International Journal of Mobile and Blended Learning
Volume 14 • Issue 4

Investigating Students' Conceptual Understanding of Socio-Environmental Problems

Kadri Mettis, Tallinn University, Estonia*
Terje Väljataga, Tallinn University, Estonia

ABSTRACT

The aim of this study was to investigate how mobile outdoor learning supports the development of students' conceptual understanding about local socio-environmental problems and students' attitudes towards the learning activity. To explore these aspects, a study following a design-based research model was designed and conducted with 68 eighth-ninth grade students. The learning design of the activity incorporated a number of mobile learning tools: environmental data collecting devices, tablets and students' smartphones with outdoor learning apps to facilitate the learning activity, which was mainly conducted outdoors. Research data was collected with semi structured pre- and post-questionnaires. The results showed that the students' conceptual understanding about the study topic developed significantly, and they were positively minded about their experience in working on a socio-environmental issue. Based on the results, it can be concluded that mobile outdoor learning activities focusing on timely socio-environmental problems have the potential to increase students' conceptual understanding.

KEYWORDS

Attitude, Concept Development, Conceptual Knowledge, Location Based, Location-Responsive Pedagogy, Mobile Outdoor Learning, Mobile Outdoor Learning App, Socio-Environmental Problems

INTRODUCTION

As part of the 2030 Agenda for Sustainable Development, world leaders agreed on seventeen objectives, the Sustainable Development Goals (United Nations, 2015). These objectives draw attention to common needs across nations, societies, and cultures for practices that preserve the survival of environmental and social institutions while also taking into account people's economic needs. Therefore, it is crucial to pay more attention to the environment and raise awareness about different problems around us and raise a new generation of people who already are prepared for the rapidly changing future. The educational system plays a significant part in increasing future generations'

DOI: 10.4018/IJMBL.315626 *Corresponding Author

consciousness. Science education in particular can be viewed as a tool for achieving social change and engaging with the world ethically (Jeong, Sherman & Tippins, 2021). Fast developing technology is giving us new ways of working and learning that have never existed before, however, technology itself won't solve the problems. People are the ones who will solve the problems, for that we need to raise students who are capable of doing it.

Outdoor learning has gained increased attention in recent years in the context of sustainability and global environmental issues. The emergence of location-based approaches has refocused attention on the pedagogical value of place and the power of direct embodied experience in education, as going outside provides numerous opportunities for learning through everyday socio-economical environmental problems inherent to a particular location (Roberts, 2018). In outdoor settings, this creates issues for pedagogical models and instructional designs (Mettis & Väljataga, 2020). There is a need for a location-responsive pedagogy that recognizes and uses the local environment, culture, and place (Gray, 2019). The core concept of place-responsive education is that it "implies openly educating by means of an environment with the goal of understanding and enhancing human–environment relationships" (Mannion, Fenwick & Lynch, 2013, p. 803).

There is a significant number of studies about mobile technology use in learning outside in both formal (Kärki et al., 2018) and informal environments (Squire & Jan, 2007; Land & Zimmerman, 2015). Several studies (Nikou & Economides, 2017; Sung, Chang & Liu, 2016; Zacharia, Lazaridou & Avraamidou, 2016) show that meaningful mobile outdoor learning events may be created that are collaborative, active, and contextual, with favorable outcomes for student learning. However, assessing students' scientific concept development and vocabulary acquisition in order to describe complex socio-environmental phenomena, as well as obtaining scientific understanding in order to present critical and evidence-based arguments, has not been a priority. In secondary science education, there is a knowledge gap in mobile technology-supported inquiry-based learning (Liu, et al., 2020), particularly in terms of understanding how to use mobile technologies to empower students' scientific inquiry and comprehension in authentic situations. Furthermore, there is also a lack of research in the non-gamified usage of mobile technology in outdoor learning (Kraalingen, 2021).

Based on the previous research, we have run an experimental study with 3 schools, using a mobile outdoor learning design, where students investigate a problem relevant to society and how to approach it in a scientific way. The instructional aim of this study was to raise students' awareness about socio-environmental problems and provide conditions to practice forming an evidence-based opinion and arguments about a specific problem in society, to start thinking in scientific terms.

