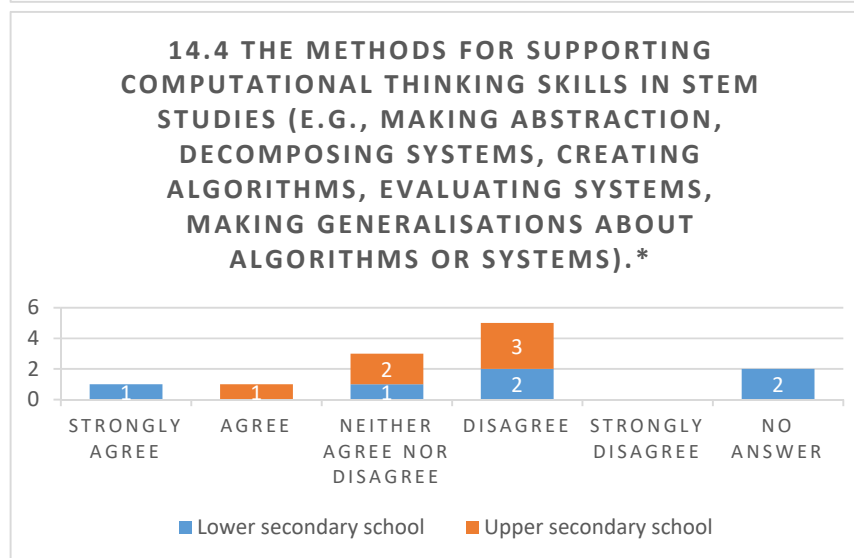


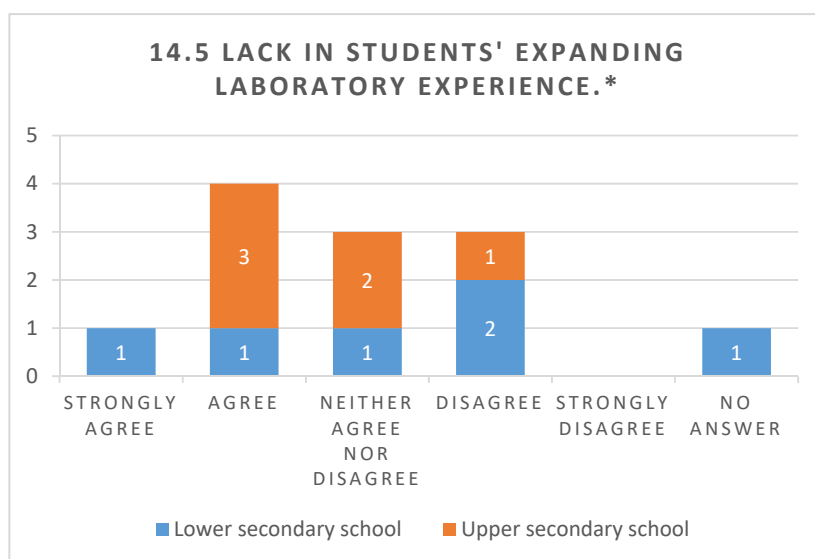


Most familiarity and use was recognized in the **methods for supporting critical thinking skills in STEM studies** (56% of respondents have used it a few times or are using it often in STEM disciplines, 22% know how to implement it but have never done that) and **methods for supporting teamwork or collaboration skills in STEM studies** (56% of respondents have used it a few times or are using it often in STEM disciplines, 22% know how to implement it but have never done that), followed by the **methods of inquiry based learning approach in STEM studies** (56% of respondents have used it a few times or are using it often in STEM disciplines, 11% know how to implement it but have never done that).

Less familiarity and use was reported with the **methods for supporting computational thinking skills in STEM studies** (33% of respondents have used it a few times or are using it often in STEM disciplines, 11% know how to implement it but have never done that).

14. What are the main challenges in your country in applying innovative pedagogies and contemporary learning approach in STEM studies?
Please reply by selecting the level of agreement with the following statements.





Analysing the responses, the most recognized challenge in applying innovative pedagogies and contemporary learning approach in STEM studies in Finland is regarded the **lack in students' expanding laboratory experience** (42% of respondents agree or strongly agree while 25% disagree or strongly disagree).

Aspects which were found less to be a challenge were the **methods for supporting critical thinking skills in STEM studies** (17% agree or strongly agree while 33% disagree or strongly disagree), the **methods for supporting computational thinking skills in STEM studies** (17% agree or strongly agree while 42% disagree or strongly disagree), **inquiry-based learning approach** (8% agree or strongly agree while 25% disagree or strongly disagree) in STEM studies and the **methods for supporting teamwork or collaboration skills** (8% agree strongly agree while 42% disagree or strongly disagree).

If you would like to describe challenges not listed in the previous question, do so here.

No responses were received.

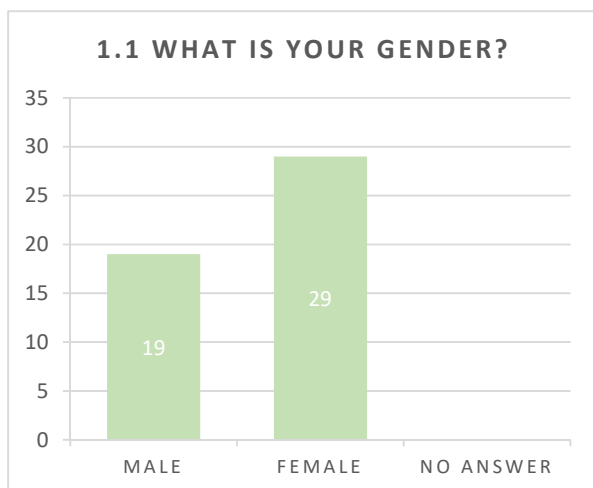
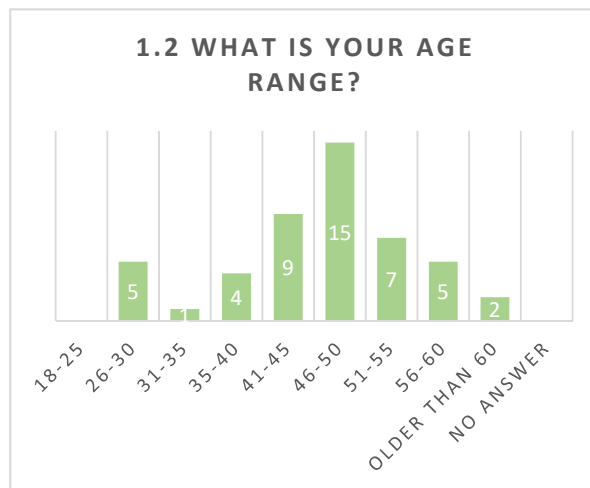
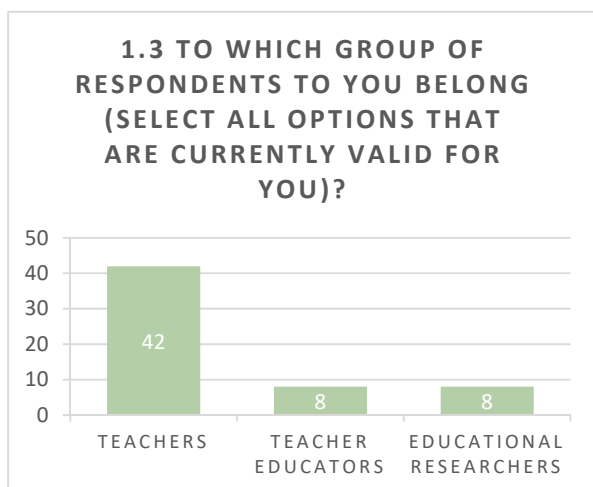
If you know then please describe one success story how innovative pedagogies or contemporary learning approach have been successfully used in STEM studies. Think on a story that could be useful to learn in other countries as well. Please provide any additional material such as links to the materials about this story (e.g., descriptions, learning materials, guidelines, videos, photos). If you have some useful files to share, then please send these to your national contact mentioned in the beginning and end of the questionnaire.

No responses were received.

5.2.4. Greece

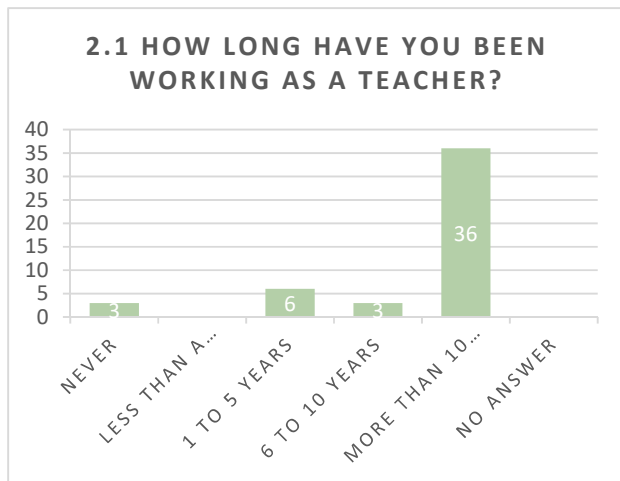
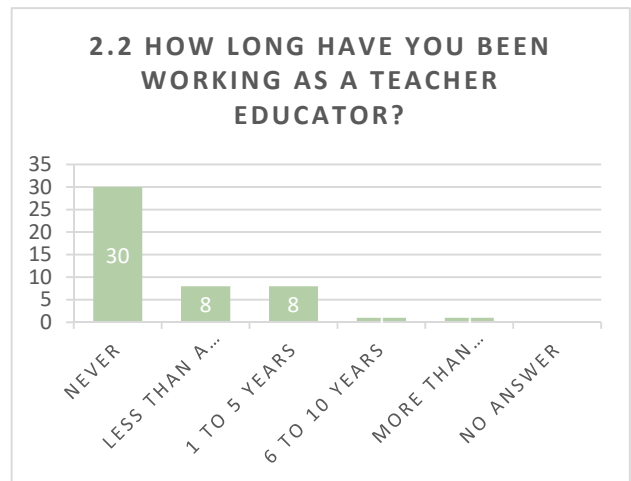
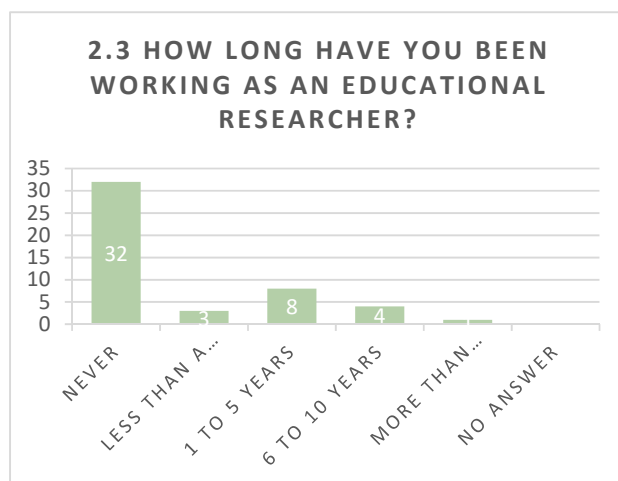
Altogether **48 people** responded to the survey from Estonia. An overview of the respondents' profile and responses will be given in the charts below.

Background information



Majority of 48 respondents in Greece are **over 41 years old**. 31% of respondents are aged between 46-50 while 19% are aged between 41-45 and 15% between 51-55.

2. How long have you been working as a... (select an answer in case of all options)



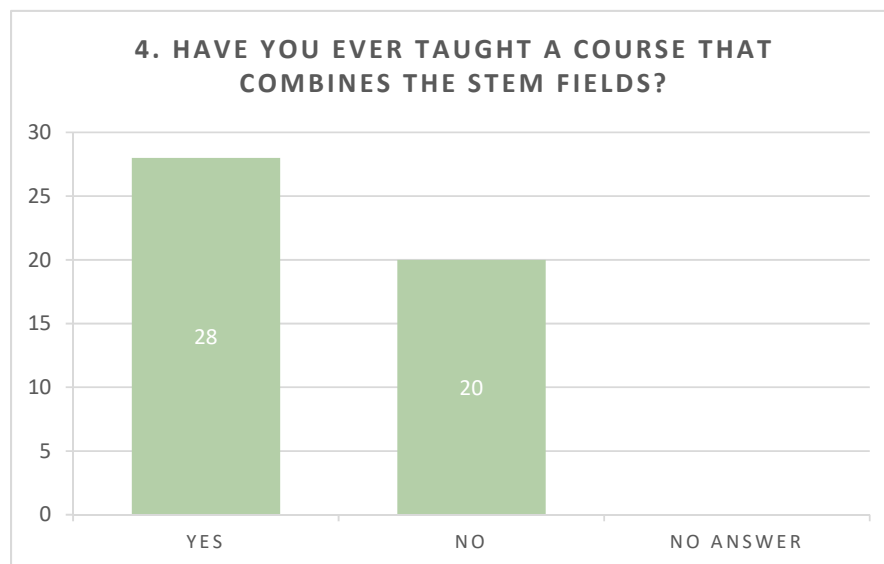
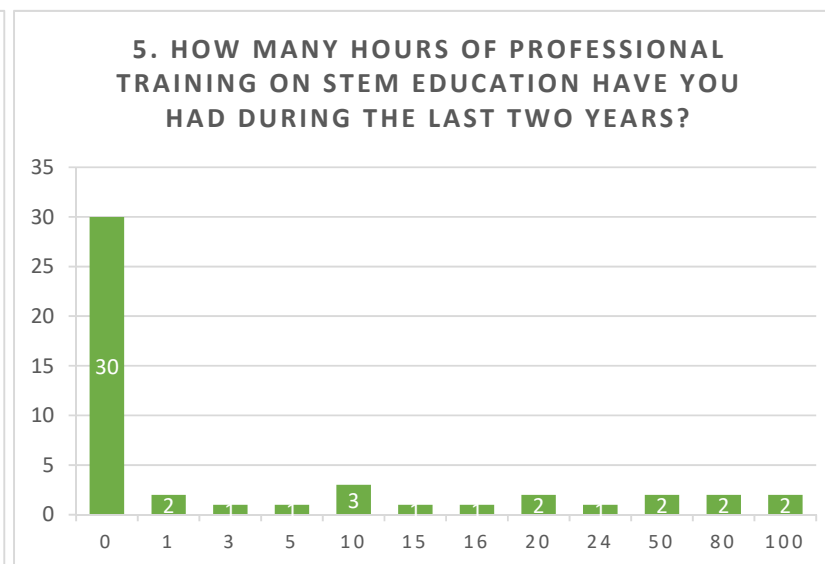
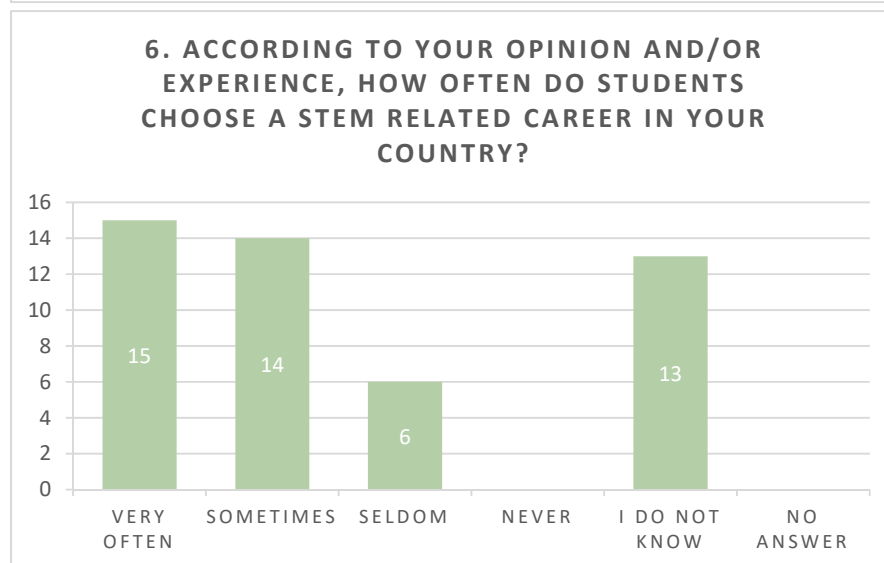
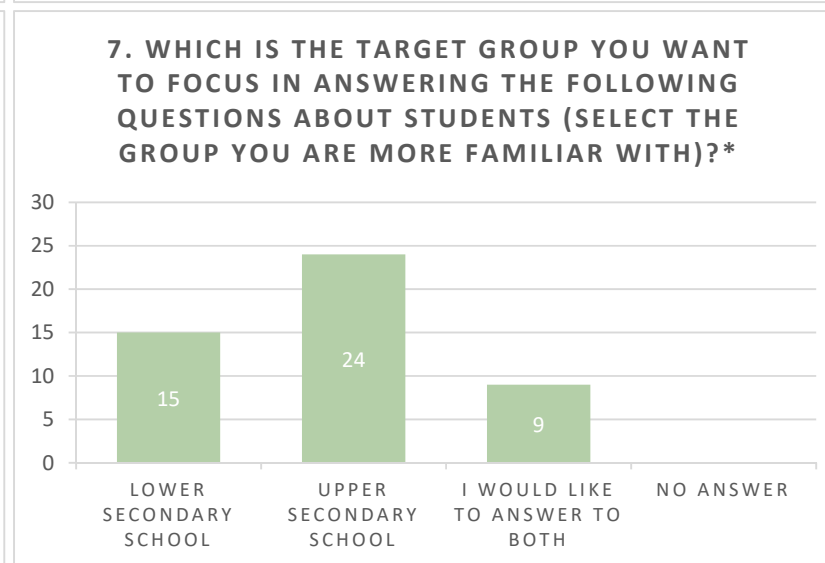
Clear majority of the respondents are working as **teachers** (88%) with over 10 years of experience (80%). Fewer people are working as **teacher educators** (17%) with mostly less than a year or 1 to 5 years of experience (respectively 44%) or **educational researchers** (17%) with mostly 1 to 5 years of experience (50%).

3. How do you understand the concept of STEM (use up to 1000 characters)

Altogether, 47 people responded to the question in Greece. The answers were categorised and an overview of the responses will be given in the table below.

