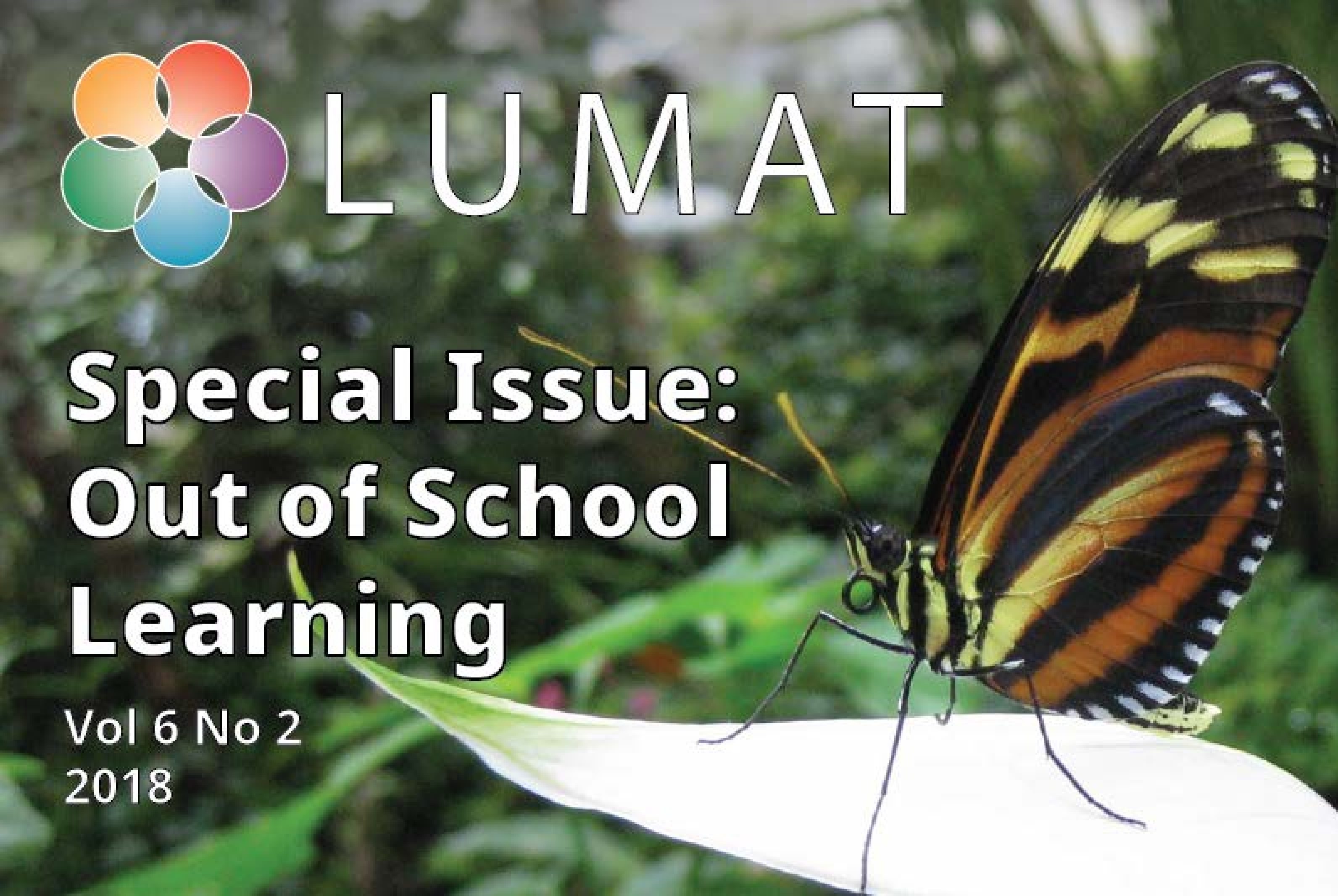

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Out of school opportunities for science and mathematics learning: Environment as the third educator

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Abstract: Out-of-school environments offer a unique opportunity for experiental learning which transcends the role of educational resources and teachers. This article introduces the special topic of out-of-school learning in science and mathematics education. First, we present the theoretical underpinnings from the movement towards crossing the boundaries of school in educational practices and broadening educational spaces. We continue with the key facets of out-of-school learning through a constructivist approach, aided by the concept of mediation environments as the third educator from a socio-material perspective. Furthermore, we focus our discussion on a selection of articles from this special number as an international overview on out-of-school learning. In the conclusion section, we discuss the gaps that the following works fill, as well as new questions that arise in the area. The closing remarks highlight the promotion of active learning in students, considering the role of the environment as the third educator.

Keywords: out-of-school, lifelong learning, science education, mathematics education

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1 Introduction

Science education has an important role in the development of citizenship and global responsibility for sustainable development (Ratcliffe & Grace, 2003). In this regard, the idea that science learning transcends the boundaries of the school classroom has become increasingly accepted. Hence, outdoor activities might become powerful learning experiences for connecting students with nature and socio-scientific issues (Beames, Higgins, & Nicol, 2012). Indeed, in some countries outdoor education has been formalized as a promotor of interdisciplinary and experiential learning from early years education to higher education (Christie, Higgins, & Nicol, 2015). Nonetheless, outdoor education is just one type of out-of-school learning and it does not exclude other possibilities.

2 Facets of out-of-school learning

Usually, out-of-school opportunities are associated with outdoor education. However, outdoor education is only one form of out-of-school learning, and also many other activities, such as visiting exhibitions, museums, camps, etc. are considered to be out-of-school education.

On the one hand, outdoor education offers structured opportunities for students to identify hazards, calculate related risks and decide the significance of a risk in order to determine and implement precautions. In this regard, this type of education promotes students' self-awareness and taking greater responsibility for their own and others' safety (Office for Standards in Education, 2004). Even so, there is a fine line between recreational and educational objectives in outdoor education (Allison & Telford, 2005).