THEORETICAL BACKGROUND

Mobile Outdoor Learning

The rapid advancement of mobile and wireless technology has resulted in a rise in the use of mobile devices in the classroom. Learning can occur and be promoted on the move with the help of various mobile devices, allowing students to leave the classroom, merge formal and informal learning outside, and bridge the gap between previously isolated contexts. Learners can hold dialogues across many settings and establish synergies to cocreate knowledge thanks to the possibilities of mobile technology. Mobile outdoor learning promotes site-specific learning experiences (Laurillard, 2007), such as learning in, about, and through context (Sharples, 2016), as well as continuity between contexts. Mobile technology, according to Suárez et al. (2018), allows students to keep track of their inquiry process, data collection, and peer-to-peer engagement while also allowing them to have discussions across multiple contexts and produce symbiosis to co-create information and timely access to content and contextual support. It has the ability to actively immerse students in authentic scientific roles (Burden & Kearney, 2016) and improve students' science learning experiences through inquiry-based learning (Liu et al., 2020). Several studies have found other benefits to using mobile technology outdoors, including the potential for a more in-depth learning experience and greater participant knowledge (of a place) (Kamarainen, et al., 2018; Zimmerman, Land, Maggiore & Millet, 2019). According to Burden and Kearney (2016), mobile devices can mediate the "flow of learning" between various contexts, bridging the gap between the classroom and the real world (Cotic et al., 2020).

Conceptual Change

Students always have some prior knowledge and ideas about different science topics. They have personal experiences, motivations and dispositions (Alongi, Heddy & Sinatra, 2016). Limón (2002) has outlined four dimensions of individuals' prior domain specific knowledge: 1) certainty of knowledge, from uncertain to certain; 2) affective entrenchment of knowledge, low emotional reactions to strong emotional reactions; 3) coherence of knowledge, from no coherence to highly structured and ordered according to the individual's theories; 4) generality-specificity of knowledge, from specific knowledge to one area of the topic to general knowledge applicable to a number of areas. It is important to notice and correct misconceptions during the learning activity, because some misconceptions can limit coherence and logical understanding of one or both sides of the issue (Alongi et al., 2016).

Conceptions can be regarded as the learner's internal representations constructed from the external representations of entities, by other people such as teachers, textbook authors or software designers (Treagust & Duit, 2008). Conceptual change is a type of learning that takes place when individuals change their knowledge from naïve, conflicting, and misconceived to more scientifically accepted knowledge (Chi, Slotta & De Leeuw, 1994; Vosniadou, 2004). Thus, a misconception is defined as knowledge that misaligns with scientific knowledge (Heddy, Danielson, Sinatra & Graham, 2017). More specifically, Chi (2013) theorizes that misconceptions can exist as either inaccurate or incommensurate with scientific knowledge. Inaccurate misconceptions are those where learners have details of the conception, but inaccuracies exist within their framework of knowledge, whereas incommensurate misconceptions are knowledge where learners place the ideas into incorrect categories or do not have the relevant schemas (Chi, 2013). Further terms like alternative conceptions, alternative worldviews, naive conceptions, and lay conceptions are used to explain a student's incomplete understanding of a concept (Vosniadou, 2013). Conceptual change theory has shed light on how individuals change or restructure their thinking to overcome preconceived notions, naïve conceptions, or misconceptions (Sinatra & Pintrich, 2003).

Conceptual Change and Attitude

Effective teaching, based on the conceptual change theories, must be done in a way that students understand the need to change the concept in their minds and should be encouraged to do so - it is required to motivate and inspire their curiosity about their daily experiences (Vosniadou, 2008). Putting students into real life situations could serve as a motivating factor. It is found that placing students in interesting and unexpected situations results in the replacement of wrong schemes with the best alternative (Redish, 1994). Giving students the possibility to simulate real life situations could change their emotions and attitudes. Previous research suggests that emotions and attitudes precede and impact knowledge change with conceptual change as the outcome (Gregoire, 2003). Also, instructors who integrate controversial and meaningful discussion in their instruction can more effectively support their students' positive attitudes, engagement, and conceptual change (Broughton, Sinatra & Nussbaum, 2013).

Existing knowledge, emotions, and attitudes influence learning in most domains (Maio & Haddock, 2010; Pekrun, Frenzel, Goetz & Perry, 2007). However, Heddy et al. (2017) bring out that this process may be particularly prominent in the science domain given the perceived controversial nature of many concepts and the conceptual nature of science (Heddy et al., 2017). For example, Heddy and Sinatra (2013) found that when individuals engage in conceptual change, they are more likely to show emotional change as well. Sinatra and Seyranian (2016) argue that those individuals who fall in the inaccurate knowledge category would be more likely to have negative attitudes and those in the accurate knowledge category would have positive attitudes. Heddy et al. (2017) noted that shifting attitudes is important because this could influence how individuals approach and acquire knowledge in the future. They also argue that if individuals have negative attitudes towards, and misconceptions about, a topic and subsequently engage in conceptual change, their attitudes may become more positive, and thus, their new positive attitudes may lead them to seek out more information on the topic, remember related information, and be more open to learning the content in the future (Heddy et al., 2017).

Understanding the complexity of environmental problems, such as road construction's influence on the local environment requires integration across disciplinary boundaries and scientific skills and knowledge from the students. Drawing upon existing education research and specifically employing insights on mobile outdoor learning, this study empirically examines how participating in authentic, inquiry-based investigation about road construction may improve students' conceptual knowledge about the environmental problem by helping them see how basic research processes (e.g., research design principles, sampling, measurement, and statistical analyses) span different disciplines.

