Mobile Outdoor Learning Effect on Students’ Conceptual Change and Transformative Experience

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Abstract
Using mobile technologies in education has a lot of potential to take learners outside of their regular classrooms and mediate learning scenarios that are related to real-life situations. Mobile outdoor learning could help students to establish connections between learned concepts and their everyday life. To find out if mobile outdoor learning could be used to shift students’ scientific understandings and to facilitate their knowledge transfer, i.e. students use their acquired knowledge in everyday life, an action research was conducted with 158 students (age 14–16). The results indicated that students gain knowledge during mobile outdoor learning and develop a conceptual change. Furthermore, the results showed that a learning scenario focusing on a socio-environmental problem had a bigger impact on students’ transformative experience towards science learning than a more biologically specific topic.

Keywords Mobile learning · Mobile outdoor learning · Conceptual change · Transformative experience

1 Introduction
Mobile outdoor learning has the potential to engage and motivate students while studying science. Taking some of the learning experiences outside the classroom into real-life environments has a lot of promise for connecting knowledge acquisition to the real world, for example outdoor learning in science education has the ability to enrich and develop students’ daily experiences (Pugh et al., 2017a). The recent empirical work on mobile outdoor learning has shown some positive results in supporting learners to actively interact with the surrounding environment (Land & Zimmerman, 2015). As described by Sharples et al. (2007), mobile learning incorporates interpersonal communication, technology usage, and location choices. Another important advantage of versatility in outdoor mobile learning spaces is the consistency of contexts. Since learning in an authentic context helps the learner develop stronger relations with later situations, where acquired information may be useful, one of the intended

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benefits of outdoor situated and contextualized learning is enhanced knowledge retention and learning transfer (Bransford et al., 2000).

Research on mobile outdoor learning has also brought out some challenges and shortcomings. Firstly, the potential of mobile technologies is not fully used (Mettis & Väljataga, 2020). Secondly, there is some skepticism related to using mobile technology for learning in nature (Hills & Thomas, 2020; Thomas & Munge, 2017). It is claimed to be distracting the learners’ attention and creating a transparent wall between the learner and the environment, which is referred to as ‘‘heads-down’’ interactions with technologies (Hsi, 2003). Furthermore, during outdoor learning events, students may attempt to multitask, and the learning workload can surpass what a person can handle during the learning process (Chu, 2014).

Thus, designing for learning activities that support learning experiences in real-world settings is a complex and faceted endeavor, which requires place-responsive pedagogy (Gray & Thomson, 2016). Learners’ immediate virtual and physical surroundings, as well as contextual knowledge, become critical components of learning design (Mettis & Väljataga, 2020). Furthermore, it is argued by Munge et al. (2017) that outdoor learning experiences should be inherently multidimensional and multidisciplinary. Studying outside the classroom in real-world settings necessitates the development of systematically integrated learning exercises in which the emphasis is on a complex real-world phenomenon or problem that requires students’ various levels of expertise and skills from different disciplines to solve.

Transformative Experience Theory focuses on how in-school learning can enrich out of school experience by expanding perception, contributing meaning and value to future experience, and transforming our relationship with the world. Mobile outdoor learning could be used to support students’ while connecting the in school knowledge with out of school experience. A systematic review of research on the use of mobile technology-based programs in K-12 settings between 2010 and 2015 (Crompton et al., 2017) revealed that too often mobile technologies are used to enable students’ consumption of information in various settings, rather than to support inquiry learning and co-creation of knowledge. However, the studies exploring outdoor technology-enhanced inquiry learning (Kilty & Burrows, 2020) have not been focusing on measuring students’ scientific concept formation and acquiring necessary vocabulary to explain the complex socio-economical environmental phenomenon as well as gaining scientific understanding to provide critical and evidence-informed arguments. Furthermore, little attention has been given to the transition of the acquired knowledge to students’ everyday lives from the perspective of mobile outdoor learning. What more, according to Kraalingen (2021), there is a lack of studies which focus on the non-gamified use of mobile technology among target groups that are older than 14 years.

Acknowledging the complex nature of mobile outdoor learning and gaps in the research, we aimed to study if mobile outdoor learning could be used to shift students’ scientific understandings and facilitate students’ knowledge transfer to everyday life through hands-on-activities and inquiry. To reach that aim an action research was conducted with secondary school students.

2 Theoretical Background

2.1 Place-Responsive Pedagogy for Outdoor Learning

Outdoor learning has traditionally settled around a set of interchangeable terms such as an adventure and experiential learning including expeditionary trips and hikes to nature
(Adkins & Simmons, 2002). In recent years outdoor learning has started to get more attention in the context of sustainability and world-wide environmental problems. Orr (2004) has pointed out that “if we want people to live well in this world, they need to be educated in this world” (Lloyd, 2018, p. 40).

Recognizing the limitations of the traditional outdoor education and the need for new conceptions and approaches of learning in nature, theorists and practitioners in outdoor education have been directing their focus on place-based education (Dolan, 2015; Quay & Seaman, 2013) in an attempt to develop new ways of learning and doing in the outside setting (Roberts, 2018). As going outdoors provides numerous opportunities for learning through everyday socio-economical environmental problems inherent to a particular location, the emergence of location-based approaches has refocused attention on the pedagogical value of place and the power of direct embodied experience in education (Roberts, 2018). This poses challenges for pedagogical models and instructional designs in outdoor settings (Mettis & Väljataga, 2020). There is a need for a place-responsive pedagogy that acknowledges and makes use of local place, environment or culture (Gray, 2019).