On the other hand, education through exhibitions, galleries or museums usually has an educational purpose clearly defined and recognised by teachers but not always by leisure visitors. Furthermore, these educational spaces need to be intrinsically motivating at every step of the interaction, have an educational purpose, and respond well to the diversity of learners (Allen, 2004), not just to those with prior scientific interest.

Modern science education needs to consider that the taught concepts, procedures and attitudes or values are relevant to students, their communities and contexts. This means that the objectives of science education contribute to living a better life, and to the protection of the environment, culture and society in particular. This is based on the assumption that each learner is a citizen independent of their age and that science education for responsible citizenship is a commitment for all (European Comission, 2015).

It is evident that science education has turned away from having its' only purpose in orienting students' scientific vocations. Nowadays, we understand that science education should be contextually relevant and pertinent to all students, which leads to new challenges in terms of teaching and learning, and new pedagogical scenarios. Thus, we can state that the contents learned within the classroom are important if they are relevant outside the classroom, too. Therefore, the interrelation between the diversity of knowledge and the development of individuals as citizens is the protagonist of the educational opportunities that cross the boundaries of classrooms. This focus in science education guides the learners to think scientifically, carry out inquiries and scientific experiments and communicate science in order to learn. This is called experiential learning. Consequently, educational spaces outside the classroom invite us, as educators, to value the usefulness of being able to reason in an evolving world, and the need for this reasoning to be connected with the environment (Izquierdo & Aymerich, 2005).

3 Mediational opportunities

Mediational opportunities in education are interactive activities that teachers organize in order to support learners in developing new content, skills, procedures or attitudes. The environment brings mediational opportunities for learning, through the framework of socio-material perspective (Impedovo, Delserieys-Pedregosa, Jégou, & Ravanis, 2017). Through this perspective, the educational opportunities, the educators, learners and the environment are inseparable as educational agents. Thus, this perspective considers social elements and experiences provided by the environment as a “living” educator. Hence, out-of-school education brings new life to interactions for learning (Strong-Wilson & Ellis, 2007).

Fraser and Wien (2001) identified eight key principles for creating meaning through the use of space: aesthetics, transparency, active promotion of learning, flexibility, collaborational processes, reciprocity, bringing the outdoors in, and relationships (Strong-Wilson & Ellis, 2007). By implementing these principles the environment becomes the third educator. An important aspect to consider in this approach is how to maintain a flexible balance between providing structure for interactions to mediate learning, whilst encouraging learners to free exploration (Tarini & White, 1998).

According to the socio-material perspective the environment is inclusive, learners are partners and collaborators in their learning and understand their inherent responsibilities as global citizens. Thus, out-of-school learning experiences, from this perspective, promote students’ sense of agency and have an influence in their world. This involves children contributing not only to making the environment safe, through for example using equipment and resources in an appropriate way, but also through giving a sense of the creation of communities and culture within the environment (ACECQA, 2016).

4 Critical findings of out-of-school experiences for science and mathematics education: contributions of this special issue

This special issue highlights the relevance of out-of-school learning opportunities from two main perspectives. The first perspective considers the teachers' views and perceptions about the facilitators and constraints of out-of-school learning, and likewise the process of changing these views among science student teachers and in-service teachers. The second perspective constitutes of studies exploring science and mathematics learning opportunities in applied out-of-school settings such as science camps, exhibitions, Olympiads and photography galleries.

This special number of LUMAT assembles eight international articles on educational experiences related to out-of-school learning. Henrikson, from Finland, collects primary school teachers' conceptions of using out-of-school settings as an educational resource for science teaching and learning. She highlights the motivational role of these experiences in contributing to students' interest for science. She also presents teachers' perceptions regarding the organizational and economic aspects of some out-of-school opportunities such as outdoor experiences. The work ends with the researchers' concern for the relevance given by the teachers to the scientific knowledge in out-of-school settings. Similarly, Hopper and Köller from Norway describe student teachers' understanding regarding an out-of-school chemistry-lab, through talking sessions, video observation and interviews. They concentrated on the teachers' expectations which were in general positive. The study focused on the relevance and worthiness of this out-of-school experience as a future pedagogical practice.

Bustamante from Chile goes one step further, asking herself about the extent to which teachers' perceptions about education in non-formal spaces – more specifically, the museums – might change. She found ontological changes in teachers' perceptions and epistemological changes in the way they conceived how knowledge and learning is constructed in science.

The next articles are based on the work of Finnish researchers. Halonen & Askela present an experience focused on science camps, combining the perceptions of children and families and the impact of children's gender as well as prior interest on chemistry-camps to the perceived relevance. They show that this type of out-of-school learning experience is particularly relevant when there is a low prior interest in science. Another experience from science camps is presented by Nuora and Välisaari, however, with students from 6th to 9th grades, and with a focus on inquiry in nature. They demonstrate that it is possible to introduce chemistry and biology concepts in a more authentic context through science camps.

Laherto's paper moves into another type of out-of-school learning experience: an exhibition for illustrating the Nano-world. He points out the role of informal educational spaces to promote public engagement in scientific issues, discussing suggestions for improving exhibitions from a visitor-oriented educational perspective. Mutanen & Askela report on an Olympiad experience, focusing on the educational relevance of a science competition and the training of highly skilled students, exploring also gender differences.

Finally, Meier, Hannula and Toivanen from Finland and Norway present a work on expanded perception through outdoors photography. They found that this experience had a positive impact on the teacher students' perceptions of the use of photography for teaching mathematics, which will be relevant for their future work as innovative teachers. This finding resonates with Hopper and Köller, who also found that student teachers had an increased interest in applying out-of-school learning in their future work after having experienced those by themselves in teacher education.