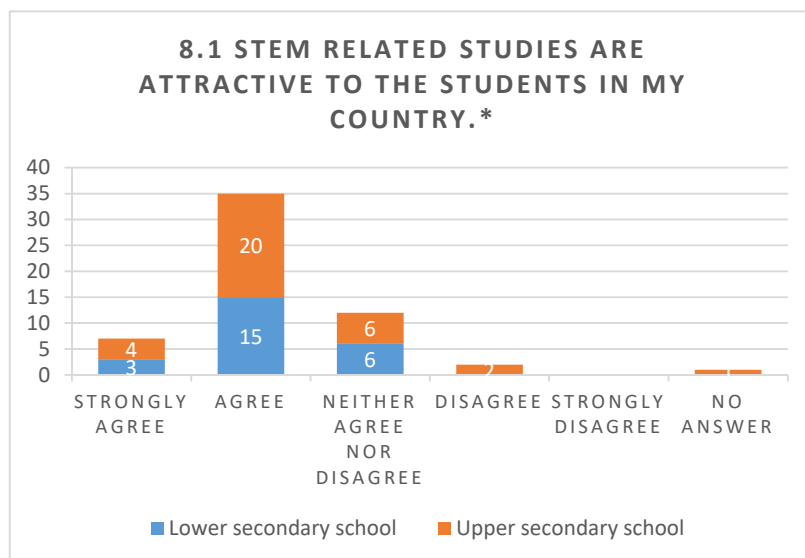
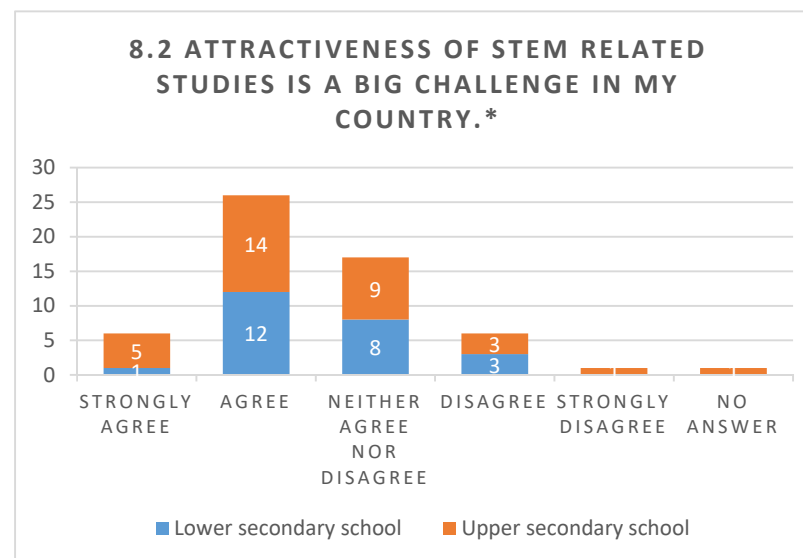
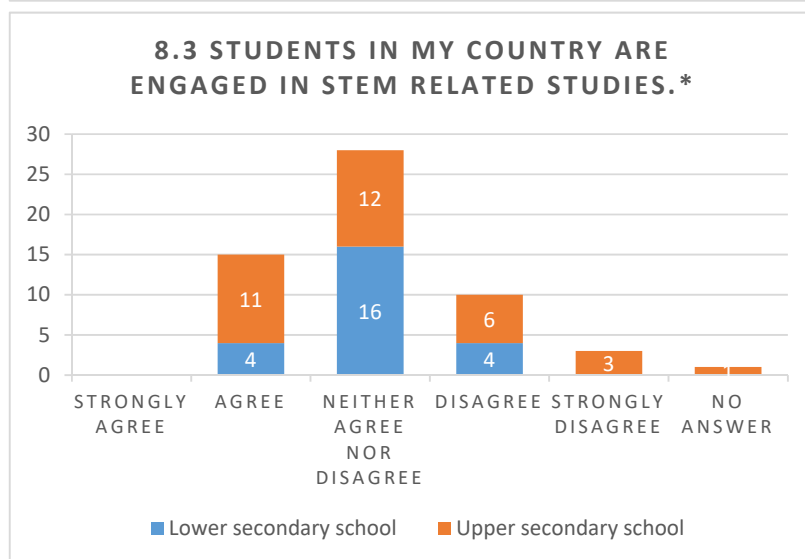
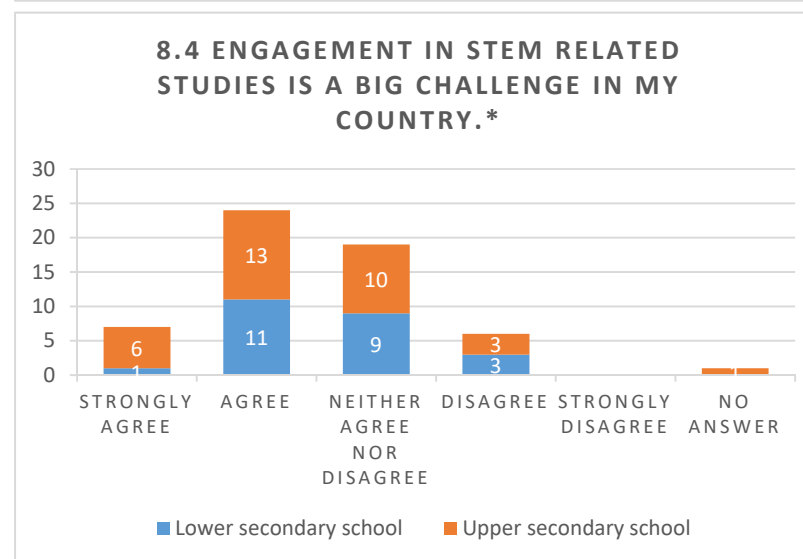
Category	Freq.
Science Technology Engineering Mathematics and the integration of these disciplines with applied approach, in order to foster understanding and connecting theoretical knowledge to practice and to develop computational, critical thinking, teamwork and collaboration skills.	16
Learning through experiments/interdisciplinary approach/holistic approach to learning/connecting theory with real life	14
Science Technology Engineering Mathematics and the integration of these disciplines/use of research based learning method/use of applied approach	9
Science Technology Engineering Mathematics	4
Not explained correctly	2
I do not know	1
Not replied to the question	1

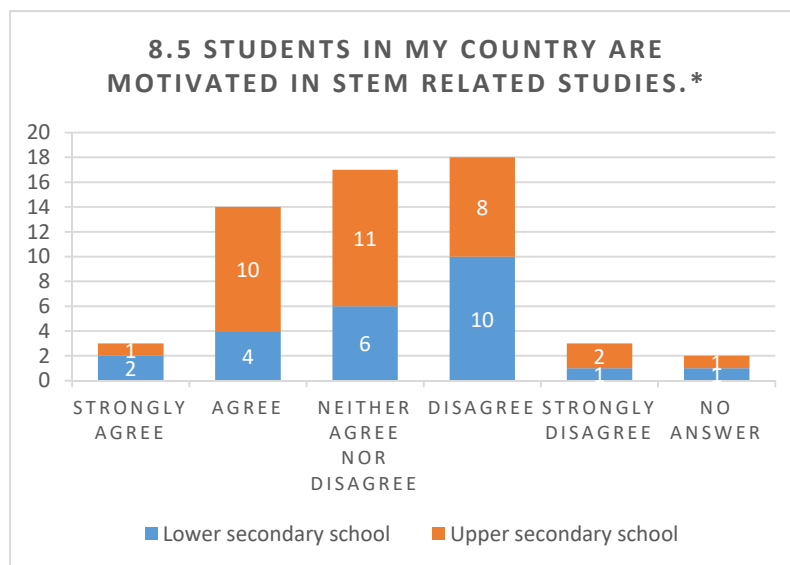
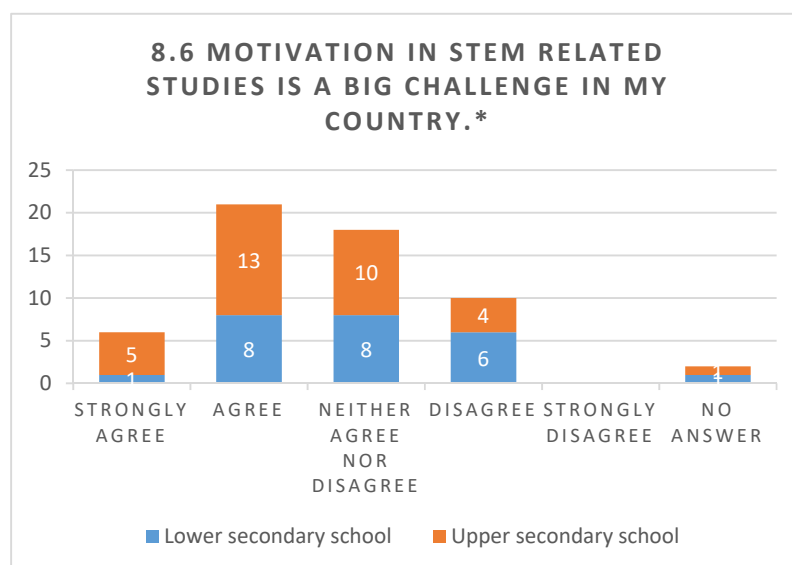
It reflects from the results approximately half of respondents are **clearly acquainted with the STEM concept** while it is more difficult to understand how other respondents have understood the concept (30% of respondents **described one aspect of STEM concept, without explaining the acronym or linking the aspect to specific discipline**, 9% wrote the **names of disciplines which compose the STEM acronym** (i.e. Science, Technology, Engineering, Mathematics). Only few respondents could be identified who undoubtedly were not acquainted with the STEM concept.



*** Note:** There were two types of questions: Firstly, questions which asked about the respondents' familiarity and experience with specific technologies or methods (to which all participants responded only once). Secondly, questions which required answering in the context of lower or upper secondary school. As 9 participants responded the questions twice (from both lower and upper secondary school), 57 responses are counted in total for these questions. These questions will be marked with an asterisk (*)

8. What is the attractiveness of STEM studies and how engaged and motivated the students are in STEM studies in different countries? Please reply by selecting the level of agreement with the following statements.

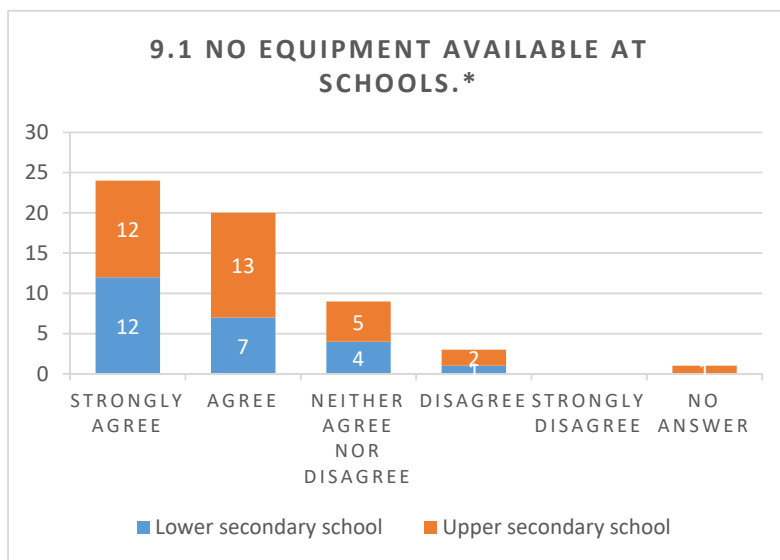
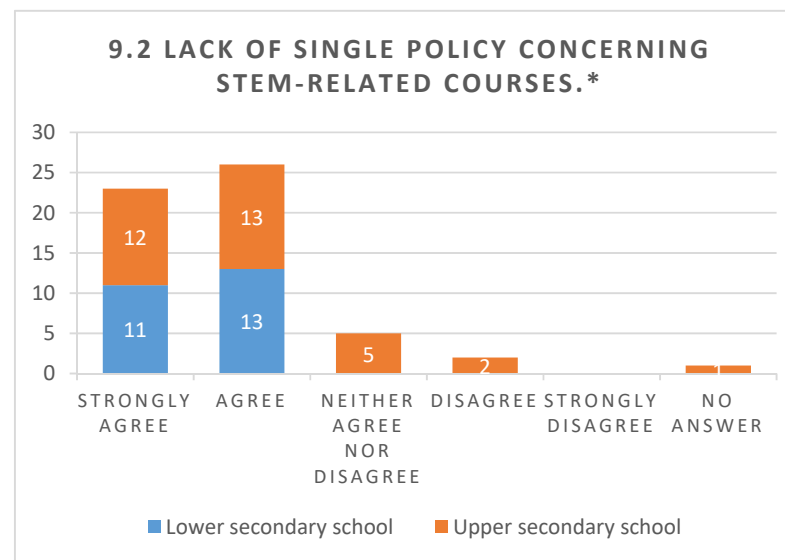
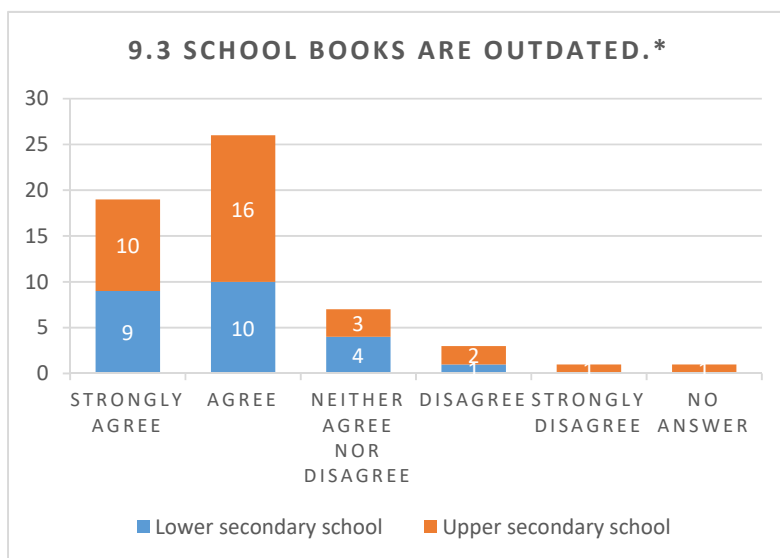
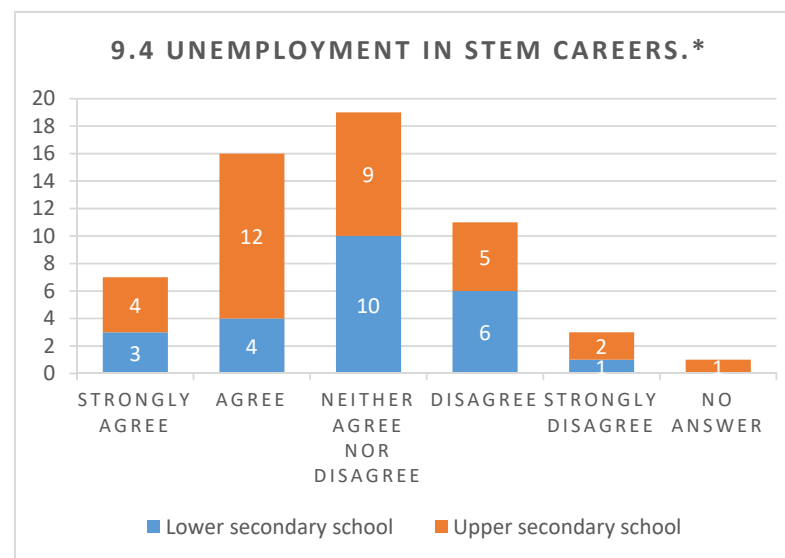


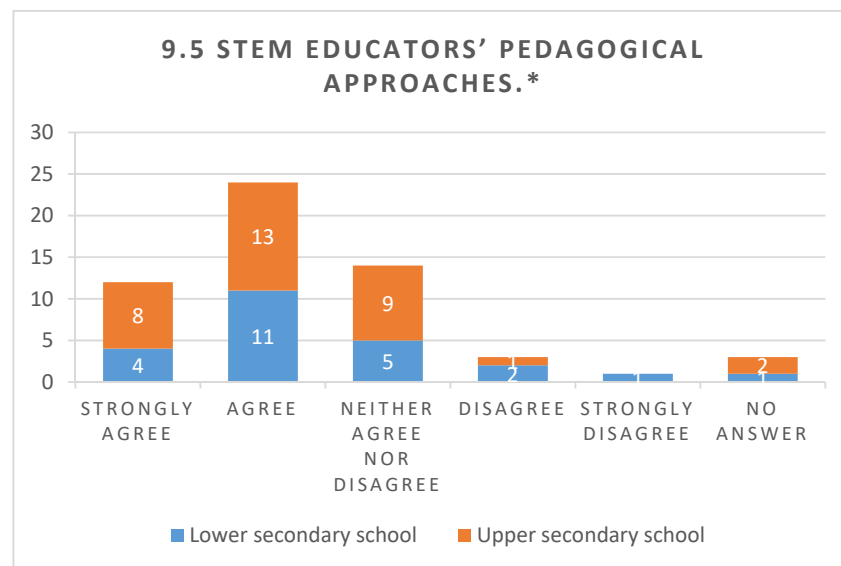
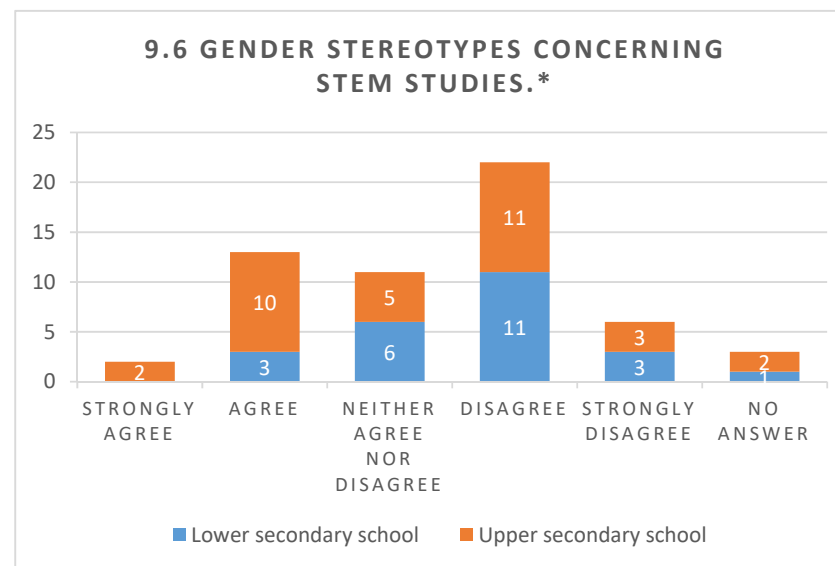
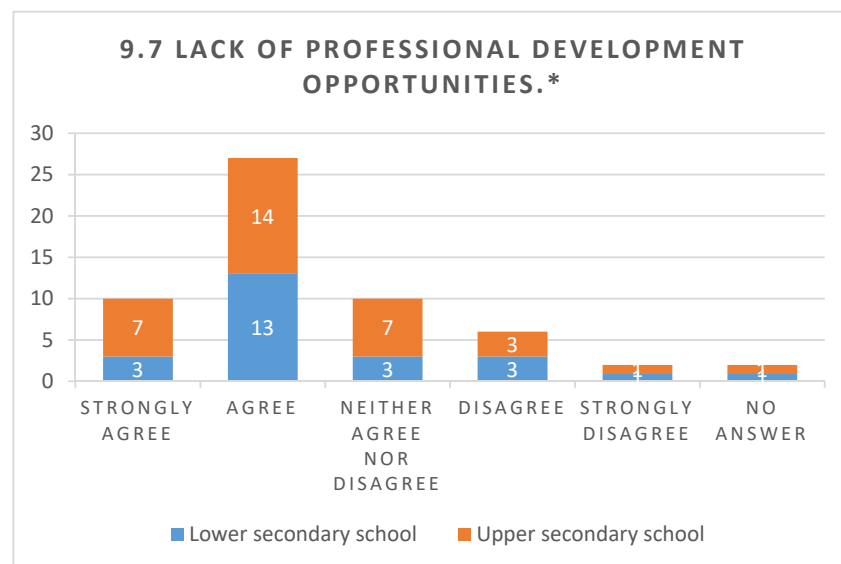
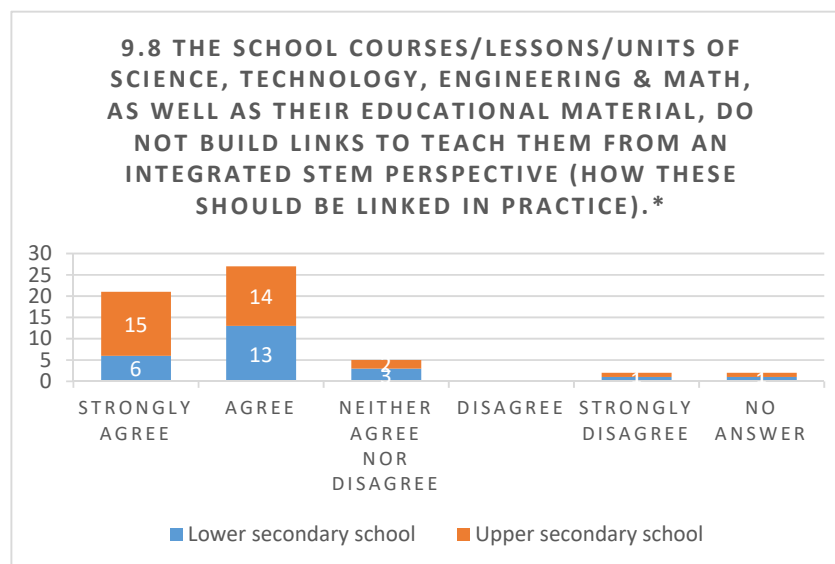


The responses indicate contradictory results: while majority of respondents found that **STEM related studies are attractive in Greece** (74% of respondents agreed or strongly agreed while 4% disagreed or strongly disagreed), over half also found **attractiveness of STEM related studies** to be a challenge (56% of respondents agreed or strongly agreed while 12% disagreed or strongly disagreed).