METHODOLOGY AND DESIGN

Research Approach and Questions

The aim of this study was to develop an experimental learning event to investigate the development of students' conceptual knowledge and attitudes towards mobile outdoor learning. Based on design-based research (Baumgartner et al., 2003) three consecutive learning events with different groups of students were organized. Every learning event was analyzed and reflected by two teachers/researchers and necessary changes were made to the design of the next event and its research approach. The guiding research questions were as follows:

1. What are students' attitudes towards the mobile outdoor learning activity?
2. How does the mobile outdoor learning activity contribute to students' conceptual understanding and how does it relate to students' attitudes towards the learning activity?

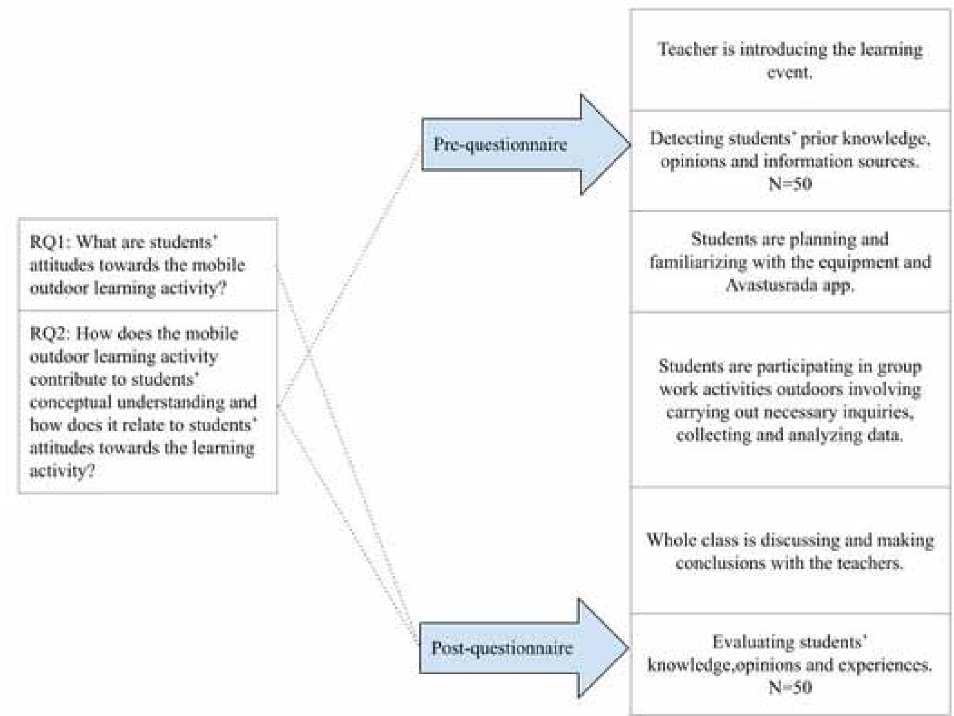
Design of The Study

A 4-hour learning event was organized around an authentic and timely problematic dilemma in Tallinn - construction of a new section of road (Reidi Road). The main focus of the learning task was to provide students with a number of different interdisciplinary learning activities (collecting, analyzing and interpreting data for mapping the current environmental situation in the location of the planned Reidi Road and drawing conclusions based on that) to form an evidence-based opinion about Reidi Road (non)construction. The activities and instructions were discussed thoroughly with the subject teachers based on the Estonian National curriculum (2011). The study had four learning goals:

- To learn how to make and justify informed decisions about socio-environmental questions taking into account social and natural science concepts, as well as ethical values;
- To set research questions and hypotheses related to the socio-environmental dilemma, analyze and interpret collected data and make conclusions from results;
- To gain know-how of how to make use of technology (web-based application, robot, sensors) for supporting environment related inquiry activities (air quality, soil quality, water quality)
- To value the environment, and a sustainable and healthy lifestyle.

The activities started with a whole class introduction to the topic which happened in the Tallinn University classroom (Figure 1). The students were given an overview of the study topic, learning goals and learning tools, which included a mobile application Avastusrada (Discovery track- https://avastusrada.ee/en), Lego EV3 robots and Vernier sensors. After the introduction the students were