5 Conclusion

Although the themes presented in this special issue are not intended to be exhaustive of out-of-school experiences, they provide an opportunity for LUMAT readers who wish to research or explore out-of-school educational spaces to do so. Considering that the environment mediates in educational processes as the third educator as well as the resources and the teacher him/herself. The experiences collected in this special issue open a window for learning more about the diverse forms and alternatives of out-of-school learning from the beginning of the school years to the professional development of science and math teachers. Additionally, in the future it would be interesting to study new questions, such as how the experiences of variation of teacher guidance in experiential activities support diverse forms of student engagement, taking into account that active learning, promoted for instance, by out-of-school experiences, increases student performance and reduces inequalities.

Acknowledgements

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Primary school teachers' perceptions of out of school learning within science education

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Abstract: This article examines what key aspects primary teachers highlight when they describe their use of out of school learning in the science subjects. The empirical study is made in the form of a semi-structured interview with primary teachers (N=15). Compared to earlier research in the area the results highlight the importance of clear learning aims for the outdoor sequence. The results show that teachers view outdoor education as an opportunity to study nature "for real", which, according to teachers, increases the interest of the children. As aspects that obstruct outdoor teaching, teachers mainly describe different organizational-economic aspects. In their description of the learning content in the outdoor education, teachers mainly talk about the students' interest (affective motivations) and the concrete activity or act (process-oriented motivations). The scientific subject knowledge is limited in the teachers' descriptions.

Keywords: primary school, teachers' perceptions, out of school learning, science education

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1 Introduction and background

In the Nordic countries there is a long tradition of outdoor education (Rea & Waite, 2009). The use of various outdoor environments as learning environments is also recommended in the national curriculum in Finland (Finnish National Board of Education, FNBE, 2014). In Finland, Environmental studies is an integrated subject group composed of biology, geography, chemistry, physics, and health education in the grades one to six (FNBE, 2014). The learning aims for the environmental studies in grades 1–6 are divided into three groups: 1) aims concerning values and attitudes and the meaning and the signification of the subject, 2) aims concerning scientific skills and 3) aims concerning scientific content knowledge and understanding. (FNBE, 2014). The ability to participate, influence and contribute to a sustainable future is one of the overall aims in the curriculum. (FNBE, 2014). Furthermore, in the curriculum text, the pupil's "personal relationship with nature" (p. 24) and that the pupil develops an environmental awareness are mentioned. Based on the national curriculum there are local curricula for each municipality in Finland. Primary teachers in primary schools in Finland usually teach most of the school subjects and have great autonomy to choose different kinds of working methods. In addition to choosing *whether* they use different outdoor environments as learning environments while teaching a science topic, teachers also choose different goals for their teaching in the outdoor environment and various activities in this environment.

The purpose of this study is, in light of previous research, to investigate what key aspects primary teachers highlight when they describe their use of out of school learning in the science subjects. The research questions were:

I. What key aspects do primary teachers highlight when they describe their use of out of school learning?
II. Based on the teachers' perceptions, what possible implications are there for school leadership, teacher education and in-service education?

2 Out of school learning

In previous research, different definitions of the concepts outdoor education and out of school learning can be found. While some researchers focus on teaching carried out in museums and various science centers (see e.g. DeWitt & Osborne, 2007) or via contacts with experts within business or e.g. agriculture, other researchers focus on teaching that takes place in nature. Rickinson et.al. (2004) groups learning outdoors in the following overall forms: a) field work and study trips, b) adventure education and c) activities on the schoolyard and in the nearby community. Remmen and Frøyland (2017) prefer to use the term extended classroom. The term supports the thought of Harlen (2007) and Lederman, Lederman and Bell (2004) that outdoor teaching is not entertaining activities outside the school but something that is directly linked to the curriculum and aims to expand the student's understanding of the subject matter. The use of out of school learning is supported by research. According to Harlen (2007) outdoor education benefits student's learning and development, both socially, personally and at a knowledge level. Research shows that when teaching often is placed outdoors in an environment known to the pupil, like the schoolyard, it may have a positive effect on the student's scientific subject knowledge, attitudes and ecological awareness (see e.g. Carrier-Martin, 2003, Liefländer, Fröhlich, Bogner & Schultz, 2013, Manni, 2015, Slade, Lowery & Bland, 2013). Rios and Brewer (2014) also highlight the importance of creative schoolyard planning in terms of creating an environment that encourages children's investigations. Several studies (e.g. Bingaman & Bradley-Eitel, 2010) show that education in the schoolyard affects pupils' science content knowledge as problem solving skills in a positive way. The positive effects of outdoor teaching can be both short-term and long-term (Rickinson et.al., 2004). Learning in an outdoor environment is holistic, and the student often utilizes several different senses associated with learning (Jordet, 2007).

Research shows that children who have positive experiences of nature are also more interested in e.g. environmental issues (Uitto, Juuti, Lavonen & Meisalo, 2006). In the European Union (EU) recommendations for competences for lifelong learning, scientific literacy is one of the eight key competences (EU, 2006). In the current curriculum in Finland (FNBE, 2014) education for sustainable life and active and responsible citizenship has an important role on a general level and in specific subjects. Positive attitudes towards environment and responsibility are fostered by positive experiences in nature and a pupil's perception of competence to act (Chawla & Flanders Cushing, 2007). Elementary grades are an opportune time to develop environmental attitudes (Rios & Brewer, 2014). Here teachers and parents are important as role models. Like science in general, environmental education can be divided into three dimensions: learning in or of the environment, learning about the environment and learning and action for the environment (Palmer, 1998). Palmer's tree model is further developed by Reunamo and Suomela (2013). At the center of the model are the goals of environmental knowledge, skills and attitudes. In the developed model, the authors further highlight the importance of the student's own experiences as well as the student's sense of participation, community and understanding.