Slightly clearer patterns could be identified in the following statements: **students are engaged in STEM related studies** (26% of respondents agreed or strongly agreed 23% disagree or strongly disagreed), **engagement is a big challenge** (54% of respondents agreed or strongly agreed 11% disagreed or strongly disagreed); **students are motivated in STEM related studies** (30% of respondents agreed or strongly agreed while 37% disagreed or strongly disagreed), **motivation in STEM related studies is a big challenge** (47% of respondents agreed or strongly agreed while 18% disagreed or strongly disagreed).

9. What are the main challenges in your country in making STEM studies attractive, to engage students more and to increase their motivation towards STEM studies and careers? Please reply by selecting the level of agreement with the following statements.





The results indicate most statements above are considered challenges for increasing students' motivation and engagement towards STEM studies. Most respondents found that there is a **lack of single policy concerning STEM-related courses** (86% of respondents agreed or strongly agreed while 4% disagreed or strongly disagreed) and **school curriculum does not build links between the disciplines** (84% of respondents agreed or strongly agreed while 4% disagreed or strongly disagreed). Another identified challenges are as follows: **school books are outdated** (79% agreed or strongly agreed while 7% disagreed or strongly disagreed), **no equipment available at schools** (77% agreed or strongly agreed while 5% disagreed or strongly disagreed), followed by the lack of **options for professional development** (65% agreed or strongly agreed while 14% disagreed or strongly disagreed) and **STEM educators' pedagogical approaches** (63% agreed or strongly agreed while 7% disagreed or strongly disagreed).

Unemployment in STEM careers (40% agreed or strongly agreed while 25% disagreed or strongly disagreed) is regarded less of a problem in Greece, along with **gender stereotypes concerning STEM studies** (26% agreed or strongly agreed while 49% disagreed or strongly disagreed).

If you would like to describe challenges not listed in the previous question, do so here.

Altogether 1 person responded to the question whose answers were categorized and will be given in the table below.

Category	Freq.
Constraints derived from the curriculum (not enough time for additional activities, curricula outdated etc.)	1
Lack in teachers' preparation/knowledge	1
Lack of finances	1

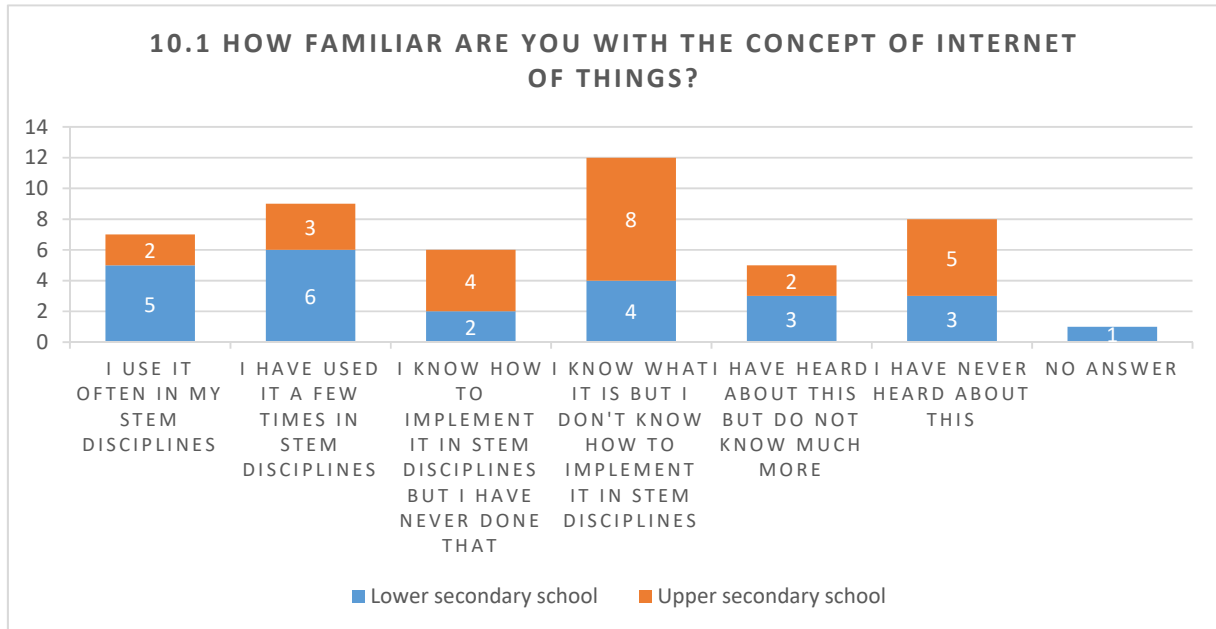
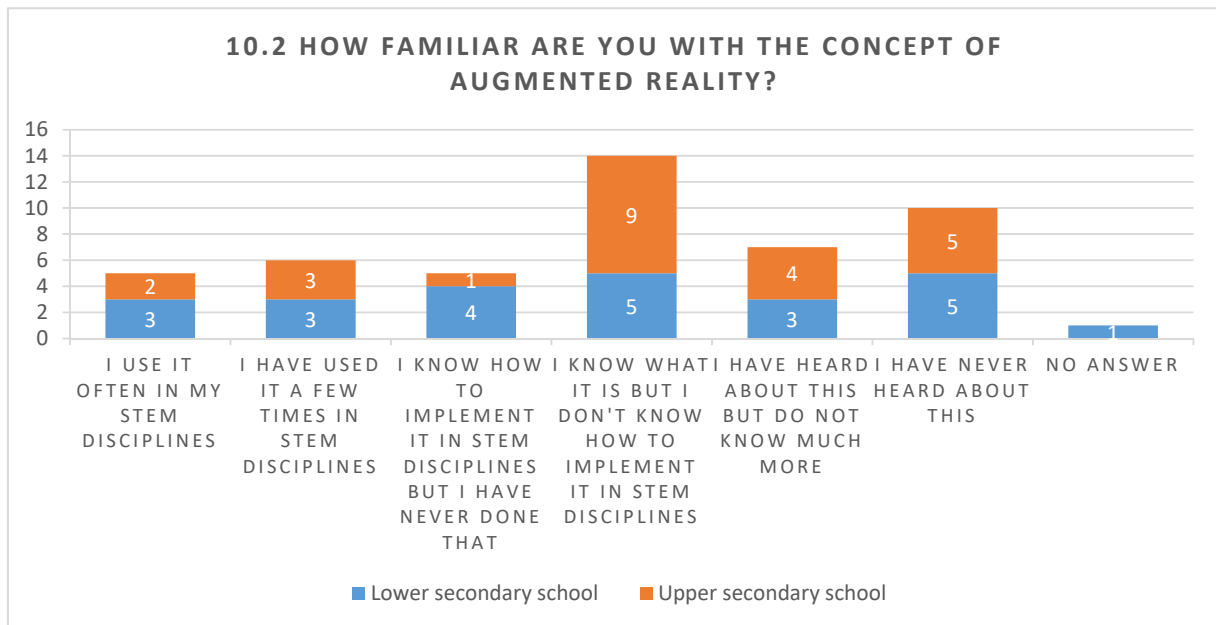
If you know then please describe one success story how STEM studies have been made attractive, and students are engaged and motivated. Think on a story that could be useful to learn in other countries as well. Please provide any additional material such as links to the materials about this story (e.g., descriptions, learning materials, guidelines, videos, photos). If you have some useful files to share, then please send these to your national contact mentioned in the beginning and end of the questionnaire.

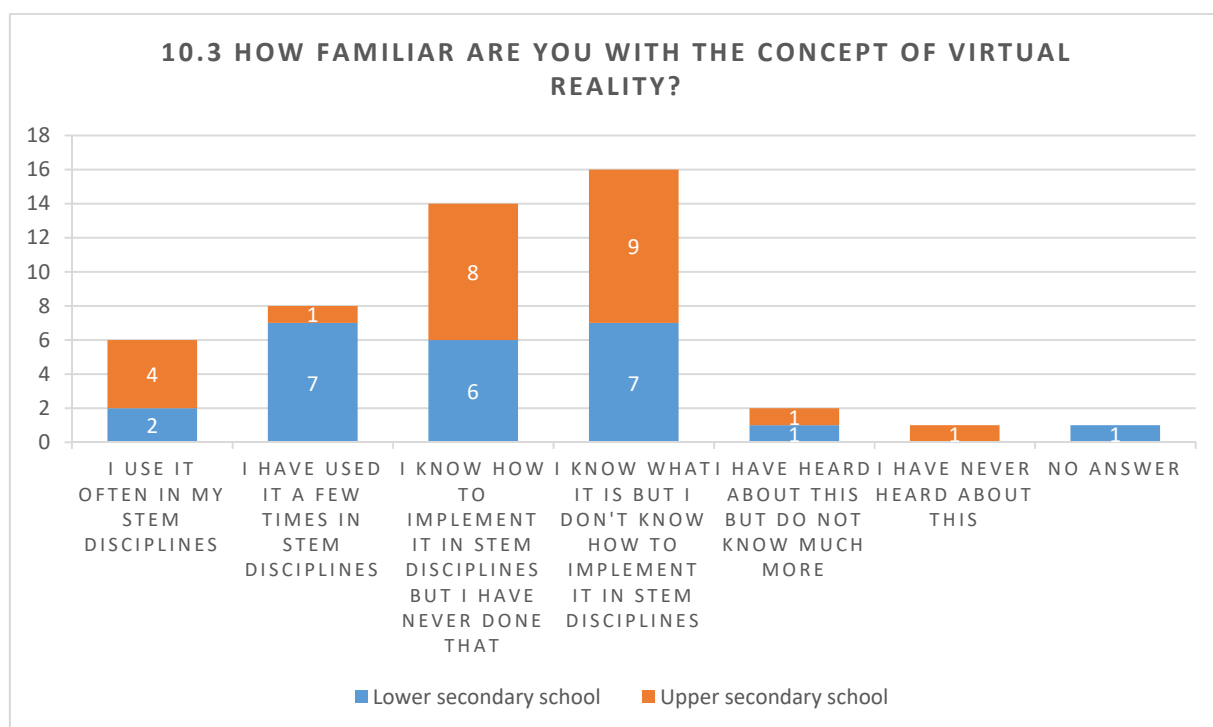
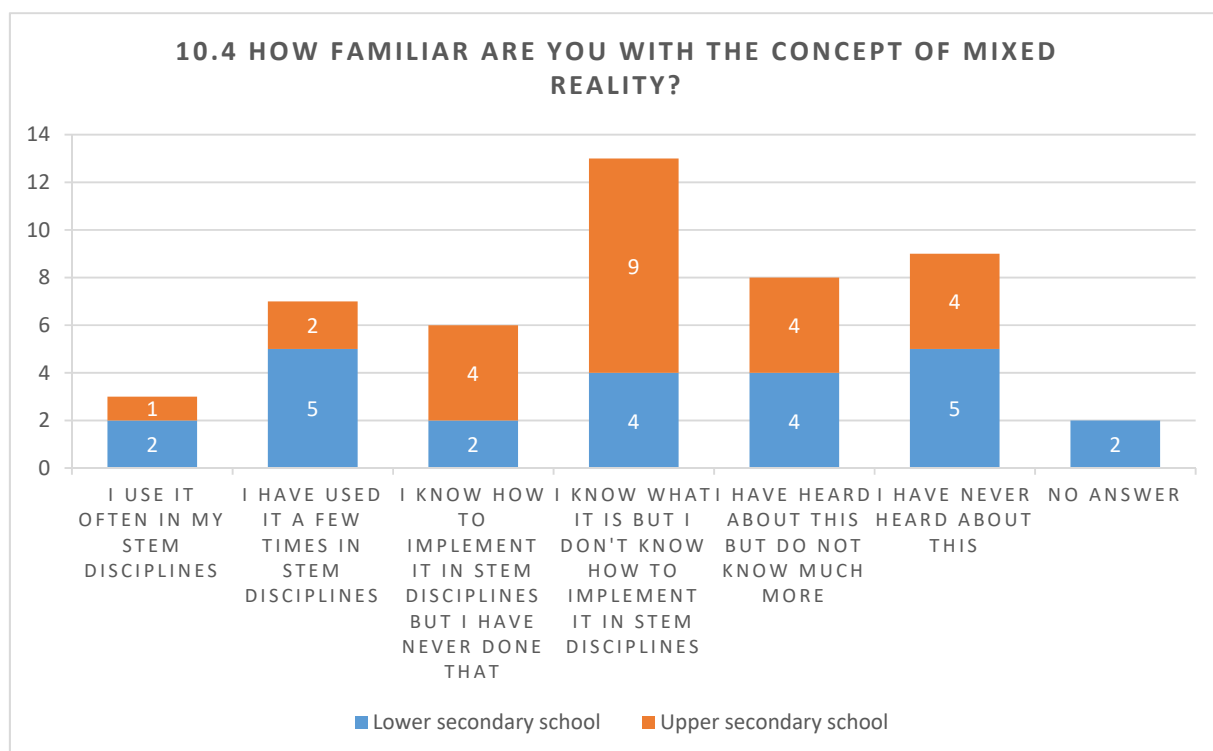
Altogether 4 people responded to the question, whose answers will be given below.

- Robotics in schools: a lot of good practices in various schools in Greece but in most cases based on the innovation and voluntarily of the teachers
<https://www.rodiki.gr/article/360430/diagwnismos-rompotikhs-pragmatopoihthhke-sth-rodiki>
- The Astronomy Lesson could be done in the classroom using new technologies and simulation programs.
- Visits to the Observatory for observations in conjunction with research. Finally, build improvised small satellites and telescopes.
- Learning Science through Theatre: <https://www.youtube.com/watch?v=iimO6Qs5qlc>

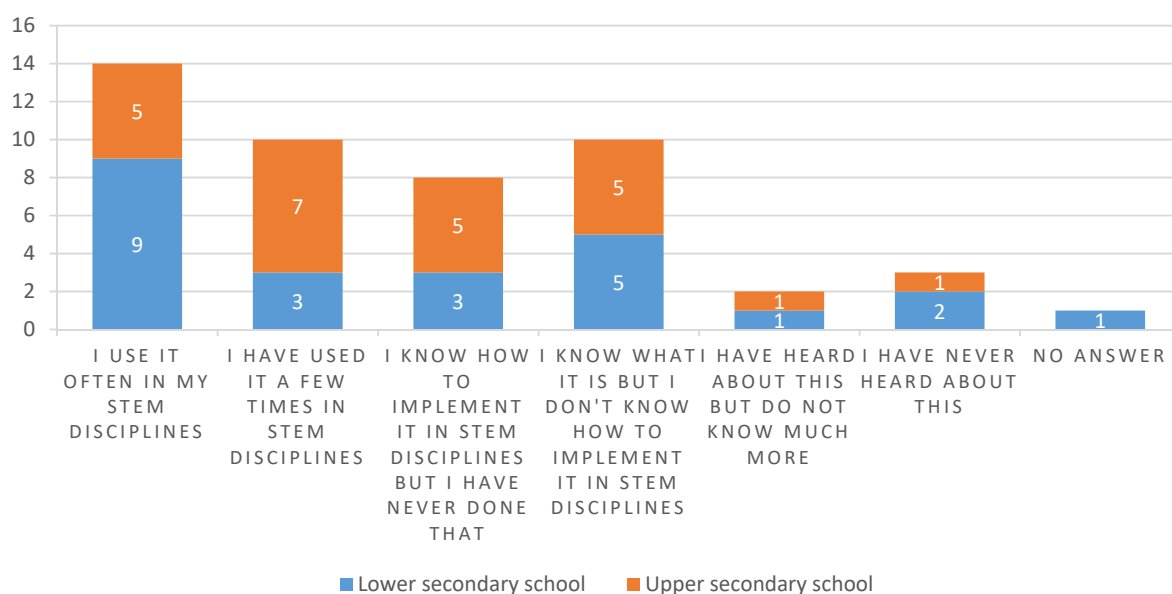
- The activities are developed in collaboration with industries or external stakeholders such as professional career center. The activities planned give opportunity to students to discuss directly with STEM professionals.
- When students attend experiment in School Lab and then are encouraged to repeat it or present it to a school fair.
- Robotics classes are offered last 3 years in Saturdays and students are excited.

10. How familiar are you with the following innovative emerging technologies? Please reply by selecting the level of familiarity with the following statements.