Figure 1. Birds-eye view of the learning event and research design



asked to fill in a questionnaire about their opinions regarding the study topic, i.e., whether to build the road or not, explanations about their opinions, and some additional descriptive information. Then collaborative inquiry-based learning activities to map the environmental situation near the planned Reidi Road construction followed. The groups were formed beforehand by their own teacher to make sure that every group had a member with a personal smartphone equipped with mobile data. Every group had a different ecological theme (air, soil, water) that they were going to investigate in this certain area near the roadworks. In groups the students searched for background information about the theme, and formulated hypotheses and research questions about their specific topic. After setting their research topic the students headed outside to start collecting data from the environment. The entire learning event was structured and framed with a location- and web-based tool Avastusrada (see a more detailed description below). Every group had a specific track with 3 marked locations in it. The Avastusrada system also provided them with instructions on how to conduct measurements and was used as a tool for collecting and saving data about different locations. Lego EV3 robots, iPads and different sensors (salinity, conductivity, temperature (2), pH (2), TRIS pH, turbidity, anemometer, barometer, dissolved oxygen, sound level sensor, relative humidity, light sensor, soil moisture sensor, infrared thermometer), presentation papers and pencils were provided for every group. Practical work outside was followed by analysis and presentation of the collected data in the classroom. Every group summarized their results and presented these to other groups. As a closure activity, whole class discussion and reflection was used and general conclusions were drawn.

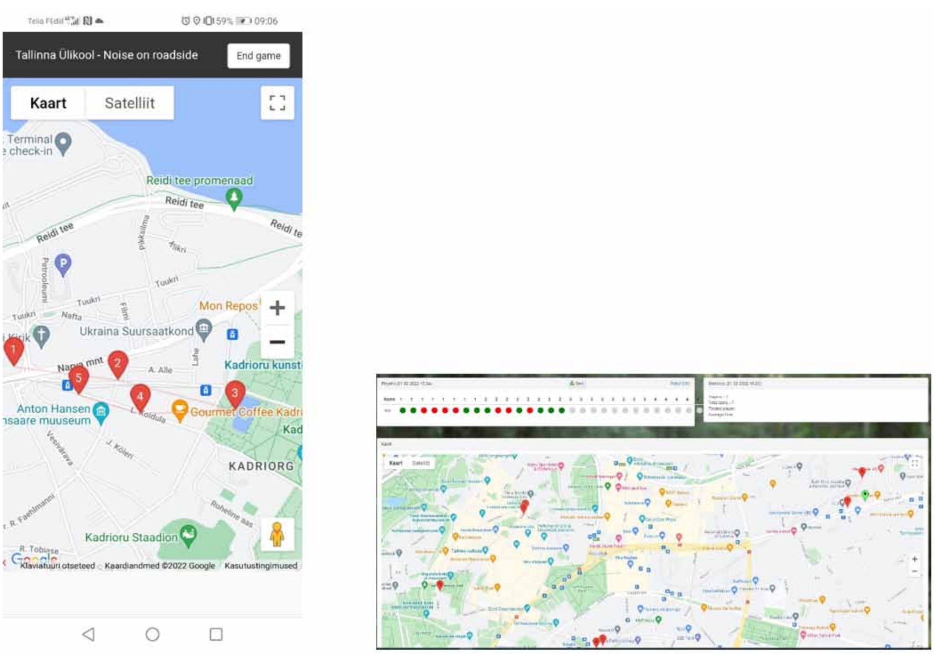
Technological support: Avastusrada; Vernier sensors and Lego EV3

The Avastusada app (Discovery Track-https://avastusrada.ee/en) was used to facilitate the outdoor group work activity. It is a browser-based platform for creating and following location-based learning tracks outside the classroom. Avastusrada was used to help students navigate in an unfamiliar location and provide them with necessary support and guidance. Avastusrada was utilized with four goals in mind: to guide instructions, give content access, facilitate data collection, and allow context and learner involvement (Suarez et al., 2018). Using Avastusrada requires a smartphone or a tablet, which has an Internet connection (WiFi, 3G or 4G) that allows making use of GPS location services. Questions related to chosen locations can be created and incorporated into meaningful tracks. Questions can be textual, including photos, videos, audio or animations for additional information.

The Avastusrada app directed the pupils to various destinations. Every specific location had a task where they had to read the instructions and then observe, measure, compare, analyze, take a picture, gather, and so on based on the information. They were directed to follow the trail and continue to fill in the tasks in other locations once the activities in one location were completed (Fig 2). The Tracks were made up of 6-8 various location points. The application offers a list of templates for creating different types of questions: multiple choice answers, free form answers, one correct answer, providing info and photos. Different types of questions could be created allowing players for instance to explore the surroundings, answer the questions or carry out some measuring in the surroundings and submit the value. To support teachers' awareness about students' progress while following the track, it is possible to see submitted answers to every location point by every student (or student group). The students' movement and their location are monitored by GPS. The location points with questions and tasks get activated when students reach the particular location (see Figure 2) and turn green as soon as the answer to the question or the task has been submitted. Depending on how the track has been designed, the students can visit location points randomly or in a predefined order. The application also displays simple statistics, such as the number of players, location points, time for completing the track etc.