Rickinson et.al. (2004) recommends that the outdoor trips should be carefully planned and formed into wholes. The trip must be prepared and afterwards processed together with the pupils, the trip and the learning should be linked to the objectives of the curriculum and assessed according to this, and the activities during the outdoor stay must be linked to the objectives. Almost identical recommendations are given by Rennie (2007) who additionally stresses the importance of teachers receiving sufficient planning time for outdoor activities from the school administration and that organizational barriers, for example, insufficient timetables, are minimized. Research (e.g. Faria & Chagas, 2013) shows that teachers rarely provide students with pre-assignments and/or post-duties in connection with outdoor teaching. On the basis of previous research findings, Remmen and Frøyland (2017) have compiled six different criteria for an outdoor teaching structure according to the model "the extended classroom" (trans. and processed by the author).

1. A chosen theme that can be investigated from many different perspectives.
2. An assignment that the students will solve.
3. Formulated learning aims (knowledge, methods, aim and form) which scaffold the pupils in solving the assignment.
4. What can the students do in this learning environment that they cannot do in the classroom?
5. Choose activities (pre-assignments, outdoor activities, post-assignments) where the pupils demonstrate their understanding and which increases their deep learning.
6. Formative assessment is used during the work in order to scaffold the pupils to solve the assignment and to investigate where the pupils are according to the learning aims.

There are numerous studies that highlight various challenges within out-of-school education. As limiting factors for the use of out of school education, teachers mention according to Harlen (2007) and Rickinson et.al. (2004) teachers' lack of self-efficacy, lack of time due to the crowded curriculum, new safety regulations, responsibility issues as well as economic factors such as transport costs. According to Wilhelmsson (2012), even the pupils' non-conformal attire can be a limiting factor. Nature can also be perceived as something scary by students (Rickinson et.al., 2004). For students who are not used to staying outdoors during instruction, the first few times the students are too busy to process the new impressions and the unfamiliar environment in order to be able to learn about the subject itself. This applies in particular to students who are used to lecture focused teaching in the classroom. However, with time and support, students can develop new effective study skills in outdoor education. (White, 1988). Outreach can be an objective in itself. Learning to move and take excursions in nature and the built environment is also a learning objective in the national curriculum (FNBE, 2014). In the results of a Swedish study (Szczepanski, 2013) about primary teachers' perceptions of the meaning of the place for teaching and learning, the teachers perceived that teaching and learning outdoors means the following: discovering other learning environments besides the classroom, using large open spaces, utilizing the spatial diversity of outdoor environments, promoting interaction between different learning environments, uniting theory with practice, applying a bodily, sensible learning, creating varied meetings with different phenomena, creating an outdoor platform for environmental work, and finally spending time more freely.

In order to increase the proportion of teaching outside the school's building, teachers according to Rios and Brewer (2014), need further in-service education on outdoor education and increased self-confidence in using different out-of-school learning opportunities. In order to create an understanding of natural concepts, meaningful goals and the ability to take responsibility for one's own actions are necessary. Natural science is also associated with ethics, morals and values (Roth, 2006).

Evoking pupil curiosity and interest for science and for phenomena in the environment is an important aim in science education overall and in out of school learning (DeWitt & Osborne, 2007). "The aim of the teaching is to awaken and deepen students' interest in the different subjects within environmental education."..."With the help of problem solving and investigative tasks, the interest in phenomena in the environment is deepened" (FNBE, 2014, p. 240). However, Andersson (2008) is critical of placing pupil interest as the most important aim for science education. Pupil interest, attitudes and process skills are important, but according to Andersson (2008) and Tobin (2006) teachers have to raise the ambitions higher and successively absorbe and use science concepts to reach systematics in the curiosity. Students do not understand more natural science just because they are socially or physically active. It depends on the quality and depth of student activity and conversation. (Remmen & Frøyland, 2017). In a constructivist approach to learning pupil motivation and consciousness of the learning aims have important roles (Gärdenfors, 2010; OECD; 2007; Sjøberg, 2000). The pupils' motivation for learning is affected by their areas of interest and their curiosity. These aspects are favored when pupils perceive challenge and work with current and actual problems from the pupil's point of view (Harlen, 2007; 2010).

3 Teachers' perceptions

Clark and Peterson (1986) divide the teaching process into two different domains: a) the teacher's (invisible) thought processes and b) the teacher's actions and observable effects of action. The teacher's thoughts affect the action, but the action in turn reflects the teacher's new thinking processes. (Figure 1.)

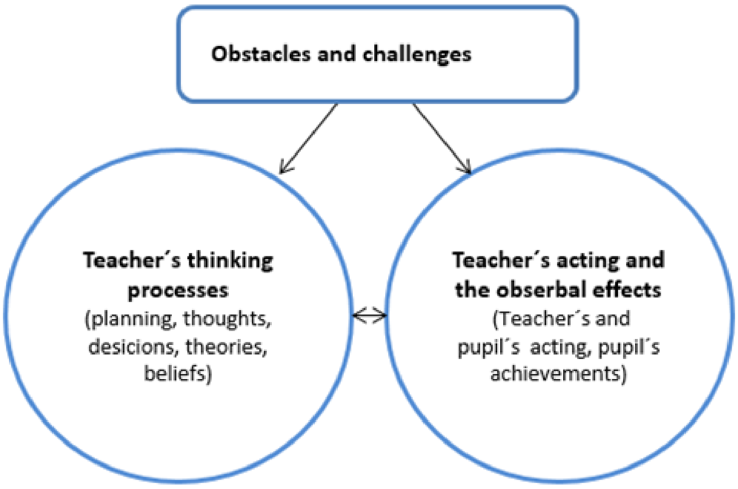

Figure 1. Model about the teacher's thoughts and actions (processed from Clark & Peterson, 1986, p. 257)