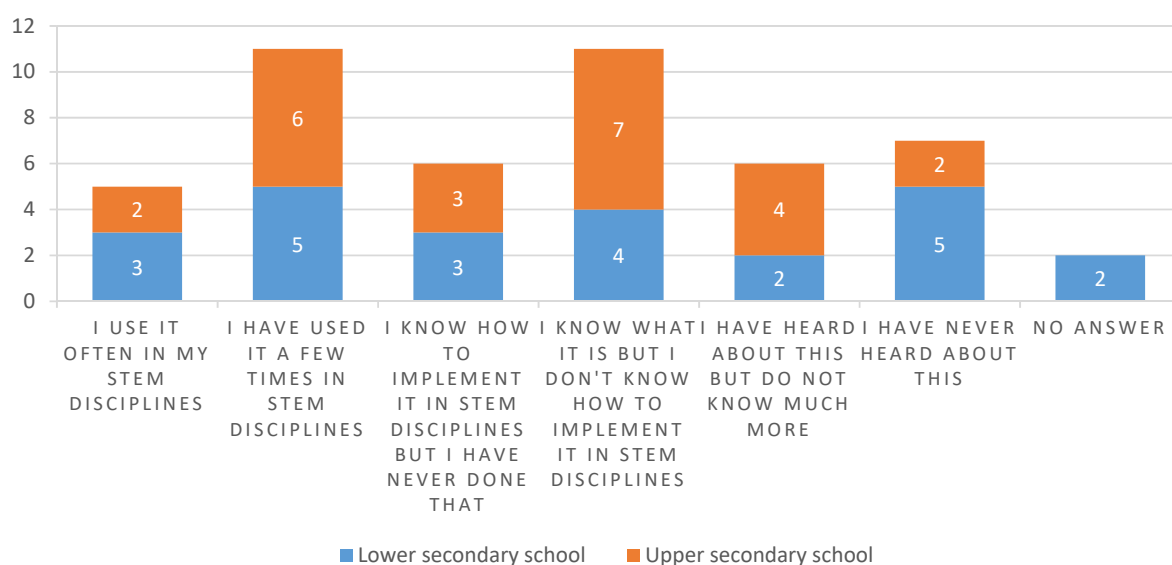




10.5 HOW FAMILIAR ARE YOU WITH THE POSSIBILITIES OF USING SMARTPHONES OR TABLETS IN STEM STUDIES?



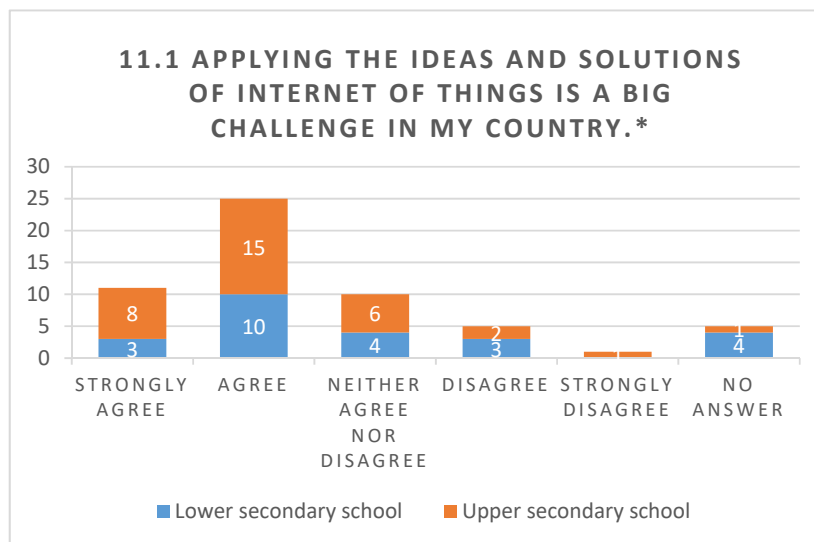
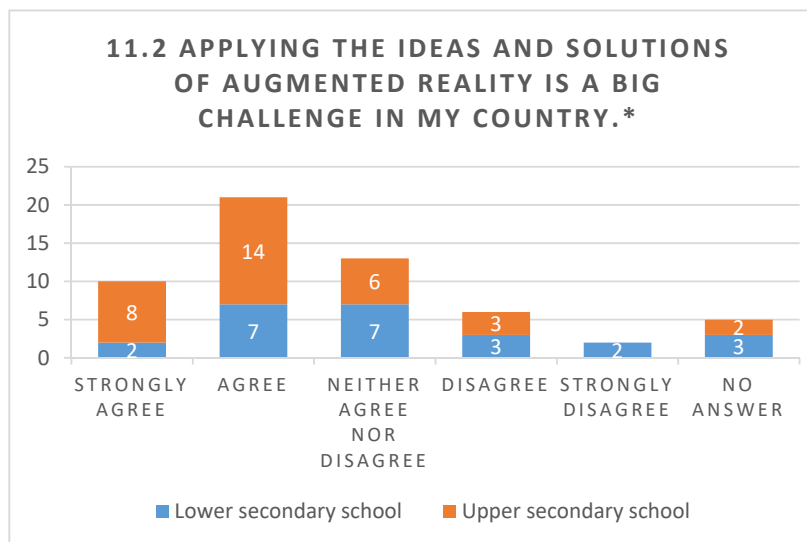
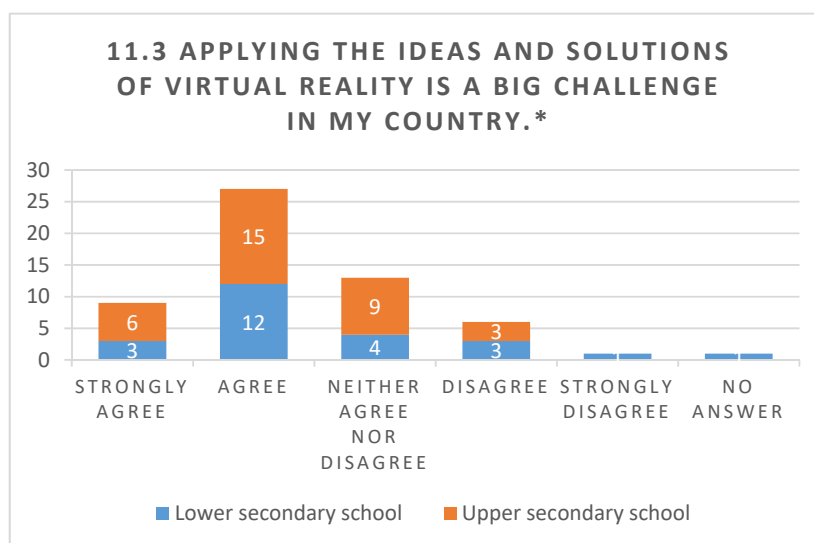
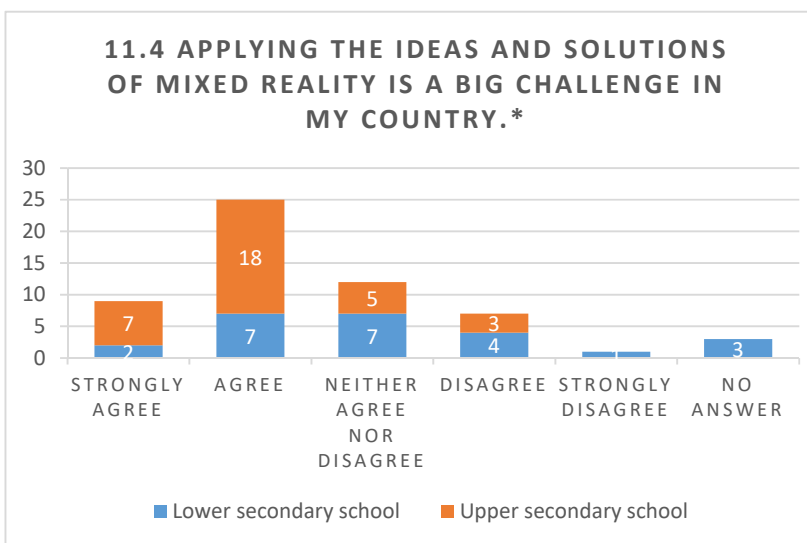
10.6 HOW FAMILIAR ARE YOU WITH THE POSSIBILITIES OF USING AUGMENTED OR VIRTUAL REALITY TECHNOLOGIES (E.G., GLASSES, TABLETS, SMARTPHONES) IN STEM STUDIES?

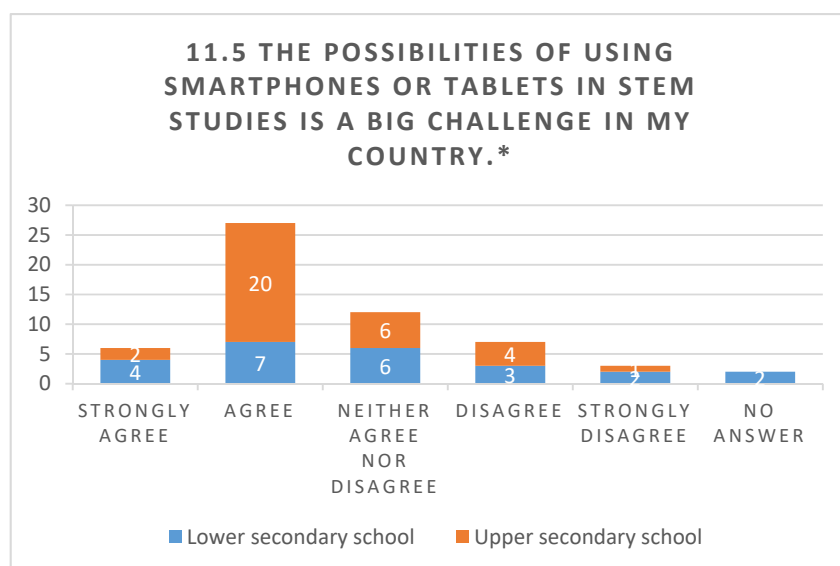
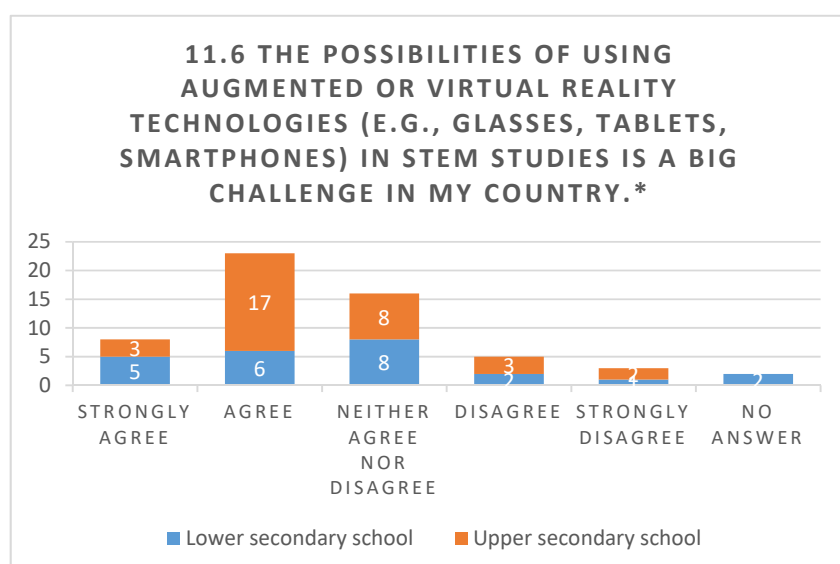


The results indicate that familiarity and use of the technologies listed above is either divided in half or rather low. The respondents are most familiar with the **possibilities of using smartphones or tablets for STEM studies** (50% of respondents have used it a few times or are using it often in STEM disciplines, 17% know how to implement it but have never done that) and the **concept of virtual reality** (29% of respondents have used it a few times or are using it often in STEM disciplines, 29% know how to implement it but have never done that), followed by the **possibilities of using augmented or virtual reality technologies in STEM studies** (33% of respondents have used it a few times or are using it often in STEM disciplines, 17% know how to implement it but have never done that).

Respondents indicated less familiarity and use with the **concept of internet of things** (33% of respondents have used it a few times or are using it often in STEM disciplines, 13% know how to implement it but have never done that), the **concept of mixed reality** (21% of respondents have used it a few times or are using it often in STEM disciplines, 13% know how to implement it but have never done that) and the **concept of augmented reality** (23% of respondents have used it a few times or are using it often in STEM disciplines, 10% know how to implement it but have never done that).

11. What are the challenges in applying emerging technologies? Please reply by selecting the level of agreement with the following statements.

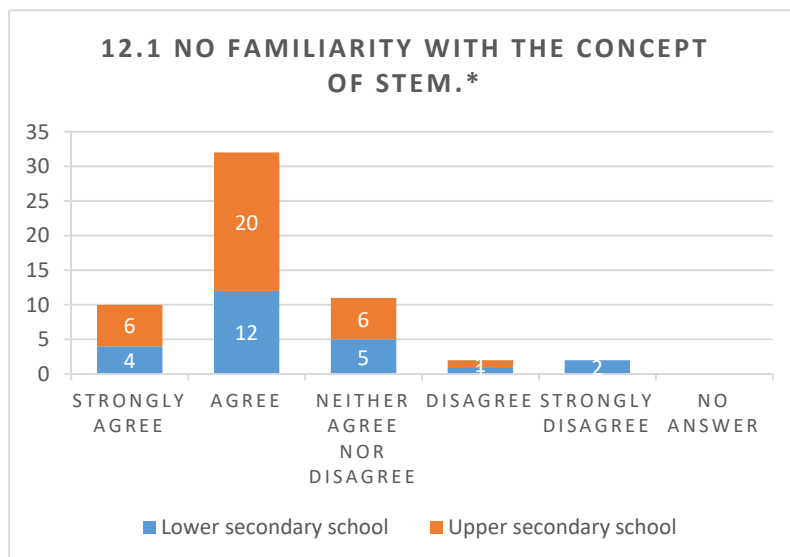
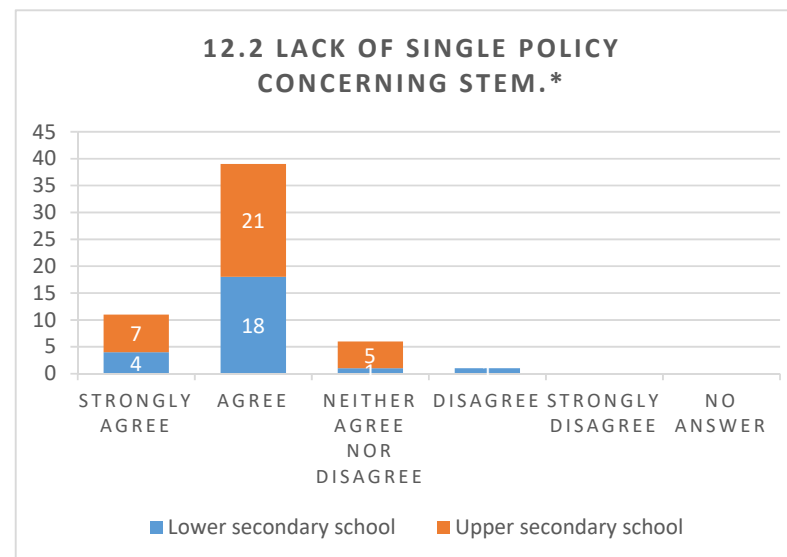
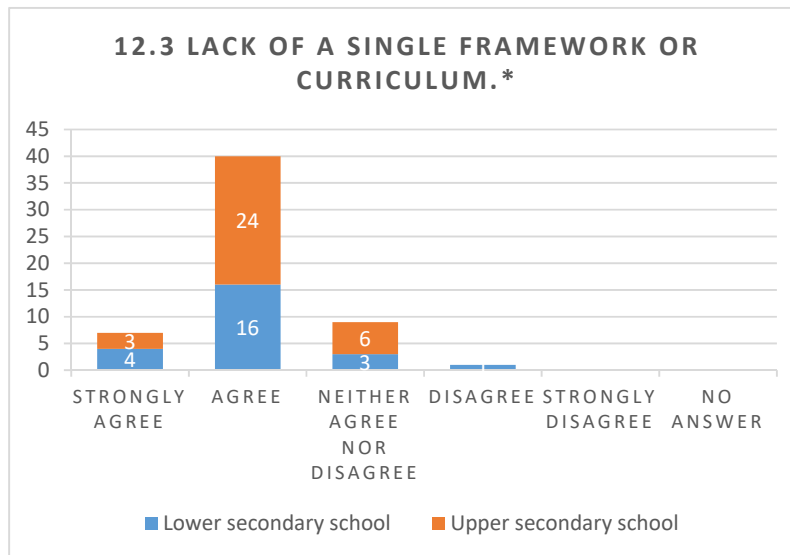
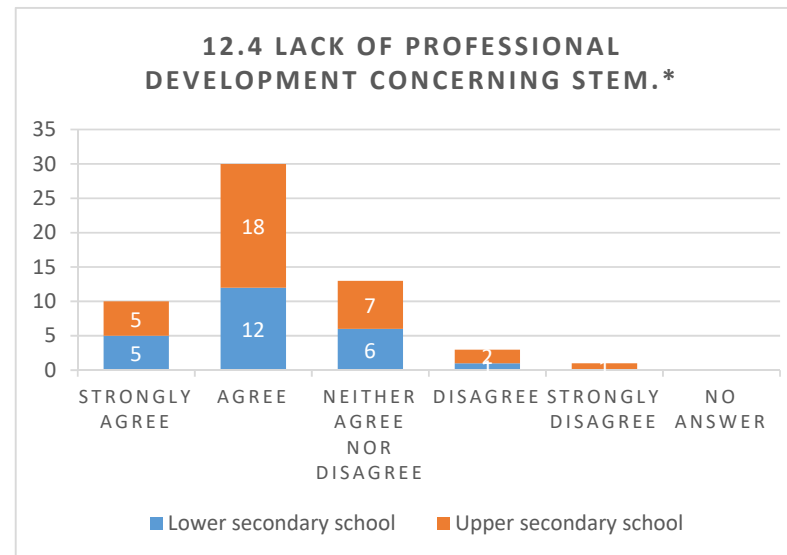


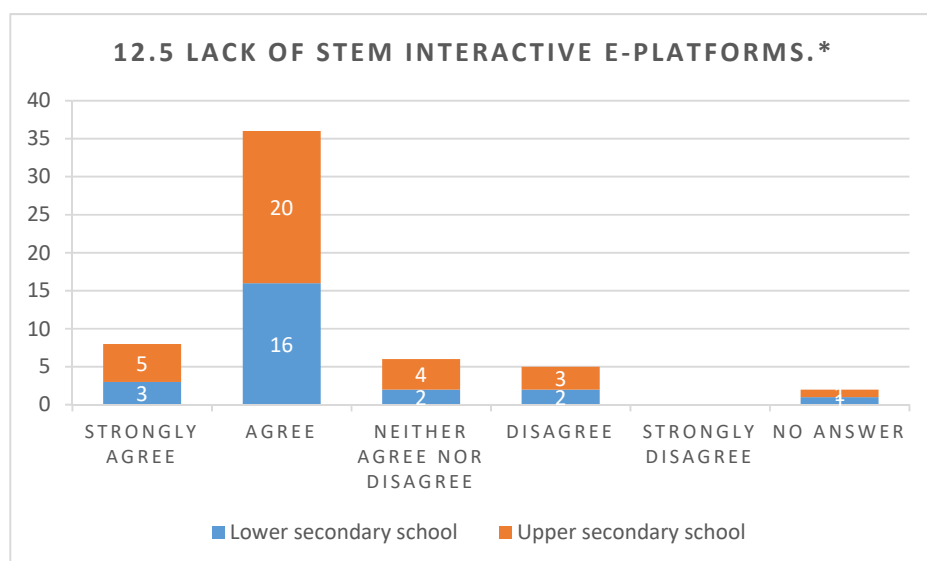
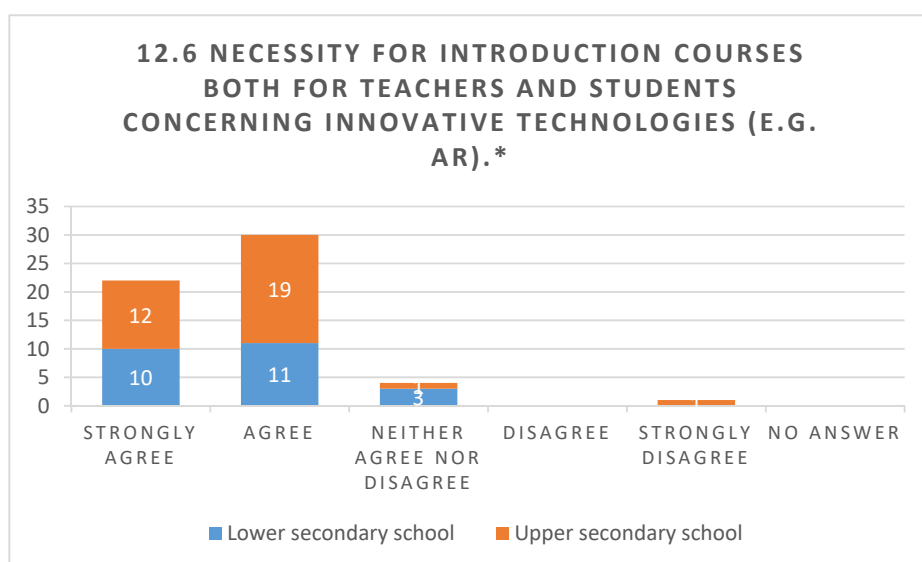


The results reflect that **using the technologies stated above are often found to be a challenge** in Greece. The most challenging aspects indicated are applying the **ideas and solutions of internet of things** (63% of respondents agreed or strongly agreed while 11% disagreed or strongly disagreed), applying the **ideas and solutions of virtual reality** (63% of respondents agreed or strongly agreed while 12% disagreed or strongly disagreed) and **mixed reality** (60% of respondents agreed or strongly agreed while 14% disagreed or strongly disagreed).