As a measuring tool Vernier sensors and Lego EV3 brains were used additionally to students' smartphones and other tools. Vernier sensors are designed specifically for active, hands-on experiments allowing carrying out various measurements in outdoor settings. Due to some economic reasons within the context of our project, the sensors are used in combination with an EV3 robot's brain to

Figure 2. Screenshots of Avastusrada



read measured data. The data can be inserted manually by students to the Avastusrada application as an answer to a question in the particular location point. The aim of this study was to develop an experimental learning event to investigate the development of students' conceptual knowledge and attitudes towards mobile outdoor learning. Based on the design-based research (Baumgartner et al., 2003) three consecutive learning events with different groups of students were organized.

Participants

This study involved 68 students from grades 8 to 9 (14-15 years old) from 3 different schools in Tallinn. 18 students were from 8th grade (school A) and 50 students were from 9th grade (25 from school B and 25 from school C). The schools who participated volunteered for this study and were informed about the goals and design of the study. All participating students had informed consents from their legal representatives. In order to compare the development of students' conceptual understandings the pre- and post-questionnaires were compared. Some data was lost due to that, because the learning events took place over a long period and some students came later and some students left earlier, therefore missing either pre-questionnaire results or post-questionnaire results. In the final sample 50 students were included who had completed the whole learning activity and had filled both questionnaires.

Data Collection and Analysis

For data collection and analysis two instruments with qualitative and quantitative methods were used. Semi-structured questionnaires were presented to the students before and after the learning activities to get information about their opinions with additional explanations regarding the study topic. The questions regarding students' attitudes towards the mobile outdoor learning activity were presented in the post-questionnaire. Both questionnaires were conducted in Google Forms. The collected data was categorized and analyzed as follows:

1. Students' explanations about their opinion of the socio-environmental problem before and after the learning event were used to determine the process of restructuring conceptual knowledge about a certain phenomenon from a non-scientific to a scientific perspective. The explanations were coded according to Alongi et al.'s (2016) operationalization of conceptual change: "0" - no knowledge, "1" – an inaccurate understanding; "2" – a hybrid conception (accurate understanding mixed with misconceptions); "3" – an accurate but underdeveloped understanding (includes 1 correct explanation); "4" – an accurate but not perfectly developed understanding (2 correct explanations); "5" – a well-developed understanding (3 or more correct explanations).
2. To explore the students' attitudes and experience regarding the overall learning event and the technology used, seven semantic differential questions on a 5-point scale with bipolar adjectives (Osgood et al., 1957) were presented in the aforementioned semi-structured post-questionnaire creating a basis to evaluate three basic dimensions of attitudes:
    a. *evaluation* as a positive or negative opinion about the overall learning experience, learning tasks, personal capability to participate in the learning activity and used technology (included statements I don't like/I like to study outside with mobiles and sensors; I was not good/I was good at solving the tasks; Avastusrada was not understandable/was understandable; It was not easy/was easy to use robots and sensors).
    b. *potency* referring to how powerful the learning experience is for the student (included statements Assignments were not/were complicated and Assignments were not interesting/were interesting).
    c. *activity* as seen active or passive for the student (included a statement I don't want/I want to study like this in the future).

All freeform answers were coded by 2 independent raters. Inter-rater reliability was calculated by using Cohen's Kappa, the result ($K= .747$, 95% CI, .659 to .835, $p< .001$) showed substantial agreement. The disagreed categories were later discussed and agreed on. After coding the students' explanations, analysis was conducted with the SPSS statistics program, using descriptive statistics and Wilcoxon Signed-Ranks test to indicate statistically significant differences in pre- and post-questionnaire answers, Cross-tabulation and Fishers' exact test were used to identify relationships between attitude and conceptual knowledge categories.

RESULTS

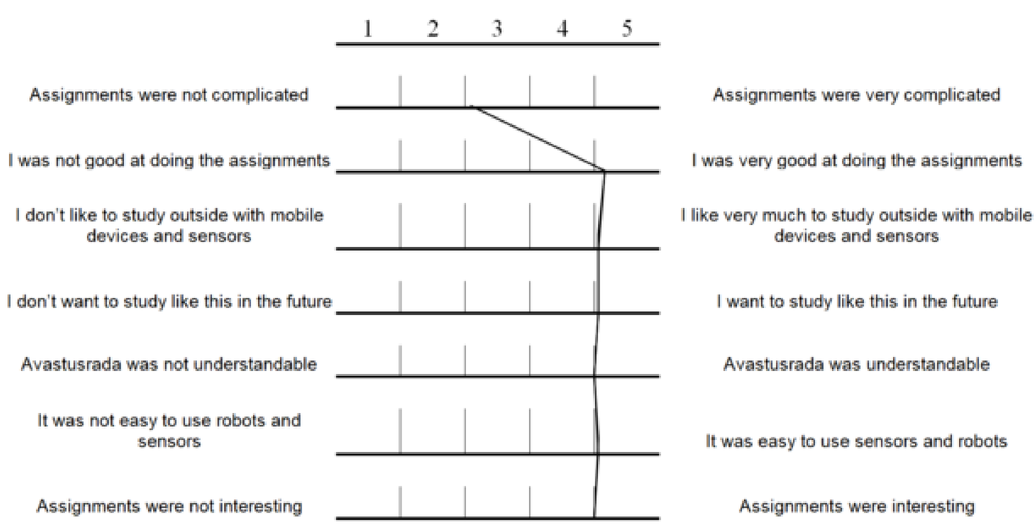
Students' Attitudes Towards the Learning Activity