Place-responsive pedagogy incorporates being present in, and with, a place, and recognises stories and narratives related to the particular location (Gray & Birrell, 2015; Gray & Thomson, 2016). The central idea of place-responsive pedagogy “involves explicitly teaching by means of an environment with the aim of understanding and improving human–environment relations” (Mannion et al., 2013, p. 803).

### 2.2 Mobile Outdoor Learning

With the support of different mobile technologies learning can occur and be facilitated on the move creating the potential to move out from the classroom, integrate formal and informal learning outdoors and bridge the gap between contexts, which have been traditionally separated.

Mobile outdoor learning emphasizes digitally facilitated site-specific learning experience (Laurillard, 2007) e.g. learning in, about and through context (Sharles, 2016; Schellinger et al. 2019), but also continuity between contexts. According to Suárez et al. (2018), mobile technology allows students to keep track of their inquiry process, data collection, and peer-to-peer engagement while enabling them to have discussions across multiple contexts and produce symbiosis to co-create information and timely access to content and contextual support.

There are numerous projects that focus on designing a mobile system for learning (Crompton et al., 2017) and substantial number of studies about mobile technology use in learning outdoors in both formal (Kärki et al., 2018; Öcal et al., 2021), and informal environments (Land & Zimmerman, 2015; Squire & Jan, 2007). Different studies (Nikou & Economides, 2017; Sung et al., 2016; Zacharia et al., 2016) demonstrate that it is possible to create meaningful mobile outdoor learning events that are collaborative, active and contextual and show positive results on student learning. Learner participation in technology-enhanced inquiry activities that occur in informal and formal environments, when accompanied by clear guidance based on metacognitive and social knowledge creation, may increase learners’ comprehension of the essence of science, according to Schellinger et al. (2016). Furthermore, many scholars argue that learning outdoors contributes to students’ transformative learning (Dowdell et al., 2011; Gray & Pigott, 2018). However, more research is needed to better understand students’ transformative experience and conceptual change outdoors.
2.3 Transformative Experience and Conceptual Change

When students apply what they’ve learned in schools to see and experience the world in different ways in their everyday lives, they have been immersed in a transformative experience (TE) (Pugh, 2011). In this case, transformative refers to the application of classroom content principles in everyday life, in order to perceive and value the world in new ways (Pugh et al., 2017a). Transformative experience is defined by three qualities (Pugh et al., 2020): (a) active, motivated use (AU) of a concept—seeking opportunities to use the learned knowledge or skills outside the classroom when it is not a requirement, (b) expansion of perception (EP)—occurs when classroom content changes the way one views the world, (c) experiential value (EV) for the concept (Pugh, 2011)—which is reflected by a student who comes to appreciate material for its ability to transform his or her experience of the world (Heddy & Sinatra, 2013).

A learner’s cognitive-affective phase of trying to incorporate new concepts into his or her current schema is referred to as conceptual transition (Gregoire, 2003). As students progress from a misunderstanding to a scientifically accepted belief, they are also said to experience conceptual change (Heddy et al., 2017). Pugh et al. (2010) found that students who reported higher levels of engagement in transformative experience were more likely than other students to display greater conceptual understanding. To foster conceptual change, attention is expected to be paid to the meaning and atmosphere of learning. Students who undergo deeper levels of transformative experience are more likely to develop deeper and more enduring learning, to experience greater conceptual change (Alongi et al., 2016; Heddy & Sinatra, 2013), and to achieve greater transfer (that is, real-world application) of learning (Pugh et al., 2020).

Thus, engaging students in mobile outdoor learning activities that are happening in real-life contexts and encouraging hands-on inquiry-based problem solving may create transformative experience and conceptual change. Therefore, we are seeking the answers on the following questions:

1. What is the effect of mobile outdoor learning activity on students’ knowledge and conceptual change about the study event topics: Air quality and Bare and covered seed plants?
2. To what extent has students’ knowledge about the study topics Air quality and Bare and covered seed plants persisted after 1 month of the learning activity?
3. How does mobile outdoor learning activity contribute to students’ transformative experience about the topics Air quality and Bare and covered seed plants?

3 Methods and Materials

3.1 Research Context

This study used an action research approach, where one university researcher and one teacher-researcher collaborated with three teachers from 2 schools to create and conduct mobile outdoor learning activities (Noffke & Somekh, 2009). More specifically the lesson study (Lewis, 2002) was used (Fig. 1).
The activities and instructions were discussed thoroughly with the subject teachers based on the Estonian National curriculum (2011) and school study plans. The aim of the 8th grade mobile outdoor learning activity was to introduce a new topic *Bare and covered seed plants* and for the 9th grade the activity *Investigating the air quality around the school* was designed to repeat the already studied topics in environmental chemistry. This decision to choose different topics for designing learning activities was based on the need to connect the action research activities into the current topics that the students were learning at chemistry and biology lessons. Furthermore, it gave us an opportunity to explore students’ transformative experience with different study topics.