The possibilities of using smartphones (58% of respondents agreed or strongly agreed while 18% disagreed or strongly disagreed), **the possibilities of using augmented or virtual reality technologies** (54% of respondents agreed or strongly agreed while 14% disagreed or strongly disagreed), along with applying the **ideas and solutions of augmented reality** (54% of respondents agreed or strongly agreed while 14% disagreed or strongly disagreed). However, considering previous answers regarding familiarity with these technologies, it must be noted that responses could differ due to respondents' varied level of awareness about these technologies.

12. What are the main challenges in your country in applying innovative emerging technologies in STEM studies? Please reply by selecting the level of agreement with the following statements.





The main challenges in your country in applying innovative emerging technologies in STEM studies: All of the statements above were found to be a challenge in Greece. The main challenges in applying innovative emerging technologies in STEM studies are regarded to be the **necessity for introduction courses both for teachers and students concerning innovative technologies** (91% agree or strongly agree while 2% disagree or strongly disagree), the **lack of a single policy concerning STEM** (88% of respondents agree or strongly agree while 2% disagree or strongly disagree), **lack of a single framework or curriculum** (83% agree or strongly agree while 2% disagree or strongly disagree), followed by the **lack of STEM interactive e-platforms** (77% agree or strongly agree while 9% disagree or strongly disagree), the **lack of familiarity with the STEM concept** (74% agree or strongly agree while 7% disagree or strongly disagree) and the **lack of professional development concerning STEM** (70% of respondents agree or strongly agree while 7% disagree or strongly disagree).

If you would like to describe challenges not listed in the previous question, do so here.

Altogether 3 people responded to the question whose answers were categorized and will be given in the table below.

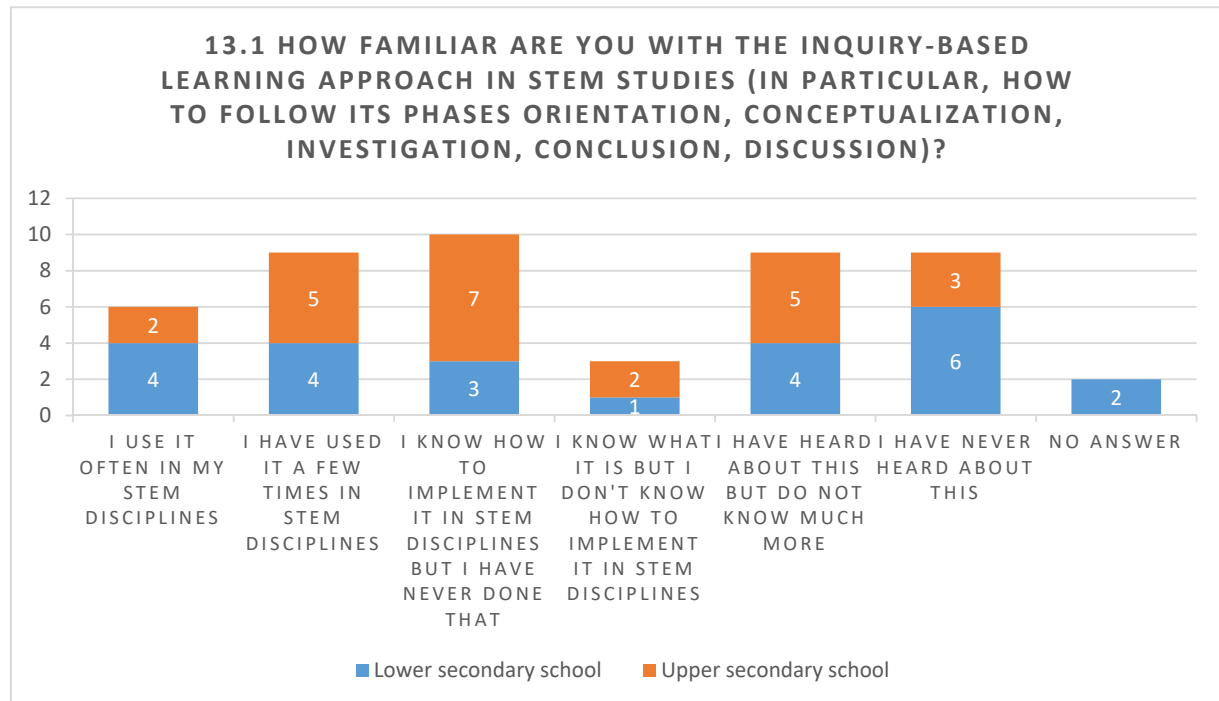
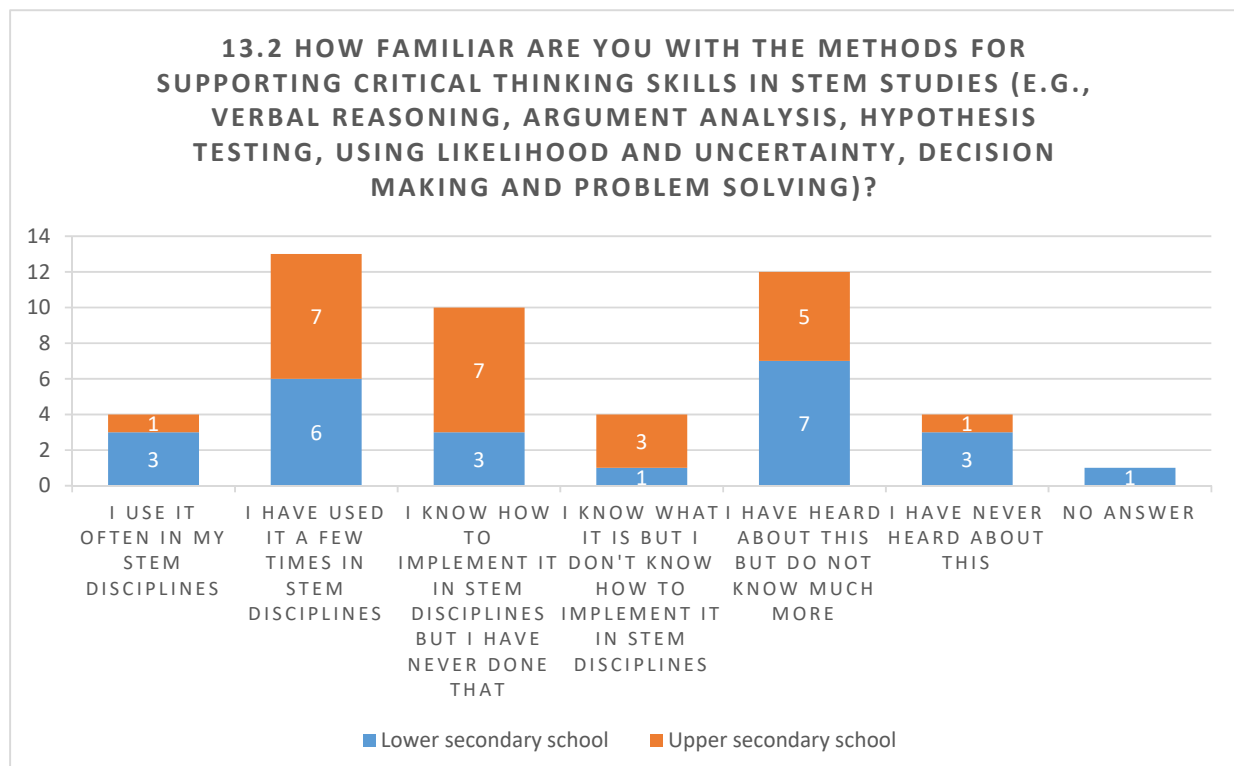
Category	Freq.
Lack of funding (e.g. lack of technological equipment in schools)	3
Constraints derived from the curriculum (not enough time for additional activities, curricula outdated etc.)	1
Lack in teachers' preparation/knowledge	1

If you know then please describe one success story how innovative emerging technologies have been successfully used in STEM studies. Think on a story that could be useful to learn in other countries as well. Please provide any additional material such as links to the materials about this story (e.g., descriptions, learning materials, guidelines, videos, photos). If you have some useful files to share then please send these to your national contact mentioned in the beginning and end of the questionnaire.

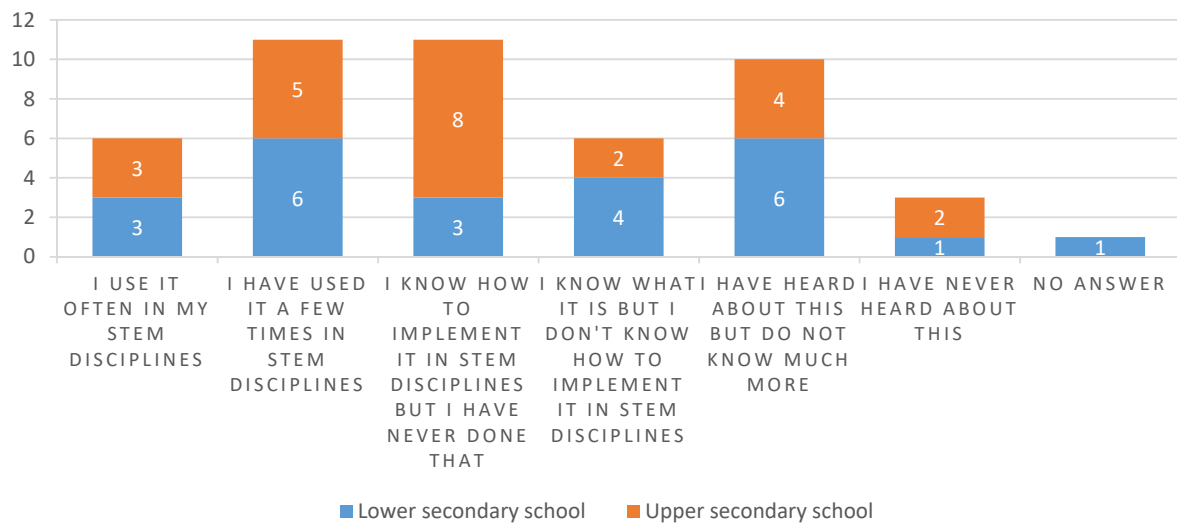
Altogether 2 people responded whose answers will be given below.

- There are some private schools in Greece that use innovative emerging technologies. Some of them are Doukas School, EllinoGermaniki Agogi. EllinoGermaniki has recently hosted LHC (<https://home.cern/topics/large-hadron-collider>).
- As I described above in the context of diplomacy, I taught the sun and moon eclipse with the help of the American Explrelearning Gizmos (3DEclipse) platform and the basic elements of the Universe with the Universe Sandbox software. The lesson went extremely well and the students showed great interest. Finally, with a group of students, we took part in an ESA ESA Space Astronomy Contest and built a small Astropi computer and we designed an experiment run by Thomas Pesquet on the International Space Station ISS.

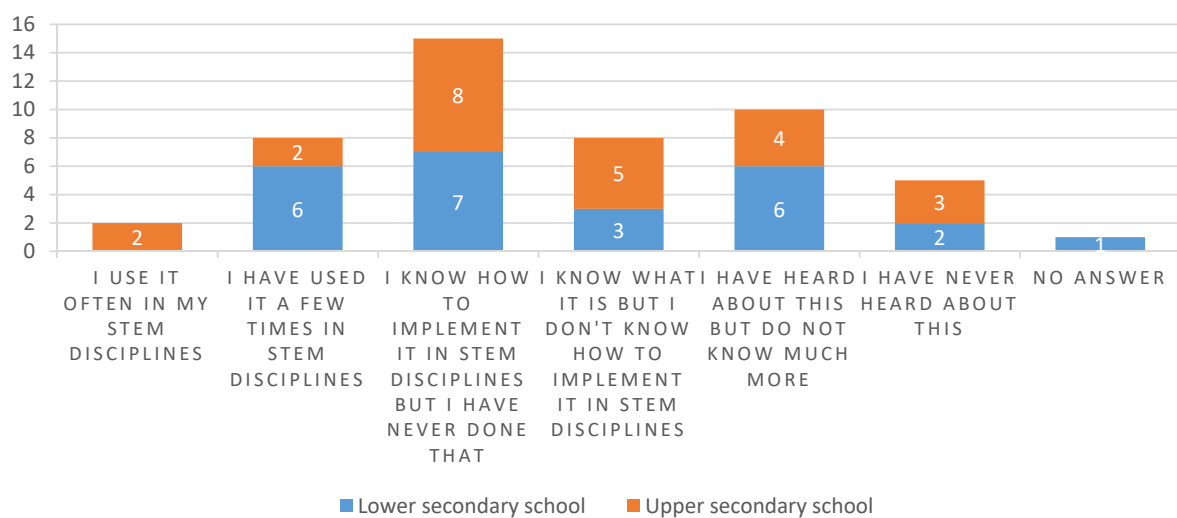
13. How familiar are you with innovative pedagogies and contemporary learning approach used in EL-STEM project and what are the challenges in applying them? Please reply by selecting the level of familiarity with the following statements.



13.3 HOW FAMILIAR ARE YOU WITH THE METHODS FOR SUPPORTING TEAMWORK OR COLLABORATION SKILLS IN STEM STUDIES (E.G., ATTENDING TEAMWORK, SEEKING AND SHARING INFORMATION, COMMUNICATING WITH TEAMMATES, THINKING CRITICALLY AND CREATIVELY)?



13.4 HOW FAMILIAR ARE YOU WITH THE METHODS FOR SUPPORTING COMPUTATIONAL THINKING SKILLS IN STEM STUDIES (E.G., MAKING ABSTRACTION, DECOMPOSING SYSTEMS, CREATING ALGORITHMS, EVALUATING SYSTEMS, MAKING GENERALISATIONS ABOUT ALGORITHMS OR SYSTEMS)?



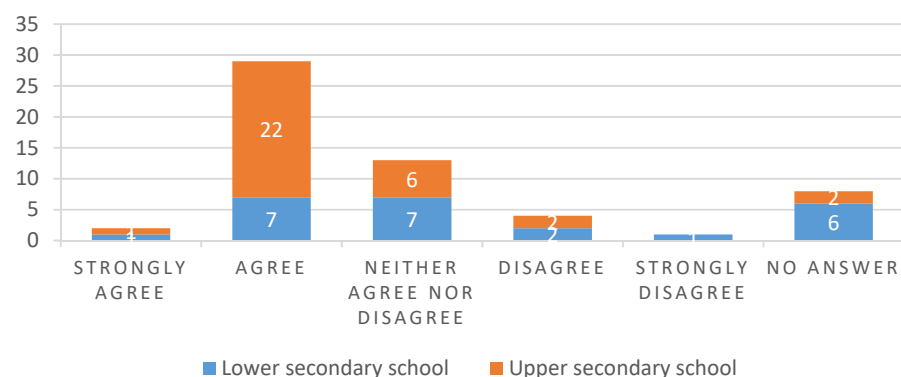
How familiar are you with innovative pedagogies and contemporary learning approach used in EL-STEM project and what are the challenges in applying them? The results indicate that the familiarity of different methods is varied approximately in half: nearly 50% of respondents are familiar and/or have been using the listed methods while about 50% are either not familiar with the method and/or do not know how to use this for their work.

Most familiarity and use was recognized with the methods for supporting **teamwork or collaboration skills in STEM studies** (35% of respondents have used it a few times or are using it often in STEM disciplines, 24% know how to implement it but have never done that), followed by the **methods for supporting critical thinking skills in STEM studies** (35% of respondents have used it a few times or are using it often in STEM disciplines, 21% know how to implement it but have never done that) and

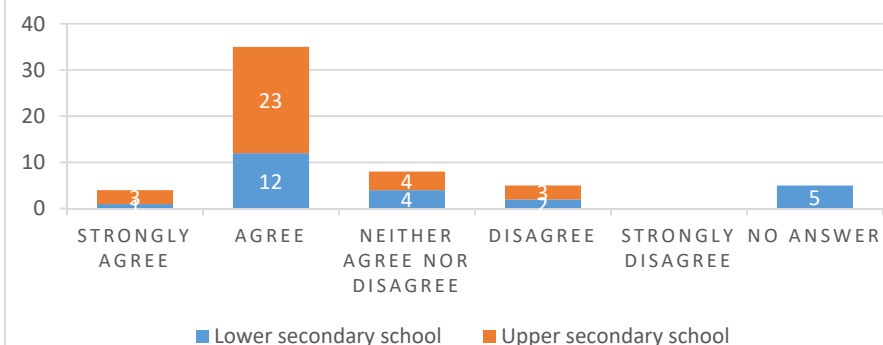
Slightly less familiarity and use was indicated with **the methods of inquiry based learning approach in STEM studies** (31% of respondents have used it a few times or are using it often in STEM disciplines, 21% know how to implement it but have never done that) and the **methods for supporting computational thinking skills in STEM studies** (21% of respondents have used it a few times or are using it often in STEM disciplines while 31% of respondents know how to implement it in STEM disciplines, but have never done that).

14. What are the main challenges in your country in applying innovative pedagogies and contemporary learning approach in STEM studies?
Please reply by selecting the level of agreement with the following statements.

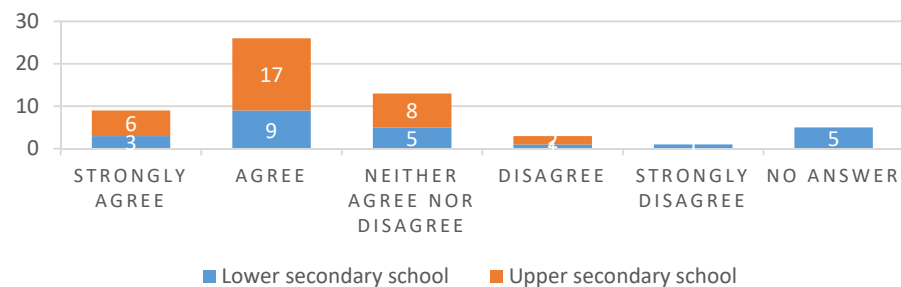
14.1 THE INQUIRY-BASED LEARNING APPROACH IN STEM STUDIES (IN PARTICULAR, HOW TO FOLLOW ITS PHASES ORIENTATION, CONCEPTUALIZATION, INVESTIGATION, CONCLUSION, DISCUSSION).*



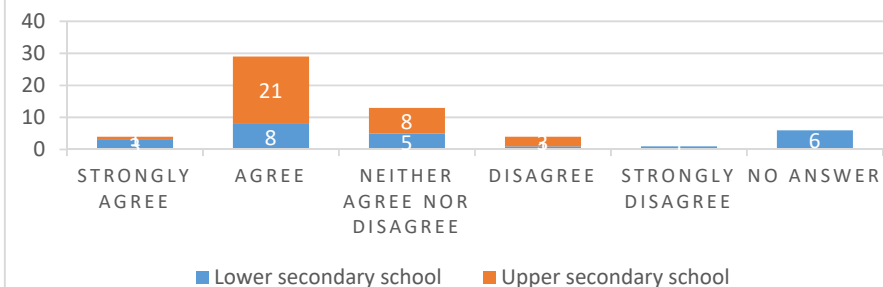
14.2 THE METHODS FOR SUPPORTING CRITICAL THINKING SKILLS IN STEM STUDIES (E.G., VERBAL REASONING, ARGUMENT ANALYSIS, HYPOTHESIS TESTING, USING LIKELIHOOD AND UNCERTAINTY, DECISION MAKING AND PROBLEM SOLVING).*

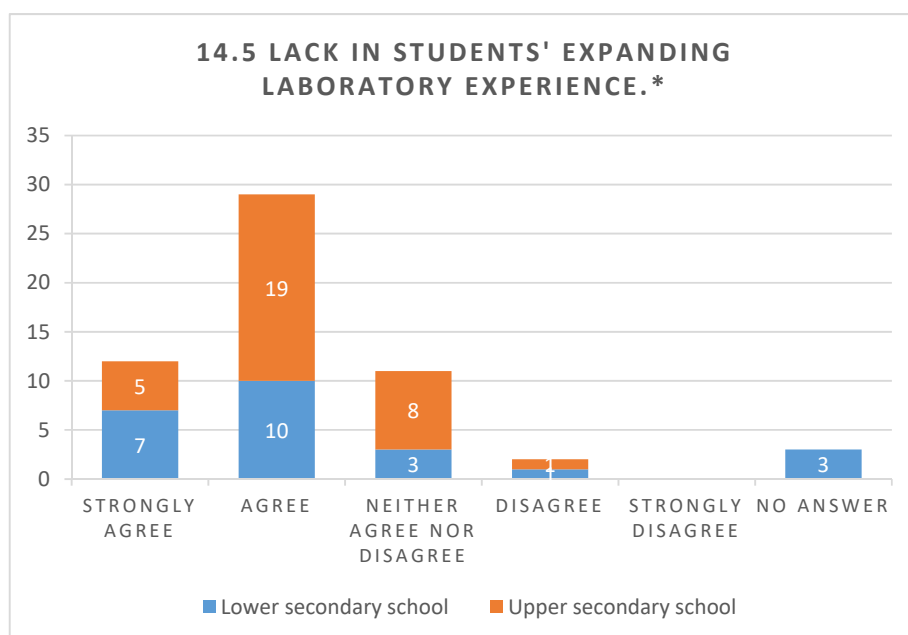


14.3 THE METHODS FOR SUPPORTING TEAMWORK OR COLLABORATION SKILLS IN STEM STUDIES (E.G., ATTENDING TEAMWORK, SEEKING AND SHARING INFORMATION, COMMUNICATING WITH TEAMMATES, THINKING CRITICALLY AND CREATIVELY, GETTING ALONG WITH TEAMMATES).*



14.4 THE METHODS FOR SUPPORTING COMPUTATIONAL THINKING SKILLS IN STEM STUDIES (E.G., MAKING ABSTRACTION, DECOMPOSING SYSTEMS, CREATING ALGORITHMS, EVALUATING SYSTEMS, MAKING GENERALISATIONS ABOUT ALGORITHMS OR SYSTEMS).*





The main challenges in your country in applying innovative pedagogies and contemporary learning approach in STEM studies: It reflects from the results that all of the statements above are considered challenges in Greece. Most challenging aspects are found to be the **lack in students' expanding laboratory experience** (72% of respondents agree or strongly agree while 4% disagree or strongly disagree) and the **methods for supporting critical thinking skills in STEM studies** (68% agree or strongly agree while 9% disagree or strongly disagree).