The teacher's thought processes can be divided into the teacher's planning categories (both before and after teaching), the teacher's interactive thoughts and decisions, as well as the theories and beliefs of the teacher. Different obstacles and challenges affect both the teacher's thought processes and the teacher's actions. This study focuses primarily on the teacher's thought processes in relation to science teaching. The teacher's aims for the teaching, classroom practices and activities are affected by the teacher's different values and perceptions of learning (Wilhelmsson, 2012) and teachers' beliefs and attitudes (Haney, Lumpe, Czerniak & Egan, 2002). Research also shows that teacher attitudes toward phenomena in nature and to sustainable development can affect students' attitudes and choices in both positive and negative directions (Carrier-Martin, 2003). In their research about primary school teachers' attitudes to science, van Aalderen-Smeets and Walma van der Molen (2015) describe how the teacher's dependency on context factors (e.g. dependency on materials and sufficient planning time) affect the teacher's perceived control. Teachers with high self-efficacy beliefs regarding science and science teaching feel less dependent on context factors. The teacher's perceived control affects the teacher's behavioral intent and behavior.

Marton (1997) warns about trying to compare different teaching methods and activities with each other. What is more important, according to Marton, is to investigate what the student is supposed to learn from the method, i.e. what competences one wants to achieve. Instead of asking the question, 'What does work?', the teacher should ask 'For what does it work?'. Hattie (2012) points out that for teachers it is also important to evaluate the effect of the methods used.

The teacher's educational actions are at best targeted. The goals for which the teacher's actions are directed can be partly the goals of the curriculum and the goals the teacher personally sets for his teaching. In order for the thinking to be targeted, the teacher should first know the goals, accept them and embrace the thinking in the goals. The curriculum goals and the teacher's thoughts and actions then form a whole (Kansanen, 2004). According to Clark and Peterson (1986), however, teachers focus their planning primarily on the substance and the students' activities. The national curriculum (FNBE, 2014) also emphasizes the importance of the student being involved in the formulation of learning objectives. Remmen and Frøyland (2007) also emphasize that the aims of the teacher and different experts do not always correspond to the pupil's aims for the out-of-school education. Research shows that the same basic aspects that benefit student learning also benefit the teacher and teacher learning and teaching. Aspects that emerge are targeting, time for reflection, collaborative learning, cooperation, interest and motivation (see e.g. Harlen & Qualter, 2014; Shulman & Shulman, 2004).

4 Methodology and analysis

This article examines what key aspects primary teachers highlight when they describe their use of out of school learning in the science subjects. Teachers' qualitatively different perceptions of phenomena and the variation in these perceptions are investigated. The epistemological approach to the study is phenomenographical. The ground unit in the research is a way of perceiving something. The object of the research is the variation in the ways of perceiving the phenomena. The empirical study is made in the form of a semi-structured interview with primary teachers (N=15). The teachers in this study are formally competent primary teachers working with children in grades 3 – 6 in various Swedish speaking schools (N=15) along the coastal boarder of Finland. The teachers' backgrounds regarding teaching career and teacher training varied as well as the size and the urban-rural surroundings of the school. Three of the teachers were male. The interviews were recorded on two dictaphones and took place after the pupils in the class had left school for the day. The verbal data was transcribed by the author in order to conduct a thematic analysis. A pseudonym was used for each of the teachers. The data corpus of teachers' experiences was then analyzed thematically on three levels:

1. a data set consisting of all instances where the teachers are referring to out of school learning
2. data extracts on a personal level are analyzed and thematically coded and
3. qualitatively different themes on a general level are coded.

Table 1 illustrates and exemplifies the procedures in the analyze process. To illustrate the meaning of the themes, quotes are used. In connection with the quotation, pseudonyms are used. The outcome of the analysis is discussed against the background of previous research and guidelines and objectives in the curriculum in section 6.

Table 1. Classification and coding during the analyze process – an example.

Data corpus	**I**	**II**	**III**	**III**
Teachers' answers during the interviews	All instances referring to out of school learning	Personal quotes – examples	Potential themes	Qualitatively different themes on a general level
		... and watch more concrete things	Concrete work	
		... for it to be still more concrete		
		... in order to get more change	Variation	
		... in this way to be able to get variation		
		... to raise the interest for the school subject	Pupil's interest	Motivating aspects
		... if you can't be in your room you have to go out.	Small and/or unsuitable classrooms	
		It is easier for me. I can work with things like forces and water.		
		When I think about outdoor teaching – one reason for me is that I am so interested in being outdoors myself	Teacher's own interest	

An inductive approach always incorporates some pre-understanding. (Bjereld, Demker & Hinnfors, 2009; Dalen, 2007; Larsson, 2005). However, the research should be valid so that it is empirically anchored and coherent. The empirical anchoring is, according to Larsson (2005), that there must be a correspondence between reality and interpretation. Within the phenomenological approach, the idea is that all analysis and interpretation should be rooted in the interviews. The various descriptive categories are therefore illustrated and highlighted by using direct quotes from the interviews as examples. There must be an internal logic or coherence throughout the work. The research purpose steers the choice of theory, research effort, methodology and analysis. Every interpretation in the analysis means, according to Larsson (2005, p. 24) ”a tension between the demands for consistency and empirical anchoring”. To obtain internal logic throughout the work the theoretical background, the results and the discussion are structured based on the research questions. Synonyms for the research reliability could be precision and accuracy. Dalen (2007) emphasizes the importance of being clear and just about the various aspects of the research process. In the account of how the empirical collection has been carried out, written and analyzed a careful description is important. During the interviews, it is important to keep in mind that the interviewer neither in the matter or in voice mode, gestures, etc. affect the interviewee in any way. The aim of this study is not to provide all possible perceptions that primary teachers generally have or will have. The goal is to get the variety of perceptions that can be studied regarding this group of qualified primary teachers. This aim is consistent with what Maxwell (2005) calls for internal generalizability.