The topic in 8th grade, *Bare and covered seed plants*, first aimed to explore how to identify different conifers and deciduous trees and secondly, to explain the role and importance of these species in Estonian nature. The topic is compulsory in the Estonian National curriculum for 8th grade students to be studied in autumn semester under the major topic “The properties of plants and life processes”. The topic for the 9th grade was *Investigating the air quality around the school* (more specifically, environmental chemistry and biochemistry). The topic is related to the Estonian National curriculum under the topic “Classification of inorganic substances”, more specifically: acid, base, oxide, salt. The topic ends with environmental chemistry, which specifically focuses on environmental contamination sources, the reasons for the contamination and the environmental issues that are related to it (acidic oxides, acid rains, dust, CO₂ and climate warming). The chemistry topics were integrated with biology through bio-indicators, e.g. identifying lichens that tolerate an acidic environment, using *Rhytisma acerinum* for estimating the presence of Sulphur oxides in the air.

The aforementioned learning activities also support the general goals of Nature sciences in Estonian National curriculum: (1) to teach students to notice, observe, analyze and explain living environment and the processes in living environment, to teach students

![Fig. 1 The lesson study cycle (based on Lewis, 2002)](image-url)
to make connections and conclusions and (2) to apply their skills in real life and to teach students how to use different technologies to acquire information and conduct experiments. Both 8th and 9th grade learning activities also integrate skills from mathematics and geography. The mobile outdoor learning app Avastusrada served the goal to teach students to use technology to collect and analyze the data and help them to learn how to solve different problems. Also it mediated the learning instructions supporting students to connect their theoretical knowledge to real-life situations.

The learning activities and instructions were created by the teacher-researcher. Three teachers were involved in the development of data gathering instruments and validated the test questions used in the pre-test, post-test and post-questionnaire.

3.2 Sample and Recruitment Procedure

The research plan was firstly approved by the university’s ethical committee. Study was conducted in October 2020 in 2 Estonian schools. The sample was a convenience sample and the results are not generalizable. 158 students from 2 schools participated in the study from grades 8 (13–14 years old) and 9 (15–16 years old). 83 of the participating students were male and 75 were female. The students’ who participated in the study were the students of the teachers’ who agreed to participate in this action research. The school directors were first approached for permission, followed by contacting the science teachers. One of the participating teachers was a chemistry teacher and the other two were biology teachers. After the agreement from the teachers the topics for learning activities were chosen. The selection of the topics was in accordance with the national science curriculum and followed the already prepared study plan of participating teachers. A letter explaining the study (purpose, data management and confidentiality, and no harm to the students) was sent to the parents, requesting their permission to allow their children to participate in the study. Individual consent was given by the participants (entering the experiment). Participants were informed that they could quit at any time.

3.2.1 Learning Design

The research activities were conducted during lessons in nature science classes (chemistry, biology) with a length of 90 min. The learning activity involved introduction, planning and familiarizing with the equipment, outdoor group work activities facilitated by Avastusrada (DiscoveryTrack) app, whole class discussion and filling in questionnaires.

The outdoor learning app Avastusada (Discovery Track—https://avastusrada.ee/en), is a browser-based platform for building and playing location-based learning tracks outside the classroom. Avastusrada was used with 4 aims: to direct instructions, to provide access to content, to support data collection and to enable interaction between context and learner (Suarez et al., 2018). Avastusrada can be used on a smartphone or tablet with a high-speed Internet connection (WiFi, 3G, or 4G) and GPS location services. Avastusrada allows users to generate questions about specific locations that can then be connected into useful tracks. For more detail, questions may be text-based or include images, videos, audio, or animations. Different types of tasks allow players to do things like explore the environment, answer questions, or measure something in the environment and insert the result. The students’ movement and their location can be monitored by GPS (Fig. 2b).

The students were guided to different locations by the Avastusrada app. In every specific location was a task where they had to read the instructions and based on the information
observe, measure, compare, analyze, take a picture, collect etc. When the tasks in one location were finished they were instructed to follow the path and continue to fill in the tasks in other locations (Fig. 2a). The Tracks were composed of 6–8 different location points.

In addition to a place-responsive pedagogy in which the learning tasks were directly connected to the chosen location point in the Avastusrada app, a set of instructional methods (Pugh & Girod, 2007) were followed while designing the tasks to facilitate engagement in transformative experience during mobile outdoor learning activity. This set of methods is known as the Teaching for Transformative Experience in Science model (TTES). Pugh and his colleagues describe the TTES model in terms of three design principles:

(a) Framing content in terms of its experiential value (EV)—students were encouraged to discuss their opinion over the air quality around their school territory. They were asked to explain and evaluate what others have said.
(b) Modelling transformative experiences—in the Air quality activity the students were addressing the problem that risk of getting killed by a bear is far less plausible than getting killed by poor air quality. The modelling was facilitated by the Avastusrada app.
(c) Scaffolding re-seeing (Pugh & Girod, 2007)—students were investigating, analysing data and making conclusions. During the activities they were scaffolded using Avastusrada to make connections to their previous knowledge and making connections to their everyday lives. Also, the whole class discussion at the end of the learning activity supported the scaffolding of students’ re-seeing.