The seven semantic differential questions with bipolar adjectives about the learning experience, tasks, personal capability to deal with the specific learning assignments and used technology were used to assess students' attitudes towards the learning activity. Cronbach's alpha was used to calculate the reliability coefficient for items in the attitude questionnaire. One of the variables was in the opposite direction. It was re-coded in the same direction as other questions. Cronbach's alpha value was 0.816, which is considered acceptable.

The analysis of the questionnaire answers revealed that in general the students had mainly positive reactions as seen in Figure 3.

Evaluation: The overall opinion about the learning experience was positive. The results show that the students' like to study outdoors with mobile devices and measuring sensors (Mdn=4, Mean=4,1). Out of 50 students 78% were positively minded, 14% of the answers were neutral and 8% were negative. Regarding the students' task solving ability (carrying out an inquiry about the environmental issues in the area), the overall opinion was confident (Mdn=4, Mean= 4,2), only 4% of the students experienced that they were bad at carrying out the tasks, 14% of the students were neutral and the rest of the students (82%) considered themselves to be good at carrying out the tasks. Regarding the ease of use of technological devices, 78% of students reported that it was easy to use robots and sensors for completing the tasks (Mdn=5, Mean=4,1). From 50 students 12% answered that it was difficult, 10% students thought robots and sensors were neither easy nor difficult to use.

Figure 3. Results of the semantic differential scale



Moreover, 80% of the students stated that Avastusrada application was understandable, 14% were neutral and 6% reported that Avastusrada was not understandable (Mdn=4, Mean=4.2).

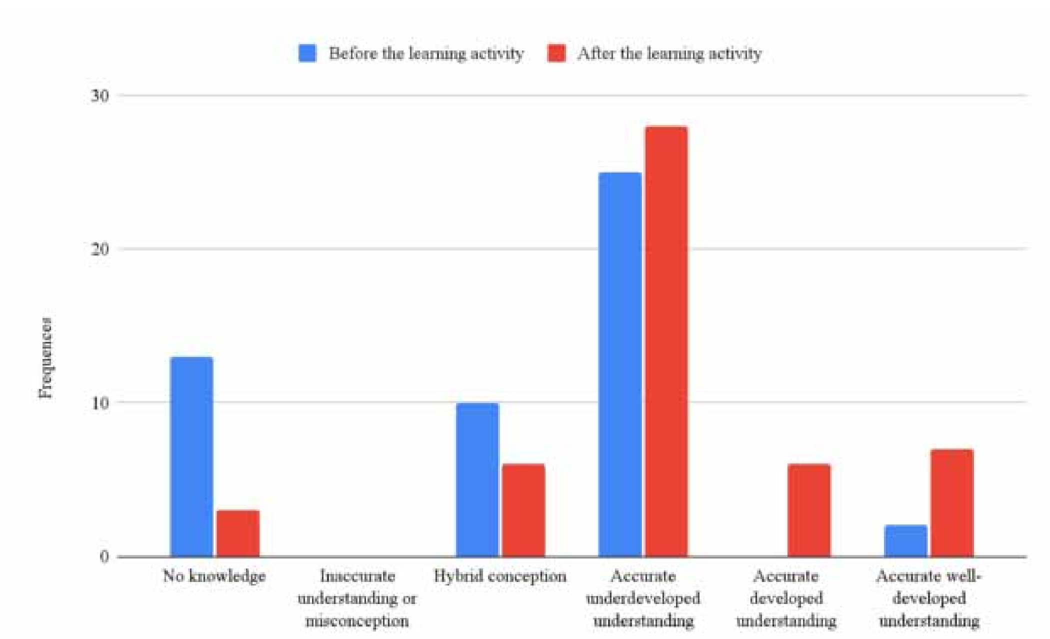
Potency: The learning activity certainly had an effect on students' experience. The majority of the students (76%) considered the tasks interesting (Mdn=4, Mean=4,1) and only 4% of the students thought that it was boring. With respect to the complexity of the learning tasks, most of the students didn't find the overall learning activity complicated (Mdn=2, Mean= 2,1) as seen in Figure 3. 66% of students stated that the assignments were not complicated, approximately 18% of the students found the assignments neutral and 16% of the students considered the learning activity to be complicated.