Another challenges identified are the **methods for supporting teamwork or collaboration skills** (61% agree strongly agree while 7% disagree or strongly disagree), the **methods for supporting computational thinking skills in STEM studies** (58% agree or strongly agree while 9% disagree or strongly disagree) and the **inquiry-based learning approach** (54% agree or strongly agree while 9% disagree or strongly disagree) in STEM studies.

If you would like to describe challenges not listed in the previous question, do so here.

No responses were received.

If you know then please describe one success story how innovative pedagogies or contemporary learning approach have been successfully used in STEM studies. Think on a story that could be useful to learn in other countries as well. Please provide any additional material such as links to the materials about this story (e.g., descriptions, learning materials, guidelines, videos, photos). If you have some useful files to share, then please send these to your national contact mentioned in the beginning and end of the questionnaire.

No responses were received.

5.3. Discussion

The participants' profiles were more **similar in Greece and Cyprus, where majority of participants are over 41 years old**. In Finland and Estonia, the age groups are more varied with the youngest participants in Estonia, where nearly half of respondents were younger than 40. In all countries **majority of respondents were working as teachers** (in Finland, Greece and Cyprus over 80%, in Estonia 68%, **fewer people with experience in working as teacher educators or educational researchers** (up to approximately 20% in all countries). In Finland, Cyprus and Greece, majority of teachers had **over 10 years of experience in this field**, while in Estonia the length of experience spanned between **less than a year to over 10 years**. However, this derives clearly from the youth of many participants.

It reflects from the results the respondents from Greece and Finland were the most acquainted with STEM concept, where majority of respondents **opened the STEM acronym and explained the concept at least in 1-2 aspects**. Nearly half of respondents in Estonia **wrote only the names of disciplines in STEM acronym**, while approximately 1/3 explained the concept further. As it is difficult to evaluate participants' familiarity with the concept, if only the acronym has been explained, it is questionable how familiar is a notable part of respondents with the concept. In Cyprus, about 1/3 respondents had given an **incorrect answer** while another 17% stated they **do not know the concept**. All in all, it reflected that only approximately 1/3 of participants **were certainly acquainted with the acronym and concept** which have most probably affected responses to further questions.

Regarding **students' attractiveness, engagement and motivation in STEM studies**, responses in all countries were often contradictory to one another: while firstly many respondents agreed with the statement that STEM related studies are attractive, engaging or motivating to students, many also found these aspects are a big challenge in their countries. However, when comparing answers to these statements, it could be noted that **STEM related studies are found rather attractive in Finland and Greece, while in Estonia and Cyprus it is rather a challenge**. Also, **students are rather engaged in STEM studies in Finland** while it is clearly a challenge in Estonia, Greece and Cyprus. Regarding **students' motivation in STEM studies**, it is **not found to be a problem in Finland** while in **Estonia, Cyprus and Greece it is rather a challenge**.

However, as a notable amount of participants in Estonia, Cyprus and Greece often responded to the statements "neither agree nor disagree", it might influence the end results. This standpoint among a number of participants might indicate the answer is dependent on various aspects, e.g. they might find the answers might vary depending on a specific age group, school, interest group etc.

The main challenges in making STEM studies attractive, engaging students more and increasing their motivation towards STEM studies and careers in all countries are the **lack of single policy concerning STEM-related courses, school curriculum not building links between the STEM disciplines** and the **lack of equipment at schools**. In the last aspect, opinions are divided in Estonia, which might be derived from the differences between schools, i.e. some schools are well equipped while others have little resources to do that. While in Estonia and Finland, the **outdatedness of school books, options for professional development and unemployment in STEM careers** was not found to be a problem, in Greece and Cyprus, **approximately half of respondents found these aspects to be a challenge**. Gender stereotypes are rather not regarded as a challenge in all countries.

Other aspects mentioned by respondents were **constraints derived from the curriculum** (not enough time for additional activities, curricula outdated) in Estonia, Cyprus and Greece; **lack in teachers' preparation/knowledge** (in Estonia, Finland and Greece); **little opportunity to collaborate with other**

teachers (no suitable classrooms, not enough time, overloaded with work, not interested in collaboration) in Estonia and Cyprus; **lack of finances** (in Cyprus and Greece); **quality control for online resources** (in Estonia). However, it must be noted that response rate to all open ended questions was low, therefore, it might not reflect the accurate situation.

Regarding success stories on how STEM studies have been made attractive, most often mentioned aspects were **robotics classes**, enabling **students to experiment themselves** and **visits to museums, science centers, observatories and various organizations**, with the reason that these activities **enable to experience the theory learnt in classes** which gives meaning to the studies.

The respondents in all countries are most familiar with the **possibilities of using smartphones or tablets for STEM studies**, along with the **concept of virtual reality**. However, even though these concepts appeared to be the most familiar, the results vary among countries: for instance, while in Estonia familiarity with the use of smartphones or tablets for learning is 93%, the results are respectively 67% in Greece, 55% in Finland, and 50% in Cyprus. In Estonia, Finland and Greece, approximately 50% of respondents are familiar with the **possibilities of using augmented or virtual reality technologies in STEM studies**, but have often not used these for their work. In Cyprus, altogether 39% of respondents are familiar with these technologies but 17% have not used these for their work. Slightly less than half of respondents are familiar with the **concept of internet of things** and approximately 1/3 with the **concept of mixed reality** in all countries. All in all, the results indicate that **familiarity and use of the technologies is the highest in Estonia**, which might be derived from the younger age of many respondents, and the lowest in Cyprus. What should be noted in several cases is that even if the respondent is aware of the technology and its possibilities to use in STEM disciplines, **it is often not being used in their work**. This might derive from aspects listed in other questions: lack of time, funding and preparation or motivation among teachers.

The survey results also reflect that in Greece, majority of respondents find applying **all of the listed emerging technologies a challenge**. In Cyprus, the **possibilities of using smartphones**, the **possibilities of using augmented or virtual reality technologies** and applying the **ideas and solutions of virtual reality** are also found a challenge by majority of respondents. The use of **ideas and solutions of augmented, virtual and mixed reality** along with the **possibilities of using augmented or virtual reality technologies** are rather found to be challenging in all countries.

In contrast to Cyprus and Greece, in Estonia and Finland, majority of respondents did not find the **possibilities of using smartphones** and **internet of things** a challenge. However, it must be noted that in several occasions, clear opinions (agree-disagree) could be identified by only approximately half of respondents. This could derive from varied level of awareness about these technologies which reflected in previous question. For instance, if respondents' familiarity to internet of things was marked low in the previous question, in this question these respondents may have remained neutral which might have influenced the results.

In Cyprus, Estonia and Greece, the results clearly show the **main challenges in applying innovative emerging technologies in STEM studies** are the need for **introduction courses both for teachers and students concerning innovative technologies, followed by the lack of a single policy concerning STEM** (while in Finland approximately half of respondents found it to be a challenge) and the **lack of STEM interactive e-platforms**. In addition, majority of respondents in Cyprus and Greece have noted the **lack of professional development concerning STEM** and the **lack of a single framework or curriculum**. In addition, in Cyprus and Greece **the lack of familiarity with the STEM concept** was found to be a challenge while in Finland and Estonia, less than half of respondents agreed to the statement.

Additional aspects mentioned by participants in Estonia and Greece, as also noted previously, were **lack of funding** (e.g. lack of technological equipment in schools); **constraints derived from the curricula** (not enough time for additional activities, curricula outdated); **lack in teachers' preparation/knowledge** and the **relevance of existing technologies to the curricula**. No respondents from Finland or Cyprus listed additional aspects.

In terms of **familiarity and challenges with innovative pedagogies and contemporary learning approach used in EL-STEM project**, in Cyprus and Greece the responses are varied, dividing often approximately in half: nearly 50% of respondents are familiar and/or have been using the methods above while about 50% are either not familiar with the method and/or do not know how to use this for their work. Most familiarity and use was recognized in Cyprus and Greece in the methods for supporting **teamwork or collaboration skills in STEM studies**. In Estonia and Finland, responses show clear familiarity and use of the **methods for supporting critical thinking skills in STEM studies** and the **methods for supporting teamwork or collaboration skills in STEM studies**. What must be noted is that while **nearly 2/3 of respondents from Estonia and Finland are familiar with the methods of inquiry based learning approach in STEM studies**, less than half of participants from Cyprus and Greece are aware and/or using the approach in their work. The results show the least familiarity with the **methods for supporting computational thinking skills in STEM studies**, where up to half of respondents in all countries are familiar and/or using it.

The main challenges in applying innovative pedagogies and contemporary learning approach in STEM studies in Estonia, Finland and Greece were found to be the **lack in students' expanding laboratory experience**, while in Cyprus the **methods for supporting critical thinking skills in STEM studies** were mapped as a clear challenge. As opinions for **the methods for supporting computational thinking skills in STEM studies**, **inquiry-based learning approach** and **the methods for supporting teamwork or collaboration skills** were divided nearly equally among participants from Estonia, it could be said these aspects are rather a challenge in Estonia, while the results in Cyprus and Greece indicate definite challenge in these areas. Most participants in Finland did not find these aspects to be a problem. Additional aspects listed by respondents in Estonia and Cyprus were also **little opportunity to collaborate between teachers**, **lack of technical equipment**, **students' low motivation**, **lack in teachers' preparation or knowledge** and **constraints derived from curricula**. No respondents from Finland or Greece listed additional aspects.

6. Discussion and summary: EL-STEM instructional approach

All in all, a number of challenges were identified for applying EL-STEM instructional approach which are often similar among all participating countries. The challenges will be given as follows, along with suggestions on tackling them.

Firstly, there is a **need for changes on policy makers' level**, in order to create a single policy/curricula which would **build links between the STEM disciplines**, leave more time in classes for **practical activities** (e.g. laboratory experience) and for **collaboration between teachers** of different disciplines. Also, in Greece and Cyprus, the **lack of career and professional development options** in STEM disciplines have been identified. While renewing policies and the lack of professional development options demand deeper analysis and long-term efforts, one possibility how to fit hands-on activities into classes could be to create AR learning objects and scenarios which include very **condensed and short engaging tasks which support the curricula**. This would not demand a lot of time and would enhance skills which have demonstrated to be difficult to achieve, yet which AR might help to overcome.

In addition, in all countries, the **lack of technical equipment** at schools has been identified. This and several of the aforementioned challenges understandably have been noted to derive from **lack of finances**. One possible way to tackle the lack of technical devices could be to implement **bring-your-own-device policy**, i.e. students would be allowed to use their own smartphones or tablets for learning activities. This, however, requires using applications which are **free and available on both Android and iOS devices**.

Finally, there is a need for **teacher and student trainings which would introduce emerging technologies** and demonstrate why and how to use these in learning (in Estonia and Finland, introduction to immersive technologies and internet of things is needed, while in Cyprus and Greece a course on the use of smartphones for learning should be also added). There is also a clearly identified need for teacher trainings to **introduce the STEM concept** and how to **bind STEM subjects, combined with emerging technologies**. Another area of improvement is to raise educators' awareness on **the methods of inquiry-based learning approach, the methods for supporting teamwork or collaboration skills** and the **methods for supporting computational and critical thinking skills** in STEM studies. In Greece and Cyprus, there is a **need for updated school books** and **STEM educators' pedagogical approaches**.

As part of the EL-STEM project, **teacher trainings are delivered and an online course has been created to enhance knowledge in immersive technologies and in inquiry-based learning method**. The blended curriculum demonstrates opportunities on using immersive technologies hand-in-hand with inquiry-based learning method, including also how to support and assess development of teamwork and collaboration skills as well as computational and critical thinking skills. Therefore, a strong contribution has been and will be continuously made to raise awareness in these fields.

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APPENDIX 1. Assessment Instrument for Evaluating and Developing Inquiry Based Learning Skills.

Description of the Instrument

Developing inquiry skills is one of the main aims in STEM subjects for middle school and high school students. In developing these skills, learning process could be divided into seven phases:

- 1) identifying the problem
- 2) stating the research question
- 3) stating the hypothesis
- 4) planning the experiment
- 5) carrying out the experiment
- 6) analysing and interpreting the results
- 7) making and presenting conclusions

Based on the phases above, we propose scales given in the tables below for assessing students' inquiry skills. The scales are intended to be used by teachers to map their students' skills as well as potential areas of development.

Scale for assessing research problem identification skills

Feature to be Evaluated	Scale
Novelty of the problem	0 – solution and solution path is known for all students 1 – solution and/or solution path is known for majority of students 2 – solution or solution path is unknown for majority of students 3 – solution and solution path is unknown for majority of students 4 – solution and solution path is unknown for all students

Interest in the problem	0 – solving the problem is not interesting for practically anyone 1 – solving the problem is interesting for few students 2 – solving the problem is interesting for a number of students 3 – solving the problem is interesting for majority of students 4 – solving the problem is interesting for practically all students
Formulation of the problem	0 – an argument or question identifiable as a problem has not been formulated 1 – an argument or question identifiable as a problem has been formulated, but does not derive from the presented situation 2 – an argument or question identifiable as a problem has been formulated which derives from the presented situation (additional levels could be recognised depending on how important is the identified problem within other problems in the presented situation)

Scale for assessing research question formulation skills

Feature to be Evaluated	Scale
Wording	0 – nothing or another sentence has been formulated instead of a research question 1 – formulated research question does not correspond to the research problem 2 – a static research question corresponding to research problem has been formulated 3 – a dynamic research question corresponding to research problem has been formulated
Impact factor	0 – impact factor has not been stated 1 – impact factor does not derive from the research problem 2 – impact factor derives from research problem, but has been stated in unmeasurable way (inaccurately) 3 – impact factor derives from research problem and has been stated precisely, in a measurable way
Attributes of research	0 – research attribute has not been stated 1 – research attribute does not derive from research problem 2 – research attribute derives from research problem, but its measurable attribute has not been stated (or has been stated inaccurately) 3 – research attribute derives from research problem, and its measurable attribute has been stated accurately

Scale for assessing hypothesis formulation skills

Feature to be Evaluated	Scale
Formulation	0 – a question has been formulated instead of an argument 1 – an argument has been formulated inadequately, not corresponding to research question 2 – a static argument corresponding to research question has been formulated 3 – a dynamic argument corresponding to research question has been formulated
Impact factor	0 – impact factor has not been stated 1 – impact factor does not derive from research question 2 – impact factor derives from research question, but has been stated in unmeasurable way (inaccurately) 3 – impact factor derives from research question and has been stated accurately, in a measurable way
Attributes of research	0 – research attribute has not been stated 1 – research attribute does not derive from research question 2 – research attribute derives from research question, but its measurable variable has not been stated (or has been stated inaccurately) 3 – research attribute derives from research question and its measurable variable has been stated accurately
Presumed relationship	0 – the coherence of impact factor and research attribute has not been stated 1 – the coherence of impact factor and research attribute does not derive from background information 2 – the coherence of impact factor and research attribute derives from background information, but has been stated statically 3 – the coherence of impact factor and research attribute derives from background information and has been stated dynamically

Scale for assessing experiment planning skills

Feature to be Evaluated	Scale
Tools and materials	0 – tools and materials for carrying out the experiment have not been listed 1 – tools or materials have been listed, but not both of these 2 – tools and materials for carrying out the experiment have been listed to a certain extent (could be varied depending on how many necessary or unnecessary tools and materials have been listed) 3 – all tools and materials for carrying out the experiment have been listed (and no unnecessary items are listed)
Plan	0 – experiment activities have not been described 1 – experiment activities have been described, but distinctive phases have not been stated 2 – experiment activities have been presented in sequential phases, but not all phases are relevant to testing the hypothesis 3 – experiment activities have been presented in sequential phases and all phases are relevant to testing the hypothesis 4 – in addition to presenting all phases for testing the hypothesis in sequence, testing methods have been described to strengthen the reliability of the experiment (in addition to impact factor, constancy of other factors in the experiment are assured, test experiments are carried out to strengthen reliability etc.)
Time planning	0 – time plan for carrying out the experiment is not created 1 – time plan for the experiment is unrealistic or inadequate 2 – time plan for the experiment is realistic and accurate

Scale for assessing experiment conduction skills

Feature to be Evaluated	Scale
Following the plan	0 – the plan has not been followed at all 1 – the plan has been followed to a certain extent 2 – the plan has been followed precisely
Collecting data	0 – collected data is not saved in written form 1 – collected data has been saved in written form, but not systematically 2 – collected data has been saved systematically in written form

Scale for assessing data analysis and interpretation skills

Feature to be Evaluated	Scale
Analysis	0 – data analysis is not based on given data, arguments or conclusions are incorrect 1 – data analysis is based on given data, but the conclusion is too general and inaccurate 2 – data analysis is based on given data and data has been described exhaustively
Interpretation	0 – attention is not paid to anomalies in data 1 – anomalies in data are recognised, but the reason for these to occur is not explained and necessary corrections are not made 2 – anomalies in data are recognised and the reason for these to occur is explained, but necessary corrections are not made 3 – anomalies in data are recognised and supporting on the reasons for these to occur, necessary corrections are made to prevent interpreting false data

Scale for assessing conclusion presentation and hypothesis formulation skills

Feature to be Evaluated	Scale
Associating conclusions with problems, research questions and hypotheses	0 – conclusion is not associated with a problem, research question nor hypothesis 1 – conclusion is associated with all of these aspects (The action of association itself is important. It may occur that the conclusion deriving from test analysis and interpretation might not solve the problem)
Choosing appropriate method for presenting results	0 – results are not presented understandably for other people 1 – there are imperfections in presenting results 2 – appropriate methods have been chosen for presenting results and the presentation is understandable for other people (evaluate also whether the presented text, tables or figures are correct)

APPENDIX 2. Computational Thinking Skills Inventory (CTSI)

Computational Thinking Tasks for Secondary School

Task 1. Algorithmic thinking. Crane Operating

The crane in the port of Lodgedam has six different input commands:

left

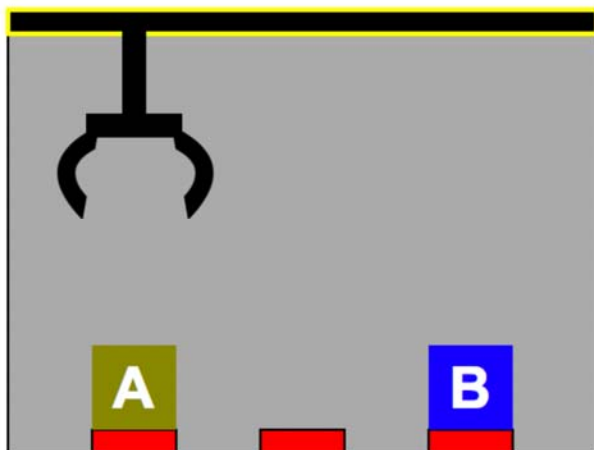
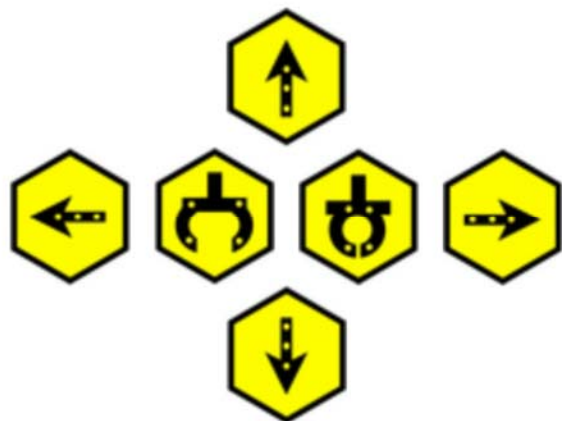
right

up

down

grab

let go



Box A is in the left position, box B is in the position on the right.