3.3 Data Collection and Analysis

The data was collected with 2 instruments (Fig. 3):

1. Semi-structured pre- and post-knowledge tests: composed of multiple choice questions targeting factual knowledge and open-ended questions to determine students’ conceptual knowledge level. Pre-and post-test consisted of the same questions.
2. Semi-structured post-questionnaire that was presented one month after the learning activity, composed of the knowledge test, open-ended questions to determine students’ conceptual knowledge level (Alongi et al., 2016) and questions exploring students’ transformative experience (Pugh et al., 2010).

The tests consisted of four multiple choice questions or closed questions and one open-ended question (Appendix). The knowledge test questions were discussed and validated with the teachers. The test answers were checked and sum scores were used for analysis. The open-ended questions were used to determine the process of restructuring conceptual knowledge about a certain phenomenon from a non-scientific to a scientific perspective and were coded according to Alongi et al. (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). All freeform answers were coded by 2 independent raters. Inter-rater reliability was calculated by using Cohen’s Kappa, the result 0.89 showed strong agreement. The disagreed categories were later discussed and agreed on.
In addition to the knowledge tests and the open-ended questions for assessing students’ conceptual level of understanding about the topics, the post-questionnaire contained also questions about students’ transformative experience. The questionnaire was based on Pugh and colleagues’ (2010) transformative experience questionnaire, which had high reliability (Cronbach’s α = 0.90). The questionnaire was shortened to make it suitable for students in age 13–16 years, by removing repetitive questions from all 3 categories AU, EP and EV. The
questions could be answered by choosing suitable values from Likert type scale from 0 to 6, where “0” was equal to “Completely disagree” and “6”—“Completely agree” (12 questions).

Pre-test and post-test were answered by all participating 158 students, 110 students from grade 8 and 48 students from grade 9 (Table 1). Regarding the post-questionnaire there was a high drop-out and it was answered by only 46 participants. The reasons for the high dropout might be that, first of all, the teachers in participating schools were asked to forward the post-questionnaire to students and this was not part of the classroom tasks. The post-questionnaire was presented to the participating students as a non-compulsory homework assignment. Also the contact with one of the schools was lost without any explanation. Covid-19 situation could have been the cause because it significantly increased workload for the teachers.

4 Results

4.1 Students’ Knowledge About the Study Topics Before and After the Learning Activity

In the study the learning activity designs for both 8th and 9th grade students followed the same principles, but the study topics and aims for the 8th and 9th grade students were
different. 8th grade students’ activity focused on introducing a new topic, the *Bare- and covered seed plants* and 9th grade activity aim was to revise the topic *Air quality*. Taking into account the different topics and aims of the activities we hereby analyze 8th and 9th grade students results separately and later generalize based on the separately analyzed results.

### 4.1.1 8th Grade Students’ Knowledge Test Results

The gathered numeric data (test scores) were checked for normality. Shapiro–Wilk test was used because of the small sample size. The test showed a significant departure from normality in pre-test ($W(110) = 0.894$, $p < 0.01$), post-test ($W(110) = 0.889$, $p < 0.01$) and knowledge test part in the post-questionnaire ($W(33) = 0.719$, $p < 0.01$). Therefore, we concluded that these variables were not normally distributed, and nonparametric tests were used for analysis.

A Wilcoxon S-R test was used to compare the pre- and post-test results. The post-test scores (Mean = 2.74, SD = 1.56, Mdn = 3) were higher than pre-test scores (Mean = 2, SD = 1.27, Mdn = 2). The Wilcoxon Signed-Rank test indicated that the difference was significant, $Z = -5.618$, $p < 0.01$.

8th grade post-questionnaire knowledge test scores that were taken 1 month after the learning event, were compared with their post-test scores. The post-questionnaire knowledge test results (Mean = 4.52, Mdn = 5) were higher than “post-test” results (Mean = 2.74, Mdn = 3). A Wilcoxon Signed-Rank test indicated that the difference was significant, $T = 307.5$, $Z = -3.939$, $p < 0.01$, which means that the students had gained knowledge about the topic also after the formal learning activity.

### 4.1.2 8th Grade Students’ Conceptual Knowledge Levels About Bare- and Covered Seed Plants

To estimate students’ conceptual change about the topic Bare- and covered seed plants after the learning activity, the open-end questions from the pre- and post-test were evaluated and coded based on Alongi et al. (2016). Students’ post-test conceptual knowledge levels (Mean = 2.17, SD = 1.50, Mdn = 3) were higher than pre-test conceptual knowledge levels (Mean = 1.31, SD = 1.62, Mdn = 0). A Wilcoxon Signed-Rank test indicated that the difference was significant, $Z = -4.732$, $p < 0.01$.

8th grade (N = 33) conceptual knowledge levels in post-questionnaire were also compared with their post-test conceptual knowledge levels. The post-questionnaire levels (Mean = 2.56, Mdn = 3) were slightly higher compared to the post-test levels (Mean = 2.17, Mdn = 3). A Wilcoxon Signed-Rank test indicated that the difference was not significant, $T = 195.50$, $z = -0.519$, $p = 0.604$, which means that the students had retained their conceptual knowledge levels they had gained from the learning activity.