5 Findings

All teachers in the study stated that at least sometimes during the academic year they go out with the students in connection with science teaching and especially in the field of biology. In the following, the teachers' perceptions are presented under the main themes that have emerged during the analysis.

5.1 Out of school learning in the form of out-door-activities

Teachers describe how they, together with the students, visit different places in the school's immediate environment. Visits are made e.g. to a nearby forest, lake, river or to the shore. Visits are made on foot or by bicycle, and it is often a visit that spans one or two lessons. Even longer-term trips are made in the form of out-of-school day (where students stay overnight in tents) or as a camp-school for a whole school week. During the outing the pupils often study plants. Pupils observe and examine plants, for example, using a microscope. During the field excursions, pupils can also study different birds. Even though Anna works in a city school, she states that she largely utilizes the schoolyard as a place where students can become acquainted with different plants and cultivation. Even Johanna and Tommy make use of their schoolyards and their possibilities in outdoor teaching. Anna also describes how she, together with the students, have created a schoolyard where students grow different grains which are then examined and used for baking. While biology-related issues are common, teachers describe fewer issues related to the knowledge content in geography and physics. Teachers emphasize the difference between biology and geography when it comes to opportunities for out of school learning, mentioning that they rarely or never go out during the geography sections. As a reason, they mention the time of year and the nature of the content.

> "Then in biology you try to go out into nature.... In the autumn ... we have a lake, a swamp actually, which has grown again. So that's good of course. But in geography, if you think about the fifth and sixth year course, they read about Europe and the rest of the world, then it's not just getting out of the door and benefiting from it. "(Olle)

Regarding different chemistry-related content topics, teachers mainly mention the theme of water. Teachers also describe how they work with subjects integrated during the outing. The subjects mentioned by teachers are sport, craft and mother tongue.

5.2 Collaboration between classroom teachers and external professionals

Teachers see cooperation with outside experts as something positive. The trips can at best enhance both the students' and teachers' learning.

> "And it was like an injection of ideas for me too. I got so many new ideas from her this teacher who is always in nature with the kids and does stuff with them and it was noticed that the kids also thought it was fun and looked forward to these times. It would be great to be able to bring in such outside experts and do fun things and go on small trips. "(Siv)

Students can either visit a natural school, or a natural school can visit the school to arrange a teaching opportunity. The Forestry Center also offers popular education opportunities for schools. In connection with time-long school trips, teachers and the students have visited a national science center that can offer lesson packages and exhibitions. Anna describes how she has visited a gardening company and a mill with her students in connection with the class culture project. School visits are also made to different services in the community. Teachers describe that they have visited, for example, power plants and water treatment plants.

5.3 Aspects that motivate out of school learning

As an advantage of outdoor education, teachers mention the possibility of studying nature in concrete terms or "on real", which increases the interest of the children. The outdoor environment offers many opportunities for concrete investigative and practical work. The outdoor environment also offers students variation in the school day. Teachers also describe outdoor teaching as a good option since the school's facilities are too small or unsuitable for teaching in e.g. physics and chemistry.

> "It will be easier for me. I can work with both power and water and different things in the water and filtering and measurements and that kind of practical things. I like to do that outdoors." (Diana)

A strongly motivating aspect is the teachers' own interest in being out with the students. The teachers' own interest in being outdoors drives them to bring the students out of the classroom. Pupils with different special interests and knowledge can be given the opportunity to show them during their stay outdoors. Anna describes how she adapts her students' pre-knowledge and interest areas and uses it as a starting point for the outdoor education.

> "... that I work very often outdoors and I work a lot based on what the children can and ... just that ... we spin on then from that and maybe take it into several different subjects or make a product." (Anna)

5.4 Purpose and learning goals

The main purpose of out of school education according to teachers is to increase or to maintain the pupils' interest in science and nature.

> "Well, in grade three and four, I just like to evoke interest and like to take them [the pupils] out in nature and sort of look at how things really are and so ... that they are really going to be interested and it is very useful then because children love both animals and nature."(Anna)

The only learning goal to be mentioned by a teacher in the study is that pupils by visiting different social services gain an idea of how society works. Teachers also express concern that learning goals are not met if the students work outdoors instead of in the classroom. Erik describes how he worries that the biology ”flows out” if students study the topics outside the classroom.

> "So what is it called ... it requires planning ... and then that not everyone is so focused. There may be some [pupils] who, as you know, understand the data, or everyone can understand ... but to do what you do not like, that the biology just flows out ... that is what you are afraid of.” (Erik)

5.5 Challenges connected to out of school learning

A challenge according to teachers is that the students' interest in science and being outdoors decreases as age increases. Nature, and especially the forest, can also be experienced by some students as scary. Diana describes how students need to work on staying in and moving in nature before they can focus on the subject matter. For students with different mobility disabilities, outdoor education can cause practical problems.

> "... ..but there I have to think that I'm doing such teaching so that the pupil can join. Having a wheelchair in the woods is not optimal ... so maybe it's better to take parts of nature in class instead of going out when everyone can’t come along "(Pia)

Olle raises a security perspective and believes that it is not safe for the teacher to take the students out if you can’t rely on them to follow the teacher's instructions. According to Tommy, there are major differences between the groups in terms of interest in outdoor education. He tells us that he has had classes that he has completely avoided going out with because of the pupils’ behavior.