Question:

How to swap the positions of the boxes using the commands given above?

Write the commands (letters), separating the letters with spaces.

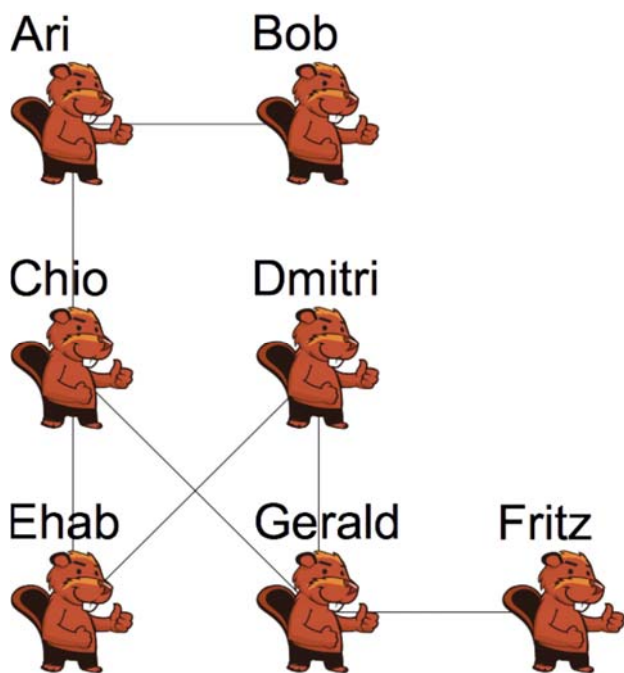
Task 2. Algorithmic thinking. Popularity

Seven beavers are in an online social network called Instadam.

Instadam only allows them to see the photos on their own and their friends' pages.

In this diagram, if two beavers are friends they are joined by a line.

After the summer holidays everybody posts a picture of themselves on all of their friends' pages.



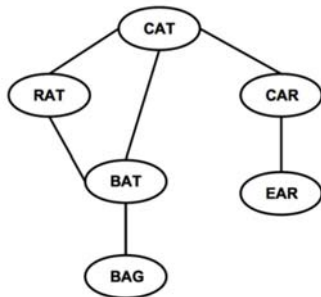
Question:

Which beavers' picture will be seen the most?

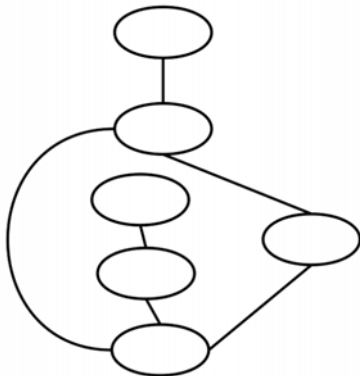
Ari, Bob, Chio, Dmitri, Ehab, Fritz or Gerald

Task 3. Algorithmic thinking. Word Chains

For his homework, Thomas had to write words on cards and connect them with rubber bands.



The teacher told him to connect any two words that differ by exactly one letter. Thomas did this, as you can see in the picture above. When Thomas returned from having a break he got a surprise. Peter, his little brother, had erased all the words!

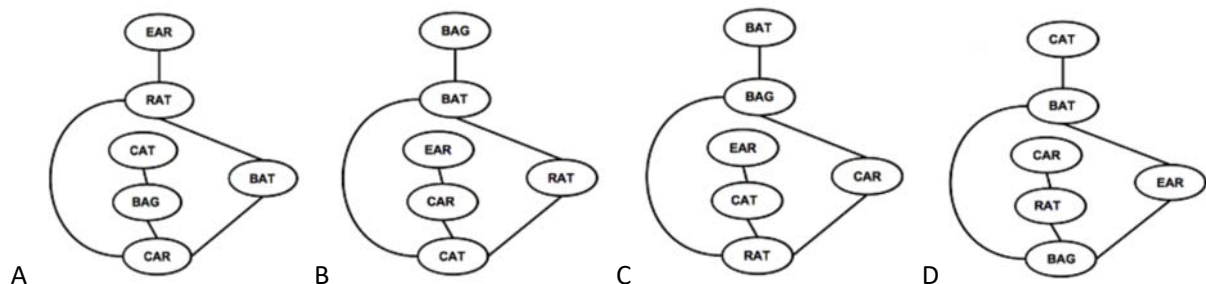


Also, the cards were completely mixed up, as you can see in the image above.

Importantly, the rubber bands still connected them as before. Thomas was sure he could put the words back in the correct place.

Question:

Which of the pictures below contains the words in exactly the right places?



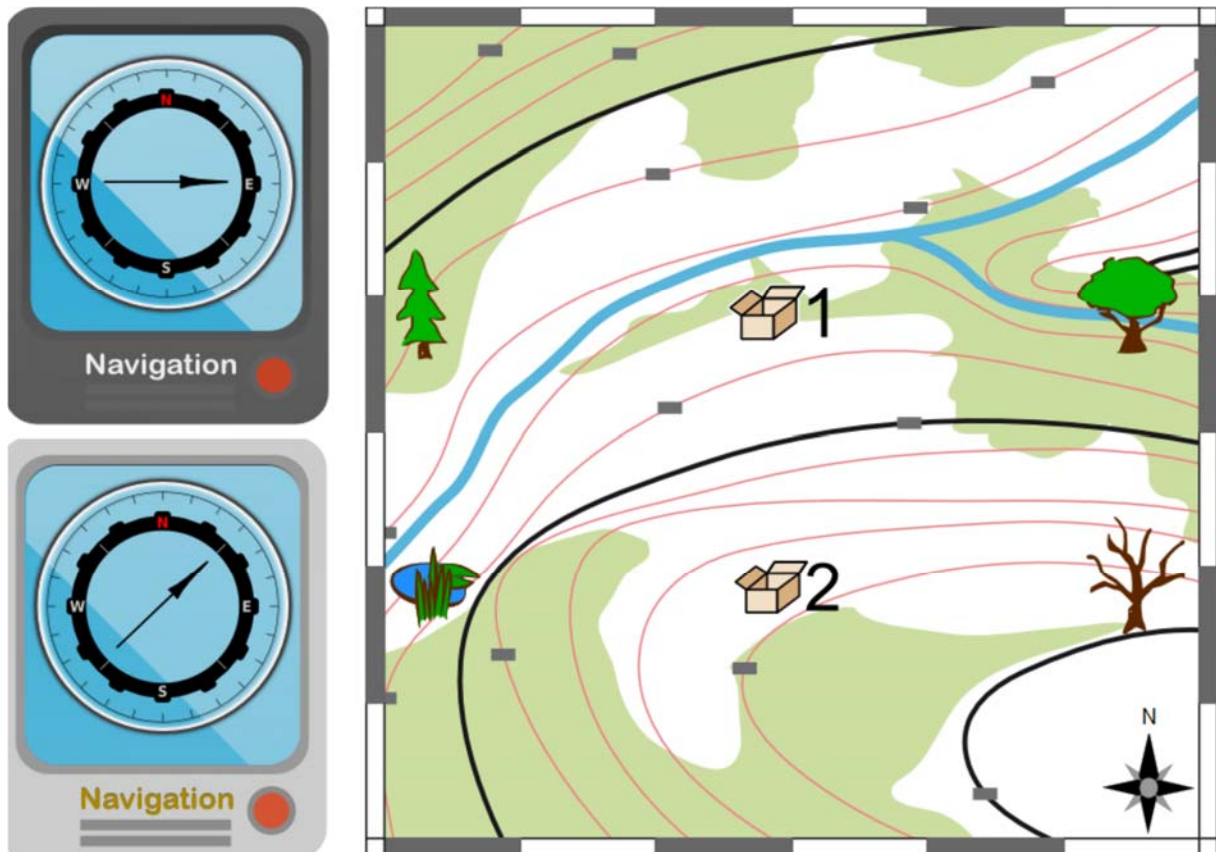
Task 4. Algorithmic thinking. Geocaching

Two friends, Anna and Bob, are searching for treasure.

They have a smartphone app that shows them the direction to the treasure they are looking for.

The two boxes on the map show where the treasure is.

Anna is searching for box 1. Bob is looking for box 2.



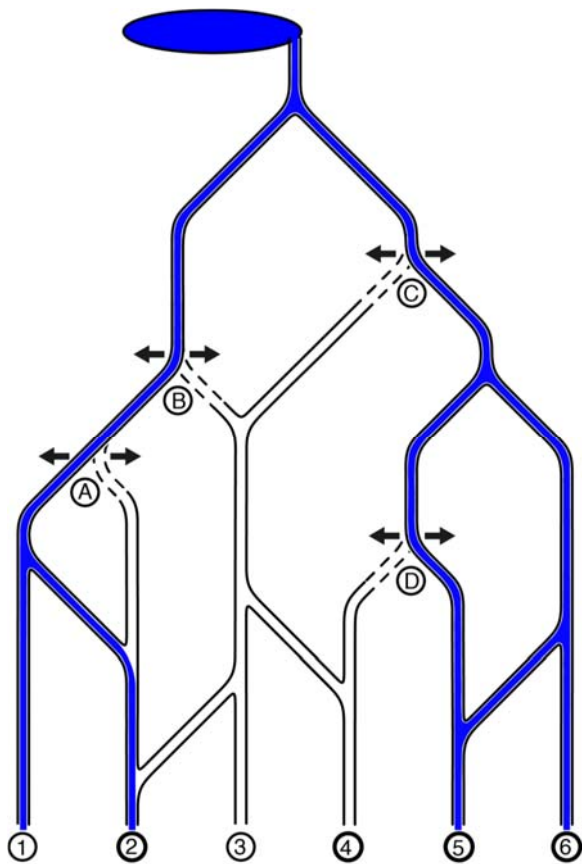
Anna and Bob are standing in the same place. The picture shows the map and a screenshot of the smartphones.

Question:

Where are Anna and Bob standing?



Task 5. Algorithmic thinking. Irrigation system



The beavers have created a clever irrigation system for their fields. The water flows from a lake at the top of the hill all the way down to the fields numbered 1 to 6 at the bottom.

Along the water canals, the beavers have installed four water gates A, B, C and D, where the water can only flow either to the left or to the right.

Question:

Which water gates' directions should be changed, so that only the fields numbered 2, 4, 5 und 6 are irrigated?

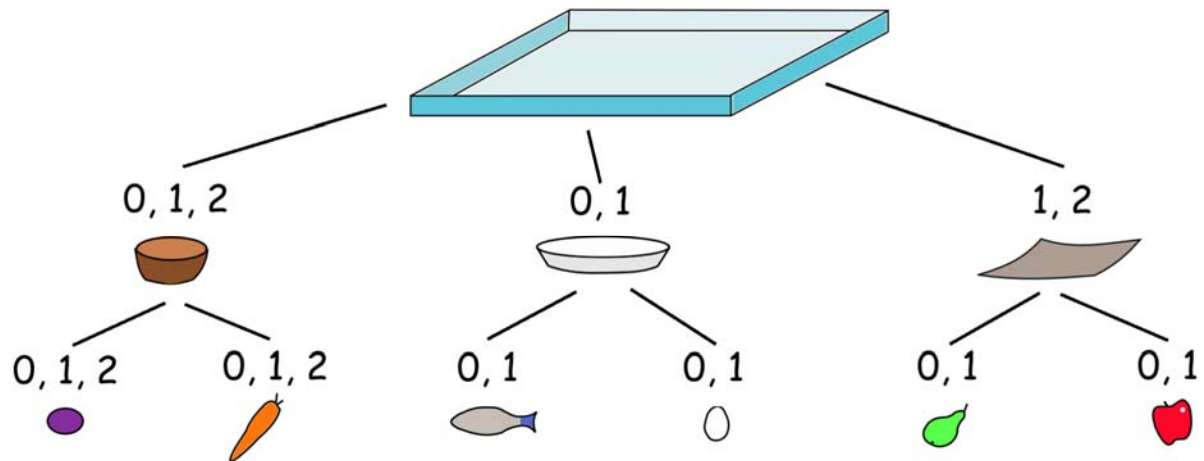
A, B, C, D

Task 6. Recognizing algorithmic patterns. Beaver Lunch

Hm, what to take for lunch today?

The cafeteria gives instructions on how to choose a Beaver lunch.

This is shown as a diagram:



Below the tray you see different types of food containers.

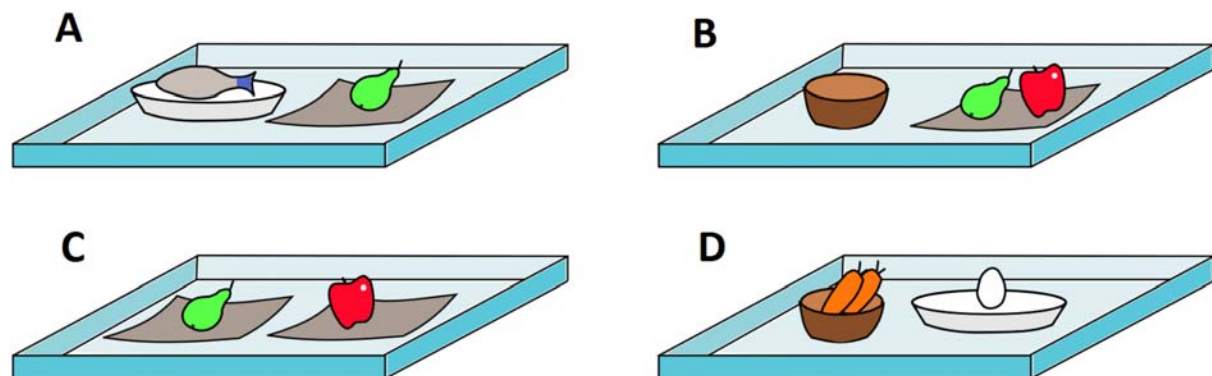
The numbers indicate how many containers of this type can be added to a tray.

Each container can only have food items put in it that are shown below it.

The numbers indicate how many food items of this type can be added to the containers.

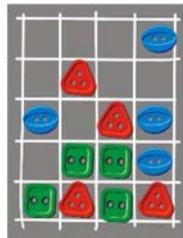
Question:

Which of the following lunches is not a proper Beaver lunch?



Task 7. Recognizing algorithmic patterns. Button Game

You can play this game on paper, using 3 different colours of buttons. For this, draw a board of 4 x 6 squares and put the buttons on top of it. With one move you can move one button to an empty square next to it (left, right, up or down).

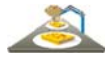


Question

What is the least number of steps to put all green squared buttons into one line at the bottom of the board?

Task 8. Recognizing algorithmic patterns. Decorating Chocolate

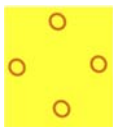
Everything is automated in a chocolate factory: the sweets are sliding on a conveyor, and there is a robot with a syringe, which draws different shapes.



The robot can perform these commands:

1. Leaf – draws: 
2. Circle – draws : 
3. Rotate k – rotates the sweet clockwise by k° .
4. Repeat n [...] – repeats the commands inside brackets n times

For example, to perform Repeat 4 [Circle Rotate 90], the robot will draw the flower as follows:



Question

Which of the following command sequences the robot does NOT draw the flower below?



A. Repeat 6 [Rotate 30 Circle Rotate 30 Leaf]	B. Repeat 6 [Leaf Rotate 60] Rotate 330 Repeat 6 [Circle Rotate 300]	C. Repeat 6 [Leaf Rotate 60] Repeat 6 [Circle Rotate 60]	D. Repeat 3 [Rotate 120 Repeat 2 [Leaf Rotate 30 Circle Rotate 150]]
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Task 9. Recognizing algorithmic patterns. Pencils Alignment



A little beaver has organised pencils in his pencil box as follows:

The little beaver wants to take a break from drawing and divide pencils from his box between Mom and Dad's boxes as follows:

- Pencils are taken from the box one by one from left to right.
- Pencils are placed in Mom's and Dad's boxes, also from left to right.
- The first pencil is placed in Mom's box.
- Each other pencil is compared with the last pencil placed in Mom's box. If it is not longer than the last pencil placed in Mom's box, then it is also placed in Mom's box. Otherwise, it is placed to Dad's box.



Mom's box after first pencil is placed



Dad's box after first pencil is placed

After placing the first pencil, Mom has one red pencil in her box and Dad's box is empty:

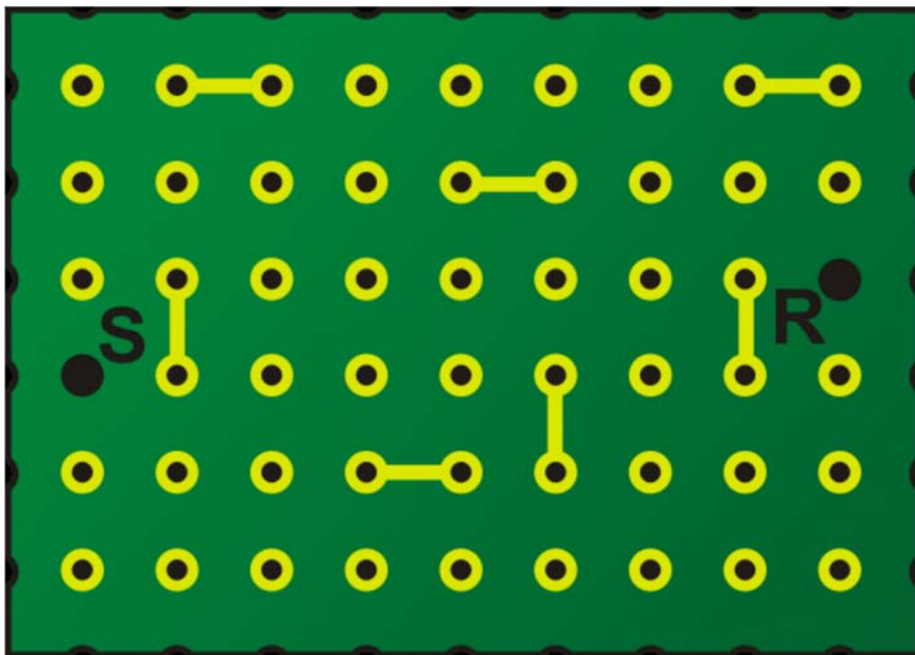
Question

What will Dad's box look like after the little beaver places the last pencil?