### Table 1: The number of students who filled in the pre-test, post-test and post-questionnaire

|                  | 8th grade | 9th grade | Total |
|------------------|-----------|-----------|-------|
| Pre-test         | 110       | 48        | 158   |
| Post-test        | 110       | 48        | 158   |
| Post-questionnaire | 33       | 13        | 46    |
4.1.3 9th Grade Students’ Knowledge Tests Results

The gathered numeric data (multiple choice questions of the knowledge test in all questionnaires) were again checked for normality. The Shapiro–Wilk test showed a significant departure from normality in pre-test ($W_{(48)} = 0.899, p < 0.01$), post-test ($W_{(48)} = 0.932, p < 0.01$) and post-questionnaire ($W_{(13)} = 0.654, p < 0.01$). Therefore, we concluded that these variables were not normally distributed, and nonparametric tests were used for analysis.

A Wilcoxon S-R test was used to compare the pre- and post-test results. The post-test scores (Mean = 3.33, SD = 1.36, Mdn = 3) were higher than pre-test scores (Mean = 2.21, SD = 1.01, Mdn = 2). The Wilcoxon Signed-Rank test indicated that the difference was significant, $Z = -4.319, p < 0.01$.

9th grade post-questionnaire knowledge test scores, that were measured 1 month after the learning activity, were also compared with their post-test results. The post-questionnaire results (Mean = 2.85, Mdn = 3) were slightly lower compared to post-test results (Mean = 3.33, Mdn = 3). The Wilcoxon Signed-Rank test indicated that the difference was not significant, $T = 22.5, z = -1.344, p = 0.179$, which means that the participating students had retained their knowledge about the topic also after the learning activity.

4.1.4 9th Grade Students’ Conceptual Knowledge Levels About Air Quality

9th grade students’ post-test conceptual knowledge levels (Mean = 2.25, SD = 1.28, Mdn = 3) were higher than pre-test conceptual knowledge levels (Mean = 1.52, SD = 1.29, Mdn = 1). A Wilcoxon Signed-Rank test indicated that the difference was significant, $Z = -2.88, p < 0.01$.

9th grade (N = 13) conceptual knowledge levels in post-questionnaire were also compared with their post-test conceptual knowledge levels about the Air Quality. The post-questionnaire levels (Mean = 2.58, Mdn = 2.5) were slightly higher compared to post-test conceptual knowledge levels (Mean = 2.25, Mdn = 3). A Wilcoxon Signed-Rank test indicated that the difference was not significant, $T = 13.5, z = -0.649, p = 0.516$, which means that the students had retained their conceptual knowledge levels they had gained from the learning activity.

4.2 Comparison of 8th and 9th Grade Students’ Results

We compared 8th grade and 9th grade students’ post-test results, to find out if there were significant differences between these two groups. To find out if we could compare the groups, the pre-test results of 8th and 9th grade students were compared. Mann–Whitney U test was used to identify if there were significant differences between 8 and 9th grade pretest results. The 8th grade students’ pretest scores (Mean = 2.00, Mdn = 2) were not significantly different from 9th grade pre-test scores (Mean = 2.21, Mdn = 2). The Mann Whitney U test didn’t indicate a statistically significant difference, $U_{(N8=110, N9=48)} = 2535.500, z = -0.408, p = 0.683$. Meaning that the students had mostly the same level of previous knowledge about the topics before starting the learning activities. We compared the 8th and 9th grade students’ post-test results using Mann–Whitney U test. There were no statistically significant differences between the
8th (Mean = 2.74 SD = 1.56 Mdn = 3) and 9th (Mean = 3.33 SD = 1.36 Mdn = 3) grade post-test results ($U_{(N8=110, N9=48)} = 2562.5, Z = -0.298, p > 0.05$). Both 8th and 9th grade students improved their factual knowledge about the topic significantly.

The 8th and 9th grade students’ post-questionnaire knowledge test scores, which were measured after 1 month, were again compared to find if there were any differences between the results. The 8th grade students’ knowledge test scores in post-questionnaire (Mean = 4.52; Mdn = 5) were higher from 9th grade students’ knowledge test results in post-questionnaire (Mean = 2.85, Mdn = 3). A Mann Whitney U test indicated a statistically significant difference, $U_{(N8=33, N9=13)} = 72.000, z = -3.5500, p < 0.001$.

We also compared 8th and 9th grade students’ post-test results for conceptual knowledge level about the topics to find out if there were any significant differences. To find out if we could compare the groups, the pre-test conceptual knowledge levels of the 8th and 9th grade students were compared. Because the data was ordinal, Mann–Whitney U test was used to identify if there were significant differences between 8 and 9th grade results. The 8th grade students’ conceptual knowledge levels (Mean = 1.31; Mdn = 0) were a little bit different from the 9th grade conceptual knowledge levels (Mean = 1.52, Mdn = 1), although the Mann Whitney U test didn’t indicate a statistically significant difference, $U_{(N8=110, N9=48)} = 2216.50, z = -1.69, p = 0.09$. Therefore, we continued to compare the two groups’ conceptual knowledge levels in post-test. Mann Whitney U test ($U_{(N8=110, N9=48)} = 2548.50, z = -0.358, p = 0.72$) didn’t indicate any statistically significant difference between 8th (Mean = 2.17, SD = 1.50 Mdn = 3) and 9th (Mean = 2.25, SD = 1.28 Mdn = 3) grade results. Both groups developed higher conceptual knowledge levels about the topics during the learning activity than before the mobile outdoor learning lessons.