For the teacher, outdoor education can mean more planning. As aspects that complicates outdoor teaching, teachers mainly mention different organizational-economic aspects. Tight timetables and, for example, taxi riders can make it difficult to carry out different trips. The school day is divided by the teacher's lessons in other classes, other teachers’ lessons in the class or lunch schedules. Pupils who come to school by taxi or public transport have difficulty taking a bike that would be needed for e.g. a field trip. Arranging trips that require transport with e.g. buses incur additional costs for the school. The tough economic times in the municipalities have meant that schools have had to cut back on these expenses. Anna believes that the lack of funds limits the use of different transports.

> "You do what is possible. No, I have quite a few lessons in my own class so it's probably good. But just this I want, I have decided that I always have two lessons after each other in science. Just because you can go out and do something. That there is no other teacher who is waiting for you." (Johanna)

Seasonal changes can also cause problems for teaching. Teachers often choose biology-related themes for outdoor activities. In schools in the northern part of Finland, spring is, according to teachers, often so late that few plants can be studied then.

5.6 Visions connected to out of school learning

Teachers wish to work with more concrete activities and increase the use of outdoor education. In order for this to be possible, teachers want flexible group divisions and/or smaller student groups. Several teachers participating together in outdoor education is viewed by teachers being positive. They ask for different models with companion teachers in the class. Overall, teachers experience a need for more adults in school.

> "Then there might be several adults in school. That you could have more flexible groups and it would be easier to do some things with the students, to go away with students or to watch a few things with fewer students. I think it could bring benefits." (Berit)

6 Discussion and implications

The teachers use outdoor education in their teaching. The environment (nature) is, in particular, actively used by teachers. Based on the positive research findings regarding outdoor education's influence on the student's science content knowledge, problem solving skills as attitudes towards environmental issues, this is positive. In the teachers' descriptions it can be seen that outdoor education mainly takes place with a focus on biology and less in the content areas of geography, physics and chemistry. Of the categories for outdoor education presented by Rickinson et.al. (2004), teachers mainly describe different activities nearby the school and in the community as well as, to some extent, different study visits while the area of adventure education is not highlighted.

Regarding aspects that obstruct outdoor teaching, teachers mainly describe different organizational-economic aspects like timetables, adult resources and transports. Some teachers would like to be out more with the students while teaching. This revolves around Rennie's (2007) thoughts that teachers from the school management need to have adequate planning time for outdoor education and that the effects of the organizational barriers, for example, tight timetables are minimized. Challenges are a fact (Clark & Peterson, 1986) but how much teachers allow themselves to be influenced by these challenges depends on the teacher's attitudes and self-efficacy (van Aalden-Smeets & Walma van der Molden, 2015).

The results show that teachers see outdoor education as an opportunity to study the nature concrete or "on real", which, according to teachers, increases the interest of the children. Learning outside the school can also be a good option as the school's spaces are too small or unfit for science teaching. A comparison between the results of this study and the Swedish survey (Szczepanski, 2013) shows that there are many similarities between teachers' perceptions. Teachers in both studies emphasize the opportunity for pupils to work practically and have varied meetings with different phenomena. The outdoor environment also offers larger areas compared to the classroom environment. The Swedish teachers feel they can spend time outdoors more freely, while the Finnish teachers highlighted the need for flexibility when it comes to timetables. In the Finnish teachers' perceptions, the environmental work is not highlighted in connection with out of school learning. However, in the new national curriculum the pupil's development of an environmental awareness is stressed (FNBE, 2014).

In their description of the learning content in the outdoor education environment, teachers mainly talk about the student's (and the teacher's) interest (affective motivations) and the concrete activity or act (process-oriented motivations). These are important aspects in order to increase the pupils' motivation for science learning. The scientific subject knowledge, in the form of increased understanding of central concepts, phenomena and relations, with the exception of the mentioning of different plant species, is limited in the teachers' descriptions. In view of the new curriculum of environmental education and its subdivisions (FNBE, 2014), teachers should gain more knowledge about the use of outdoor education in the areas of physics chemistry, health education and geography. The linking between learning aims, theory and practice is not highlighted in the teachers' perceptions. For the pupil's motivation, it is important that he experiences a sense of participation, community and understanding (see e.g. DeWitt & Osborne, 2007, Reunamo & Suomela, 2013). The pupil's ownership of his knowledge and active participation in the goal setting work is also emphasized in the curriculum (FNBE, 2014). Clear learning goals, pre- and post-assignments and a formative assessment aimed at supporting pupil learning are also criteria for a good outdoor education according to Remmen and Frøyland (2017).

As with other teaching methods and environments, teachers in the study indicate that students need to practice to stay and move in nature before they can begin to immerse themselves in the subject matter. This is also emphasized by White (1988). According to Anna, children are sometimes afraid of going out into nature, as is also evident from the research compilation of Rickinson et al. (2004). The schoolyard as a learning environment is highlighted by teachers, but only to a very small extent. Not having to travel long distances for outing facilitates simplifies the teacher's planning in several ways. The proximity to school can make the teacher to feel more safe to supervise a group of students outdoors. Outdoor visits can be done more often and thus become a recurring part of the teaching, which is also recommended by, for example, Carrier-Martin (2003). The fact that teaching is conducted in the vicinity of the school also means that transport costs are avoided. In view of the positive results (according to science content knowledge, pupil's attitude, ecological awareness and problem solving skills) from outdoor learning on the schoolyard (e.g. Bingaman, Bradley-Eitel, 2010) an increased use of school grounds as a learning environment is recommended.

The study is about the teachers' perceptions regarding outdoor learning and what they highlight. It is important to hear what the teachers say, but it is also important to reflect on what aspects these teachers do not mention. As stated, teachers talk very little about the learning aims for teaching in out-of-school settings. Furthermore, they do not describe how and if they do prepare the pupils for the tasks with pre-assignments or if they follow up the tasks with post-assignments. Not one of the teachers mentions the children's or the teacher's use of digital tools during the outdoor education.