Activity: Whether the students would like to participate in this kind of learning activity in the future, the results show that in general they were positively minded about the learning activity (Mdn=5, Mean=4,1). 76% of the answers were positive, 12% neutral, 10% would prefer not to learn in this way again.

Students' Conceptual Understanding of the Socio-Environmental Topic

Regarding the students' conceptual change, i.e., their overall understanding of the socio-environmental problem and the use of scientific terms to explain their opinion (Figure 4), demonstrates that there has been a development in students' conceptual understanding about the socio-environmental issue. The number of students who stated to have no knowledge of the problem was reduced from 13 to 3. There were no students who had completely inaccurate conceptions in their explanations before and after the activity. The number of students who had hybrid conceptions reduced from 10 to 6. The most numerous category was "Accurate underdeveloped understanding" with 25 responses before and 28 after the activity. No students had an accurate developed understanding before the activity but there were 6 after. Also, the number of students with the highest conceptual knowledge category increased from 2 to 7. The Wilcoxon Signed-ranks test was conducted to compare the categories of explanations before and after the activity. There was a significant difference in the explanation before (Mdn=3) and after (Mdn=4) the learning event; Z=-4.02, p<0,001. These results suggest that

Figure 4. Students' conceptual understanding about the socio-environmental problem



during the learning event the students acquired more detailed and in-depth knowledge about the study content. The possibility to practice a scientific approach to the problem raised their awareness about the socio-economic situation, resulting in more thorough explanations in their answers.

Students' Conceptual Understanding in Relation to Attitudes Towards the Learning Activity

To see if the attitude had an influence on the development of students' conceptual understanding, we created two new variables. The first variable was attitude which was calculated as the mean of all the 7 questions of attitude block. The variable was then recoded into two categories: negative and positive attitude (the values from 1 - 2.5 were coded as negative and from 2.6 - 5 were coded as positive). The second new variable was conceptual change. The conceptual change variable was calculated by subtracting the pre-questionnaire conceptual understanding category from the post-questionnaire conceptual understanding category. The new variable was then recoded into two categories: no conceptual change and conceptual change (no conceptual change was representing values that were smaller than or equal to 0, conceptual change was representing all positive values). Cross-tabulation was used to identify the distribution of the results. Because of the small sample size, Fishers' Exact Test was used to identify significant differences in the distribution of data. The test indicated no significant relationships between the created variables' attitude and conceptual change ($p>0.05$).

From this cross tabulation we can see that there were 10 students who had a negative overall attitude about the learning activity but still developed their conceptual understanding further and there were 18 students who had a positive attitude but did not develop their conceptual understanding further. In a closer look at the data we found that there was a significant number of students who already had a high conceptual understanding of the topic. Mostly these were the students who also didn't develop conceptual understanding further even though they liked the activity.

DISCUSSION

It is important to study students' attitudes because increased motivation, interest, and confidence helps students learn (Su & Cheng, 2015; 2013). The results of our study show students' positive attitude towards the designed learning activity. The students see this kind of learning event as a powerful and promising experience also in the future. Based on the collected data it is not possible to firmly detect, which element of the learning activity played the biggest role, the use of technology or the novel problem based outdoor activity as they both received equally positive feedback (ease of Avastusrada use and interesting learning activity) from students. However, the overall positive attitudes towards the learning activity, the interdisciplinary, mobile outdoor learning activity about the timely socio-environmental problem in students' hometown can be considered motivating for students. Although some studies show (for instance, Cavagnetto, 2010) that bringing socio-scientific issues into the school lessons outside the safe classroom supported by a set of mobile devices is more demanding for students, our learning design has demonstrated the opposite. Being an interesting task for students and carrying the tasks out in groups definitely reduces the feeling of the level of difficulty for individual students. Nevertheless, being a small-scale study, we don't want to diminish previous research results

Table 1. Cross Tabulation of variables attitude and conceptual change

	Conceptual change	No conceptual change	Total
Negative attitude	10	4	14
Positive attitude	18	18	36
Total	28	22	50

regarding the increased challenges for students that real socio-scientific problems and dilemmas as a study topic brings along. Mobile outdoor learning with location-responsive pedagogy that recognizes and uses the problems in local environment, culture, and place (Gray, 2019) unquestionably creates another layer of complexity that needs to be studied further and taken into consideration while designing such learning activities.

Being positively disposed, our study demonstrated that conceptual understanding of the complex socio-environmental problem was developed further. This finding is in line with Heddy & Sinatra (2013) in that when individuals engage in conceptual change, they tend to show positive emotions. Similar arguments have been made by Sinatra and Seyranian (2016) - individuals who fall in the inaccurate knowledge category would be more likely to have negative attitudes and those with accurate knowledge would have positive attitudes. According to Heddy et al. (2017) positive attitudes may lead students to seek out more information on the topic, remember related information, and be more open to learn the content in the future i.e., experience transformative learning (Pugh et al., 2017). It was beyond the scope of this study to explore students' transformative experience, however, this is one of the further steps in our research line.