The 8th and 9th grade students’ post-questionnaire conceptual levels about the study topics were again compared to find if there were any differences between the results. The 8th grade students’ conceptual levels in post-questionnaire (Mean = 2.56, Mdn = 3) were very similar to 9th grade students’ conceptual knowledge levels about the study topic in post-questionnaire (Mean = 2.58, Mdn = 2.5).

Based on the students’ results who were willing to fill in the follow-up post-questionnaire (N = 46 total), we can conclude that the students who participated in the mobile outdoor learning activity retained their knowledge after the learning activity for a long period of time. During 1 month, the conceptual understanding levels remained the same for both groups. Also, the 8th grade students who performed better in factual knowledge questions did not increase their conceptual understanding further but retained the levels that were established during mobile outdoor learning activity.

We were also interested in how big was the overall conceptual change about the study topic for the students. The graph (Fig. 4) below shows the change in students’ conceptual knowledge levels (post-test level minus pre-test level). Negative values indicate that the presented post-test explanation was at a lower level than the pre-test explanation and positive results show the opposite. It can be seen that approximately 40% of the students developed a positive shift in conceptual knowledge level, which means that their understandings changed from missing, naive or from misconceptions towards more scientifically accurate understanding. Also 35% of the students did not develop any conceptual change.

Most of the students whose results showed no change or even negative conceptual change had already a relatively high level of previous understanding about the topic (levels 3–5) and we hereby assume that this was participants’ lack of motivation to provide the same explanation again at the end-questionnaire. This aspect in research design should be reconsidered in the future.
4.3 Students’ Transformative Experience

Students’ transformative experience was measured by using a modified version of the Heddy and Sinatra (2013) transformative experience questionnaire. The overall results didn’t indicate very strong transformative experience. The average results for the statements were from lowest 1.57 (the mean value for the statement “I have started looking for examples of TV shows, movies, books or elsewhere on this topic.”) to highest 3.30 (the mean value for the statement “I found it interesting to learn about this topic”).

4.3.1 Comparing 8th and 9th Grade Students’ Transformative Experience

Mann–Whitney U test was used to compare the answers of 8th and 9th grade students. From the graph below (Fig. 5), we can see that in some aspects’ there were differences between 8 and 9th grade students’ answers.

Significant differences were found in 3 questions. The 8th grade students’ results (Mean = 1.82, Mdn = 2) for the question “I have started thinking about this topic outside of school.” were lower compared to 9th grade students’ answers (Mean = 3, Mdn = 2) and the difference was statistically significant, U = 118.500, z = −2.475, \( p = 0.013 \). The 8th grade students’ results (Mean = 1.73, Mdn = 1) for the question “I have begun to look for ways to use knowledge I have learned on this topic.” was statistically significantly lower than 9th grade students’ answers to this statement (Mean = 2.69, Mdn = 2), U = 140.500, z = −1.926, \( p = 0.054 \). For the statement “I found it interesting to learn about this topic” 8th grade students’ answers (Mean = 3.18, Mdn = 1) were slightly lower than 9th grade students’ answers (Mean = 3.62, Mdn = 3), but a Mann–Whitney U test indicated statistically significant difference, U = 131.000, z = −2.098, \( p = 0.036 \). In all these questions 9th grade students’ answers were higher. For other statements, the results didn’t have any significant differences (\( p > 0.05 \)). From this perspective we can conclude that 9th grade students had a stronger transformative experience than 8th grade students.

Fig. 4 Change in students’ conceptual knowledge category based on pre-and post-questionnaire
5 Discussion

5.1 What is the Effect of Mobile Outdoor Learning Activity on Students’ Knowledge and Conceptual Change About the Study Event Topics: Air Quality and Bare and Covered Seed Plants?

The results showed that the students gained knowledge about the topics Air quality and Bare and covered seed plants while participating in the mobile, place-responsive outdoor learning activities. These results are in line with the previous research that have reported positive outcomes of students’ learning during mobile outdoor learning (Chin et al., 2020; Choi et al., 2018; Liu et al., 2009).

Despite the different instructional goals and topics, it is interesting to note that although for 8th grade the study topic Bare and covered seed plants was new and for 9th grade the study topic Air quality was a repetition through hands-on activities outdoors, both groups demonstrated knowledge gain and conceptual change. Approximately 40% of students improved their conceptual understanding, which confirms the results of the research from Schellinger et al. (2019), who have reported that learner engagement in technology-enhanced inquiry activities that occur in informal and formal settings when supported through explicit instruction focusing on metacognitive and social knowledge construction, can improve learners’ understanding about the nature of science. Our findings also support the results of other research that state that the use of technology in outdoor learning might play a role in influencing participants’ knowledge gain (Hougham et al., 2018; Kamarainen et al., 2018).

Regarding conceptual change, the results of this study show similarities with the work of Heddy et al. (2017), 35% of the students did not develop a change in their conceptual knowledge level. Further analysis revealed that these were mostly students who already had quite an elaborated conceptual understanding of the topic, especially with the 9th grade students. This result was expected as the students had already learned the
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Based on these results we can conclude that outdoor learning supported with mobile technologies has a potential to contribute to students’ knowledge gain and conceptual change despite the study topic and rather sophisticated learning design with many outdoor distractions. It must be emphasized that the learning design of the outdoor activity was clearly focusing on several design aspects, such as, the design was following the place-responsive pedagogy, Teaching for Transformative Experience in Science model (TTES) and acknowledged the importance of contextualizing learning tasks and inquiry supported by technological solutions, which are connected to real-life situations.