Task 10. Recognizing algorithmic patterns. Building a Chip

A small chip is composed of a grid of contacts (marked as dots). Some are already connected (marked as line segments). Connectors are always only between adjacent contacts, horizontally or vertically. We want to connect S and R with a continuous sequence of connectors, which do not touch any already connected contacts.



Questions

What is the smallest number of connectors that should be used to connect S and R?

How many different ways are there to connect S and R with the least possible number of connectors?

APPENDIX 3. Teamwork Skills Inventory (TSI)

In order to better understand how well you work together with your teammates, please respond to each of the following statements from the perspective of “When I am in a science course...”. Please note that the statements are worded in general but keep always in mind to express your self-evaluations based on your experience in science learning. Please mark the option that is most correct in your case.

Attending to Teamwork	Not at all true – 1	2	3	Very true – 4
1 I show acceptable attendance for meetings.				
2 I arrive on time for scheduled team meetings.				
3 I Stay focused on the task during group work.				
4 I Fulfil individual role assigned by the group.				
5 I do fair share of work expected of everyone.				
Seeking and Sharing Information				
6 I admit uncertainty about what to do.				
7 I asks questions that help understand lessons.				
8 I help by explaining or reviewing lessons.				
9 I bring reading materials for the group.				
10 I refer to reading materials during discussions.				
Communicating with Teammates				
11 I share feelings, ideas, or opinions.				
12 I speak clearly with acceptable vocabulary.				
13 I limit length of comments so others can talk.				
14 I listen to everyone and respects their views.				
15 I recognize individual contributions.				
Thinking Critically and Creatively				
16 I evaluate evidence for different opinions.				
17 I use logic to challenge group thinking.				
18 I think carefully before reaching conclusions.				
19 I combine and builds on the ideas of others.				
20 I offer new ways of looking at problems.				

Getting Along in the Team				
21 I take criticism in a friendly way.				
22 I avoid using put-downs or blaming others.				
23 I accept compromise to deal with conflict.				
24 I keep trying when a task becomes difficult.				
25 I express hope about group success.				

APPENDIX 4. Engagement vs Disaffection with Learning (EDL)

In order to better understand how engaged you have been in your science courses, please respond to each of the following statements from the perspective of “When I am in a science course...”. Please note that some of the statements are worded in general about school or classwork but keep always in mind to express your self-evaluations based on your experience in science learning. Please mark the option that is most correct in your case.

Behavioural Engagement	Not at all true – 1	2	3	Very true – 4
1. I try hard to do well in school.				
2. In class, I work as hard as I can.				
3. When I’m in class, I participate in class discussions.				
4. I pay attention in class.				
5. When I’m in class, I listen very carefully.				
Emotional Engagement				
1. When I’m in class, I feel good.				
2. When we work on something in class, I feel interested.				
3. Class is fun.				
4. I enjoy learning new things in class.				
5. When we work on something in class, I get involved.				
Behavioural Disaffection				
1. When I’m in class, I just act like I’m working.*				
2. I don’t try very hard at school.*				
3. In class, I do just enough to get by.*				
4. When I’m in class, I think about other things.*				
5. When I’m in class, my mind wanders.*				
Emotional Disaffection				
1.a. When we work on something in class, I feel bored.*				
b. When I’m doing work in class, I feel bored.*				
c. When my teacher first explains new material, I feel bored.*				
2. a. When I’m in class, I feel worried.*				

b. When we start something new in class, I feel nervous.*				
c. When I get stuck on a problem, I feel worried.*				
3. When we work on something in class, I feel discouraged.*				
4. Class is not all that fun for me.*				
5. a. When I'm in class, I feel bad.*				
b. When I'm working on my classwork, I feel mad.*				
c. When I get stuck on a problem, it really bothers me.*				
d. When I can't answer a question, I feel frustrated.*				

*reversely coded items

APPENDIX 5. Science Motivation Questionnaire II (SMQ-II)

In order to better understand what you think and how you feel about your science courses, please respond to each of the following statements from the perspective of “When I am in a science course...”. Please mark the option that is most correct in your case.

1. Intrinsic Motivation	Never	Rarely	Sometimes	Often	Always
1. The science I learn is relevant to my life.					
3. Learning science is interesting.					
12. Learning science makes my life more meaningful.					
17. I am curious about discoveries in science.					
19. I enjoy learning science.					
2. Self-Efficacy					
9. I am confident I will do well on science tests.					
14. I am confident I will do well on science labs and projects.					
15. I believe I can master science knowledge and skills.					
18. I believe I can earn a grade of “A” in science.					
21. I am sure I can understand science.					
3. Self-Determination					
5. I put enough effort into learning science.					
6. I use strategies to learn science well.					
11. I spend a lot of time learning science.					
16. I prepare well for science tests and labs.					
22. I study hard to learn science.					

4. Grade Motivation					
2. I like to do better than other students on science tests.					
4. Getting a good science grade is important to me.					
8. It is important that I get an "A" in science.					
20. I think about the grade I will get in science.					
24. Scoring high on science tests and labs matters to me.					
5. Career Motivation					
7. Learning science will help me get a good job.					
10. Knowing science will give me a career advantage.					
13. Understanding science will benefit me in my career.					
23. My career will involve science.					
25. I will use science problem-solving skills in my career.					

Note. The SMQ-II is copyrighted and registered. Go to <http://www.coe.uga.edu/smq/> for permission and directions to use it and its discipline-specific versions such as the Biology Motivation Questionnaire II (BMQ-II), Chemistry Motivation Questionnaire II (CMQ-II), and Physics Motivation Questionnaire II (PMQ-II) in which the words biology, chemistry, and physics are respectively substituted for the word science. Versions in other languages are also available.

APPENDIX 6. Survey for understanding challenges and collecting success stories in applying contemporary IBSE based STEM learning in innovative learning environments

Introduction

This is a survey carried out by the EL-STEM Erasmus+ project team internationally in Cyprus, Greece, Finland and Estonia. Behind the acronym EL-STEM is the long title of the project: The Enlivened Laboratories within STEM Education. Our aim is to motivating students to choose STEM studies & careers and improving their performance in courses related to STEM education. Therefore, we are developing instructional designs and based on these learning scenarios for using mixed reality and augmented reality in education. Your expertise would very valuable to understand the current situation and challenges in your country regarding the key aspects of the EL-STEM project – attractiveness of STEM studies and career, inquiry-based science education, innovative emerging technologies, contemporary learning approach and the characteristics on what we could have effect with the new learning scenarios we are developing.

The survey consists of 41 questions of which most are multiple choice items but some are open-ended questions. In case you have no answer to a question you can simply skip it. Depending on your familiarity with the fields of our interest the survey could be completed in about 30–50 minutes. We hope you are happy to contribute. In case of questions about the survey or if you are interested in the summary of the findings please contact with prof Margus Pedaste from the University of Tartu, Estonia (margus.pedaste@ut.ee).

Thank you!

I agree to participate and let the EL-STEM team to use my answers in project-related research and development work. YES/NO

Background

1. To which group of respondents to you belong (select all options that are currently valid for you)?
 - a) teachers
 - b) teacher educators
 - c) educational researchers

2. How long have you been working as a... (select an answer in case of all options)
 - a) teacher: never / less than a year / 1 to 5 years / 5 to 10 years / more than 10 years
 - b) teacher educator: never / less than a year / 1 to 5 years / 5 to 10 years / more than 10 years
 - c) educational researcher: never / less than a year / 1 to 5 years / 5 to 10 years / more than 10 years

What is the attractiveness of STEM studies and how engaged and motivated the students are in STEM studies in difference countries?

3. How attractive are STEM (Science, Technology, Engineering and Mathematics) related studies to the lower secondary school students (age 12–15) in your country?
 - a) the percent of students to whom these are very attractive
 - b) the percent of students to whom these are attractive
 - c) the percent of students to whom these are moderately attractive
 - d) the percent of students to whom these are not attractive
- 3.1 How big challenge is this in general in your country in 12–15 year olds STEM studies?
 - a) it is not something important
 - b) it is somewhat important but not a challenge
 - c) it is important and there are moderate challenges to achieve it
 - d) it is important and there are significant challenges to achieve it
4. How attractive are STEM related studies to the upper secondary school students (age 16–18) in your country?
 - a) the percent of students to whom these are very attractive
 - b) the percent of students to whom these are attractive
 - c) the percent of students to whom these are moderately attractive
 - d) the percent of students to whom these are not attractive
- 4.1 How big challenge is this in general in your country in 16–18 year olds STEM studies?
 - a) it is not something important
 - b) it is somewhat important but not a challenge
 - c) it is important and there are moderate challenges to achieve it
 - d) it is important and there are significant challenges to achieve it
5. How engaged are lower secondary school students (age 12–15) usually in STEM studies in your country?
 - a) the percent of students who are very engaged
 - b) the percent of students who are engaged
 - c) the percent of students who are moderately engaged
 - d) the percent of students who are not engaged
- 5.1 How big challenge is this in general in your country in 12–15 year olds STEM studies?
 - a) it is not something important
 - b) it is somewhat important but not a challenge
 - c) it is important and there are moderate challenges to achieve it
 - d) it is important and there are significant challenges to achieve it
6. How engaged are upper secondary school students (age 16–18) usually in STEM studies in your country?
 - a) the percent of students who are very engaged
 - b) the percent of students who are engaged
 - c) the percent of students who are moderately engaged
 - d) the percent of students who are not engaged

- 6.1 How big challenge is this in general in your country in 16–18 year olds STEM studies?
- it is not something important
 - it is somewhat important but not a challenge
 - it is important and there are moderate challenges to achieve it
 - it is important and there are significant challenges to achieve it
7. How motivated are lower secondary school students (age 12–15) usually in STEM studies in your country?
- the percent of students who are very motivated
 - the percent of students who are motivated
 - the percent of students who are moderately motivated
 - the percent of students who are not motivated
- 7.1 How big challenge is this in general in your country in 12–15 year olds STEM studies?
- it is not something important
 - it is somewhat important but not a challenge
 - it is important and there are moderate challenges to achieve it
 - it is important and there are significant challenges to achieve it
8. How motivated are upper secondary school students (age 16–18) usually in STEM studies in your country?
- the percent of students who are very motivated
 - the percent of students who are motivated
 - the percent of students who are moderately motivated
 - the percent of students who are not motivated
- 8.1 How big challenge is this in general in your country in 16–18 year olds STEM studies?
- it is not something important
 - it is somewhat important but not a challenge
 - it is important and there are moderate challenges to achieve it
 - it is important and there are significant challenges to achieve it
9. How often your students choose a STEM related career in your country? What is the percent of students who relates their career with STEM?
10. What are the main challenges in your country in making STEM studies attractive, to engage students more and to increase their motivation towards STEM studies and careers?
11. If you know then please describe one success story how STEM studies have been made attractive, and students are engaged and motivated. Think on a story that could be useful to learn in other countries as well.

How familiar are teachers and teacher educators in different countries with innovative emerging technologies and what are the challenges in applying them?

12. How familiar are you with the concept of Internet of Things?
- a) I have never heard about this
 - b) I have heard about this but I do not much more
 - c) I know what it is but I don't know how to implement it in STEM studies
 - d) I know how to implement it in STEM studies but I have never done that
 - e) I have used it a few times in STEM studies
 - f) I use it often in my STEM studies
- 12.1 How big challenge is there in general in your country in applying the concept of Internet of Things with 12–18 year olds STEM in studies?
- a) it is not something important
 - b) it is somewhat important but not a challenge
 - c) it is important and there are moderate challenges in applying it
 - d) it is important and there are significant challenges in applying it
13. How familiar are you with the concept of Augmented Reality?
- a) I have never heard about this
 - b) I have heard about this but I do not much more
 - c) I know what it is but I don't know how to implement it in STEM studies
 - d) I know how to implement it in STEM studies but I have never done that
 - e) I have used it a few times in STEM studies
 - f) I use it often in my STEM studies
- 13.1 How big challenge is there in general in your country in applying the concept of Augmented Reality with 12–18 year olds in STEM studies?
- a) it is not something important
 - b) it is somewhat important but not a challenge
 - c) it is important and there are moderate challenges in applying it
 - d) it is important and there are significant challenges in applying it
14. How familiar are you with the concept of Virtual Reality?
- a) I have never heard about this
 - b) I have heard about this but I do not much more
 - c) I know what it is but I don't know how to implement it in STEM studies
 - d) I know how to implement it in STEM studies but I have never done that
 - e) I have used it a few times in STEM studies
 - f) I use it often in my STEM studies
- 14.1 How big challenge is there in general in your country in applying the concept of Virtual Reality with 12–18 year olds in STEM studies?
- a) it is not something important
 - b) it is somewhat important but not a challenge
 - c) it is important and there are moderate challenges in applying it
 - d) it is important and there are significant challenges in applying it

15. How familiar are you with the concept of Mixed Reality?
- I have never heard about this
 - I have heard about this but I do not much more
 - I know what it is but I don't know how to implement it in STEM studies
 - I know how to implement it in STEM studies but I have never done that
 - I have used it a few times in STEM studies
 - I use it often in my STEM studies
- 15.1 How big challenge is there in general in your country in applying the concept of Mixed Reality with 12–18 year olds STEM in studies?
- it is not something important
 - it is somewhat important but not a challenge
 - it is important and there are moderate challenges in applying it
 - it is important and there are significant challenges in applying it
16. How familiar are you with the possibilities of using smartphones or tablets in STEM studies?
- I have never heard about how to use them effectively
 - I have heard about how to use them effectively but I do not much more
 - I know how to use them effectively but I have never done that
 - I have used them a few times in STEM studies but I'm not sure how effective it was
 - I have effectively used them a few times in STEM studies
 - I use them often in my STEM studies and usually with a good effect
- 16.1 How big challenge is there in general in your country in using smartphones or tablets with 12–18 year olds in STEM studies?
- it is not something important
 - it is somewhat important but not a challenge
 - it is important and there are moderate challenges in applying it
 - it is important and there are significant challenges in applying it
17. How familiar are you with the possibilities of using Augmented or Virtual Reality technologies (e.g., glasses, tablets, smartphones) in STEM studies?
- I have never heard about them
 - I have never heard about how to use them effectively
 - I have heard about how to use them effectively but I do not much more
 - I know how to use them effectively but I have never done that
 - I have used them a few times in STEM studies but I'm not sure how effective it was
 - I have effectively used them a few times in STEM studies
 - I use them often in my STEM studies and usually with a good effect
- 17.1 How big challenge is there in general in your country in using Augmented or Virtual Reality technologies with 12–18 year olds in STEM studies?
- it is not something important
 - it is somewhat important but not a challenge
 - it is important and there are moderate challenges in applying it
 - it is important and there are significant challenges in applying it

18. What are the main challenges in your country in applying innovative emerging technologies in STEM studies?
19. If you know then please describe one success story how innovative emerging technologies have been successfully used in STEM studies. Think on a story that could be useful to learn in other countries as well.

How familiar are teachers and teacher educators in different countries with innovative pedagogies and contemporary learning approach used in EL-STEM project and what are the challenges in applying them?

20. How familiar are you with the inquiry-based learning approach (in particular, how to follow its phases Orientation, Conceptualization, Investigation, Conclusion, Discussion) in STEM studies?
- a) I have never heard about inquiry-based learning approach
 - b) I have heard about this but it's completely different what's described here
 - c) I know about this but I don't know how to use it effectively
 - d) I know about this and how to use it effectively but I have never used this
 - e) I have used this a few times but I'm not sure how effective it was
 - f) I have effectively used this a few times in STEM studies
 - g) I use this often in my STEM studies and usually with a good effect
- 20.1 How big challenge is this in general in your country in 12–18 year olds STEM studies?
- a) it is not something important
 - b) it is somewhat important but not a challenge
 - c) it is important and there are moderate challenges in applying it
 - d) it is important and there are significant challenges in applying it
21. How familiar are you with the methods for supporting critical thinking skills (e.g., verbal reasoning, argument analysis, hypothesis testing, using likelihood and uncertainty, decision making and problem solving) in STEM studies?
- a) I have never heard about methods for supporting critical thinking skills
 - b) I have heard about them but I don't know how to use them effectively
 - c) I know about them and how to use them effectively but I have never used them
 - d) I have used them a few times but I'm not sure how effective it was
 - e) I have effectively used them a few times in STEM studies
 - f) I use them often in my STEM studies and usually with a good effect
- 21.1 How big challenge is this in general in your country in 12–18 year olds STEM studies?
- a) it is not something important
 - b) it is somewhat important but not a challenge
 - c) it is important and there are moderate challenges in applying it
 - d) it is important and there are significant challenges in applying it

22. How familiar are you with the methods for supporting teamwork or collaboration skills (e.g., attending teamwork, seeking and sharing information, communicating with teammates, thinking critically and creatively, getting along with teammates) in STEM studies?
- I have never heard about methods for supporting critical thinking skills
 - I have heard about them but I don't know how to use them effectively
 - I know about them and how to use them effectively but I have never used them
 - I have used them a few times but I'm not sure how effective it was
 - I have effectively used them a few times in STEM studies
 - I use them often in my STEM studies and usually with a good effect
- 22.1 How big challenge is this in general in your country in 12–18 year olds STEM studies?
- it is not something important
 - it is somewhat important but not a challenge
 - it is important and there are moderate challenges in applying it
 - it is important and there are significant challenges in applying it
23. How familiar are you with the methods for supporting computational thinking skills (e.g., making abstraction, decomposing systems, creating algorithms, evaluating systems, making generalisations about algorithms or systems) in STEM studies?
- I have never heard about methods for supporting critical thinking skills
 - I have heard about them but I don't know how to use them effectively
 - I know about them and how to use them effectively but I have never used them
 - I have used them a few times but I'm not sure how effective it was
 - I have effectively used them a few times in STEM studies
 - I use them often in my STEM studies and usually with a good effect
- 23.1 How big challenge is this in general in your country in 12–18 year olds STEM studies?
- it is not something important
 - it is somewhat important but not a challenge
 - it is important and there are moderate challenges in applying it
 - it is important and there are significant challenges in applying it
24. What are the main challenges in your country in applying innovative pedagogies and contemporary learning approach in STEM studies?
25. If you know then please describe one success story how innovative pedagogies or contemporary learning approach have been successfully used in STEM studies. Think on a story that could be useful to learn in other countries as well.

Conclusion

Thank you for your answers!

Some of them might need some additional clarifications. Therefore, we would be delighted if you could give you contacts. However, if you want to be anonymous then this is your choice.

Name:

E-mail:

Exit page

Thank you for submitting your answers!

If you have any questions, you are interested in our findings or you want to share some materials about the success stories then please e-mail to your national coordinator of the survey:

- Margus Pedaste from the University of Tartu, Estonia (margus.pedaste@ut.ee)
- Maria Meletiou-Mavrotheris, Ilona-Eleftherya Lasica from the European University of Cyprus, Cyprus (M.Mavrotheris@euc.ac.cy, i.lasica@research.euc.ac.cy)
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