Although many students liked the learning activity, there was no connection found between students' attitudes and conceptual change. One of the explanations might be the previously mentioned notion that solving socio-scientific issues in the class might be too challenging for students resulting in hardly improved conceptual understanding. The students might have a positive experience and be engaged in the activity, but it doesn't necessarily mean that they would develop their conceptual understandings further. Another explanation can be related to the lack of scaffolding and the specifics of the learning design. In particular, carrying out an open inquiry outdoors is a complex task, which consists of several smaller steps and student decisions of how to proceed, therefore more targeted procedural and metacognitive scaffolding could have played a role to elaborate their conceptual understanding and make meaningful connections. Inquiry-based methods are promising approaches to learning, but it also needs to be emphasized that scaffolding in the inquiry-based learning process plays a crucial role (Hmelo-Silver et al., 2007), especially in the first phases where students get into the topic and start planning their inquiry, setting up hypotheses (Xing et al., 2019). Without a question, decisions for learning design play an important role here. However, everyday life situations and debates in the society that are connected to the students could be engaging, especially in authentic contexts, being in the middle of the actual problem under study.

As demonstrated, not all the students benefited equally from this learning experience in terms of acquiring a higher-level conceptual knowledge about the topic. One reason here could be the level of students' previous conceptual understanding. As we also noted in the Results section there was a significant number of students who didn't develop further their conceptual understanding about the socio-environmental topic. These students already had some proper conceptual understanding about the topic, thus obviously the design of the learning activity didn't provide an opportunity for them to improve their knowledge base. This demonstrates quite clearly that the learning activities should be more personalized, taking into account students' previous knowledge and capabilities. It should be noted here as well that the research design could have hampered students' motivation to answer the post-questionnaire, not demonstrating their actual knowledge gain because the same questions were presented to them before and after the learning activity related to their opinion and understanding of the socio-environmental problem. Therefore, both the learning activity itself and also the research design should be reconsidered in future studies.

CONCLUSION

The presented study introduced a learning design that incorporates ideas from mobile outdoor learning and the development of conceptual understanding. In particular, this study provided evidence on how practicing scientific methods and introducing an authentic socio-economic-environmental problem can affect students' conceptual understanding and opinion formation. Despite the positive research results in terms of students' knowledge gain, we are well aware that they are not generalizable due to the small sample size of the study. However, gaining a better understanding of how this particular learning design supports conceptual change in terms of more accurate and better developed scientific explanations, allows us to further take up at least two directions among many others. On the one hand, we may further develop the design of the learning event and study more in depth individual students' learning gains and paths in collaborative settings, as well as the limiting factors for further personal growth, be they technological solutions, collaboration settings, or personal particularities with prior knowledge and motivation. In particular, an effect on the students' immediate, out of school life - transformative experience (Pugh et al., 2017) would be of interest. On the other hand, the case study has provided a solid basis to scale up the implementation of this design and widen the research scope and focus. Namely, exploring teachers designing, implementing, scaffolding and monitoring these types of outdoor learning events in which every student group operates on their own. As the current formal science education often fails to address a holistic view on life-related phenomena not connecting learning tasks with actual everyday socio-economical-environmental problems, finding ways to demonstrate how science relates and influences every person and the whole society (Claussen & Osborne, 2013), one of the further steps is also to explore the actual potential of this type of design to contribute to person's science capital (Archer et al., 2015).

ACKNOWLEDGMENT

The authors of this publication declare there is no conflict of interest.

This project is partially funded by the European Union's Horizon 2020 Research and Innovation Programme [grant agreement No. 669074]; and the European Union's Horizon 2020 research and innovation programme [grant agreement No 856954].

Conflicts of Interest

We wish to confirm that there are no known conflicts of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome.

Funding Statement

No funding was received for this work.

Process Dates:

Received: August 21, 2022, Revision: December 3, 2022, Accepted: December 3, 2022

Corresponding Author:

Correspondence should be addressed to Kadri Mettis, kadrimet@tlu.ee

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Kadri Mettis is a PhD student and junior researcher in Tallinn University, school of Digital Technologies. She holds a Master's degree from Tartu University High school science teacher (Biology, chemistry) curriculum. Currently her research interests are related to mobile outdoor learning, educational technology, and STEAM education.

Terje Väljataga is an Associate Professor in new learning environments and technologies at Tallinn University, School of Educational Sciences. She holds a Master's degree in Geoecology, Tallinn University, Estonia; a Master degree in Telematics Applications in Education and Training, University of Twente, The Netherlands, and a Doctor of Science in Technology, Hypermedia Lab, Tampere University of Technology, Finland. Currently her research interests are related to mobile outdoor learning, educational technology and learning design.