Although, in general, our study demonstrated a positive effect on students’ learning, to support all the students in their learning, the design could be differentiated more based on the students’ needs. At the moment the students who already have more knowledge about the topic are left without attention. This is also partly related to the affordances of the used technology. One of the possibilities could be further developing the used mobile outdoor learning app Avastusrada in a way that it would provide individualized instructions based on the students’ preferences and previous knowledge (Li et al., 2019).

5.2 To What Extent has Students’ Knowledge About The Study Topics Air Quality and Bare and Covered Seed Plants Persisted After 1 Month of the Learning Activity?

Interesting outcomes were revealed from the post questionnaire. The level of students’ knowledge (test scores as well as the level of conceptual understanding) was higher in 8th grade after 1 month. As the outdoor learning activity for the 8th graders was to get started with the new topic in their curriculum, the students continued to learn more about this topic in the following lessons.

The level of knowledge for the 9th grade students decreased a little after 1 month of the outdoor learning activity, despite the fact that the study topic Air quality was to repeat the material already covered in previous lessons. It seems that environmental conditions with the place connected to students (air quality around the school house) did not have a huge effect on students’ factual knowledge gain, however, it positively influenced the level of conceptual understanding. Kraalingen (2021) points out that one of the benefits of using technology in outdoor learning is deepened learning experience about the place and it also seems to be the case in this study. Most likely the real-life learning setting outdoors helped them to establish meaningful connections and conceptions. We can assume that the conceptual change took place during the mobile outdoor learning activity and remained. In the case of studying a new topic, we can confirm prior empirical work that mobile learning outdoors has a potential to support the acquisition of factual knowledge (Liu et al., 2009). Furthermore, being aware of not overstating our claims, however, we can conclude that our conducted place-responsive outdoor learning activity supported with mobile technologies has a potential to facilitate conceptual change.
5.3 How does Mobile Outdoor Learning Activity Contribute to Students’ Transformative Experience About the Topics Air Quality and Bare and Covered Seed Plants?

Although taking the place-responsive pedagogy with place-essential tasks (Mannion & Lynch, 2016) and TTES model as a basis for designing mobile outdoor learning activity as well as providing the students to gain first-hand experiences in, and with the environment (Hill & Brown, 2014), the students didn’t have particularly strong transformative experiences, however, there were slight differences between the 8th and 9th grade results. Even though both learning activities were designed based on the same principles it seems that the concrete environmental problem explored by the 9th grade students’ was more attractive yielding to develop values and an expanded perception, influencing students’ thinking about the subject and arousing interest. This demonstrates clearly that the choice and the framing of a study topic in these activities should be more related to some real-life problem, meaningful and connected to the students. Studying air quality in your own environment has a direct influence on well-being, thus potentially shaping one’s identity together with values and attitudes of environmental issues (Pugh et al., 2009). Identity, however, plays a role in the development of content-related interest and appreciation (Brophy, 2004) as well as willingness to engage, thus, contributing to transformative experience.

Furthermore, Pugh et al. (2017a) have described that for students to experience transformative experience there has to exist a certain motivation to achieve or perform better in the class. In contrast to previous research about increased motivation (Kumar & Chand, 2019), in general, the results didn’t demonstrate students’ high motivation and interest. However, the constructs “I have started thinking about this topic outside of school” and “I have begun to look for ways to use knowledge I have learned on this topic” being higher in the 9th grade than in 8th grade, refer to active, motivated use of transformative experience i.e. choosing to apply learned knowledge in out of school environment without no pressure. Though, neither 8th grade nor 9th grade study topic was interesting enough to direct students to look for more information and materials, to transform their ways of seeing nature or to increase their urge to explore outdoors on their own, the learning experience had a slight positive effect on the 9th grade students cognitive (related to expansion of perception) and affective (related to experiential value) components.

Without any specifically targeted instruction transformative experiences occur infrequently (Pugh et al, 2009). Implementing TTES principles and specific classroom strategies require practising and thus might not have been successful enough to frame the content as ideas, scaffold re-seeing and modelling transformative experience, especially in the case of 8th grade. Providing students’ transformative experience is dependent on a teacher’s mindset and capabilities to appropriate the design principles of transformative experience and not to remain on only „add-ons “ to existing practice but rather bring in fundamental shifts, e.g. second-order change (Pugh et al., 2017a, 2017b).

Yet another variable causing a relatively modest transformative experience here might be that the 9th grade students are already more mature and see the value and importance of these kinds of learning activities.

It has been found that transformative experience should promote conceptual change (Heddy & Sinatra, 2013). Also, Pugh et al. (2010) found that students who reported higher levels of engagement in transformative experience were more likely than other students to display greater conceptual understanding. In current study students developed conceptual change, but it seems that the transformative experience didn’t play
a role in supporting the conceptual change, because even though the 9th grade transformative experience results were higher, they didn’t show significantly higher conceptual level in the post-test and post-questionnaire compared to the 8th grade students. These results are contrasting many other previous studies, which state that students who undergo deeper levels of transformative experience are more likely to develop deeper and more enduring learning, to experience greater conceptual change (Alongi et al., 2016; Heddy & Sinatra, 2013). One of the reasons for the lack of this relationship in this study might be that the complexity of the natural environment might be too difficult for students to engage in learning tasks independently (Choi et al., 2018). Another explanation for modest transformative experience might be that a place-responsive pedagogy and mobile outdoor learning activity, being a complex endeavor, require different design principles and “classroom strategies” to facilitate transformative experience.

Furthermore, while in the previous studies where transformative experience was studied, the teacher played a significant role in the learning process, in our study the teacher had more of a side role as some of the instructions and scaffolding according to the TTES model were presented through the Avastusrada app. The teacher made the introduction and the whole class discussion at the end of the learning activity, but this might not have been enough to make the transformational connections for the students.

Different authors have pointed out that the educators need to better evaluate what underlying messages the use of equipment will convey to the participants and what the implications are for the learning process (Hills & Thomas, 2020; Thomas & Munge, 2017). In this study the technology was not in the central focus of the attention. Instead of the common gamified outdoor learning apps (Gao et al., 2020; Kraalingen, 2021), similarly to EduPark (Pombo et al., 2019) and Actiontrack (Kärki et al., 2018), the devices were means to guide students in their learning process, and also means to collect and make sense of data, to not to take away the focus from the surrounding environment. All the activities were designed in a way that students were encouraged to explore and investigate outdoors on their own, interact with the surrounding environment avoiding the invisible barrier and rather merging virtual and real world. Might be that the reason for a modest transformative experience is related to the use of technology in outdoor learning. The non-gamified approach for using mobile technologies is helpful for providing the instructions and orchestration of the activity but at the same time it might become dull.

It has to be mentioned here, that one of the pitfalls of using the technology in outdoor learning are the skills of students and teachers. Hills (2019) has suggested assessing the student’s abilities to work with technological devices and providing extra guidance before departure to prevent complications during outdoor learning (Hills, 2019). In this study students were introduced how to use the app and additional data collection devices. Also instructional support was provided in the specific locations in the assignments mediated by the Avastusrada app. This helped to reduce the risks of students not being capable of using the devices. All students used their own smartphones with what they were already familiar with. Still, the capabilities of students are different and tackling both with technology and real world practical tasks might be too burdening for the students.

Despite that, there are studies which claim that the use of technology increased the participants’ knowledge (Hougham et al., 2018; Kamarainen et al., 2018). Our study demonstrated similar results, i.e. many students improved their conceptual understanding. Also the connections that students acquired during the learning activity remained for long term.
6 Conclusion

The study presents a complex mobile outdoor learning design followed by TTES and place-responsive pedagogy, and its impact on students’ knowledge gain, conceptual change and transformative experience. In particular, this study aimed to investigate if mobile outdoor learning could be used to support students’ while acquiring conceptual understanding about environmental topics and connecting the in school knowledge with out of school experience. The results show that implementing mobile outdoor learning activities had definitely an impact on students’ factual knowledge growth and facilitated conceptual change about the topics Air quality and Bare and covered seed plants. Furthermore, the study explores the connection between the mobile outdoor learning design and the students’ transformative experience. The non-gamified use of mobile technology in outdoor learning helped students to gain knowledge but on the other hand it didn’t have the expected effect on students’ motivation as in previous studies. The transformative experience of the students was rather weak, even though the TTES principles were considered while designing the learning activities. There are many different reasons which could have affected the students’ experience in mobile outdoor learning: students’ skills, motivation and willingness to study, importance of a study topic, technological solution used, teachers’ proficiency to implement TTES teaching strategies, etc. Students’ interest towards studying the topic, their motivation and level of engagement must be considered while designing and measuring transformative experience, especially when it is decided to use non-gamified use of mobile technology. In addition, mobile outdoor learning applications should be developed further to support students’ personal needs and transformative experience.

Appendix

Test used in Pre-test, Post-test and Post-questionnaire for 8th grade.

1. Choose the correct answer: How are thorns attached to a spruce branch? *
   - By 1 thorn
   - By 2 thorns
   - By 3 or more thorns

2. Choose the correct answer: How are thorns attached to a yew branch?
   - By 1 thorn
   - By 2 thorns
   - By 3 or more thorns

3. Evaluate the statement: The Douglas-fir cone has tails attached. *
   - Correct
   - Incorrect

4. Explain: How to distinguish between silver fir and spruce? *

5. Sort the species by thorn length, starting with the shortest thorn length.: *
   - pine, cedar, yew, spruce, fir.
   1.
   2.
3. 
4. 
5. 

Test used in Pre-test, Post-test and Post-questionnaire for 9th grade.

1. Which oxides cause acid precipitation? *
   - SO2
   - NOx
   - SO3
   - CO2
   - SiO2

2. Why are lichen good air quality indicators? Mark the correct answer.
   - They are sensitive to air quality because they have no roots and are completely dependent on the humidity in the air.
   - They are sensitive to air quality because they like an acidic environment
   - They are sensitive to air quality because they have long roots

3. Name one lichen species that can grow in dusty and acidic environments? *

4. Evaluate the statement: The presence of maple pitch spots means that the air is clean. *
   - Correct
   - Incorrect

5. Assess the air quality around the school. Justify your assessment, why do you think so?
   - Very good
   - Good
   - Average
   - Bad
   - Very bad.

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Declarations

Conflict of interest The submitted work is original and is not submitted elsewhere.

Data Availability Not applicable.

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