The teachers' attitudes towards outdoor education are important. The teachers' lack of self-confidence in outdoor education is according to e.g. Harlen (2007) and Rickinson et.al. (2004) an aspect that decreases their use of outdoor environments for learning. Teachers need support to increase their confidence. As Rios and Brewer (2014) suggest this actualizes the importance of teacher education and in-service education regarding the teaching of science content in an outdoor setting. Teachers can be educated to see the possibilities of outdoor education from a broader perspective and to scaffold the pupils into deeper learning.

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Outdoor chemistry in teacher education – a case study about finding carbohydrates in nature

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Abstract: In this case study, we describe an inquiry-based approach to enhancing tuition in chemistry by taking student teachers out of the lab and into nature. We used video observation and interviews to gain insight into student teachers' expectations and experiences of such fieldwork. Through thematic analysis, we found that the participants perceived the approach as individually relevant and worthy of integrating as a teaching method in future practice. Further, we discussed challenges presented by outdoor chemistry and ways to overcome these. Overall, we show that fieldwork in chemistry contributed to a better understanding of chemistry as an integral part of nature.

Keywords: inquiry-based, linking domains, outdoor chemistry, outdoor learning, relevance

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1 Introduction

School students rarely perceive chemistry lessons as relevant or motivating (Sjøberg & Schreiner, 2010). In many cases, concepts are presented in an abstract way and in a strange and unfamiliar language. All too often, they are related neither to the students' lives nor to the world they live in (Childs, Hayes & O'Dwyer, 2015). A recent study confirms the challenge in attitudes among students towards different fields of science, with chemistry generally viewed as "toxic", whereas nature is perceived as "idyllic" (Krischer, Spitzer & Gröger, 2016). Suggested approaches to making school chemistry more relevant include teaching chemistry in realistic contexts by employing everyday-products (Gilbert, 2006; Parchmann et al., 2006). Another possibility is emphasizing education for sustainable development (Burmeister, Rauch & Eilks, 2012; Jegstad & Sinnes, 2015). Still, chemical substances are mostly examined in the laboratory, often separated from their normal range of use or occurrence, leading to critique and calls to take chemistry out of the classroom (Ceci, 2015). Here we describe an approach to outdoor chemistry that was inspired by the concept of "chemistry trails" (Borrows, 2006).

1.1 Theoretical background

School-based outdoor teaching of chemistry is a rare occurrence, and is mostly confined to the context of larger projects within geology or biology, or to visiting external resources such as factories, semi-natural outdoor-labs or science centers (Burmeister et al., 2012; Gröger, 2013; Thorsheim, Kolstø & Andresen, 2016). Our proposed approach to outdoor chemistry consists of short field trips that are compatible with a normal chemistry curriculum, thus creating a low threshold for teachers to take chemistry outside. Thorburn & Allison (2010, p. 101) discuss the benefits of such an approach as "low in risk and high in transfer value", compared to outdoor center visits, which are often "disassociated from current school-based learning contexts and lacking in transferable value". Instead of traditional teacher-centered excursions, we propose active student-led learning outside the classroom or laboratory. Our approach is based on sequences of outdoor experiments that are fast (5-45 minutes), simple, and require collaborative work. This allows science teaching to become more relevant, thereby fostering deeper learning. This was also demonstrated in a new framework for the "extended classroom" (Remmen & Frøyland, 2017).

Relevance is a commonly used term in connection with curriculum development and in science education research. However, in many cases the conceptualization of relevance is inadequate. In our analysis, we use the model of three dimensions of relevance, suggested by Stuckey, Hofstein, Mamlok-Naaman & Eilks (2013). The individual dimension incorporates aspects like personal interest, new knowledge and comprehension or achieving good marks. The societal dimension includes different aspects about the individual's place and behavior in society. The vocational dimension focuses on aspects relevant for the students' future professional development. Within each of these dimensions, there are components of relevance, ranked along a present-future and an intrinsic-extrinsic range (ibid.).

The benefits of outdoor teaching, when well planned and coordinated, have been documented (Dillon & Dickie, 2012; Dillon et al., 2006; Fiennes et al., 2015; Glackin, 2016). Fieldwork "offers learners opportunities to develop their knowledge and skills in ways that add value to their everyday experiences in the classroom." (Dillon et al., 2006, p. 107). Scott et al. (2012) show similar effects for students in higher education. At the same time, there are challenges related to achieving the intended learning outcomes through practical work. For example, it has been argued that practical work can involve a lot of physical, but not enough cognitive activity and suffer from a lack of focus (Abrahams & Millar, 2008; Remmen & Frøyland, 2017).

In this context, Abrahams & Millar (2008, p. 1948) state that "the fundamental purpose of practical work in school science is to help students make links between the real world of objects, materials and events, and the abstract world of thoughts and ideas". However, it has been shown that students need considerable help to actually make links between these two worlds, which represent two domains of knowledge (ibid.). Scott, Mortimer & Ametller (2011, p. 5) state: "It is clear that if link-making is not addressed through teaching, then it is unlikely to emerge in students' learning." Three forms of pedagogical link making that foster learning were identified: supporting knowledge building, promoting continuity and encouraging emotional engagement (ibid.). Misconceptions may impede link-making. We follow the definition of misconceptions as misunderstandings, formed after formal teaching in the subject, compared to those before formal teaching (pre-concepts) (Stojanovska, Petrusevski, Köller & Karlsen, 2015). Such misconceptions, held by students at different levels, from school to university, have to be identified first, and in the next step addressed and challenged (Abell, 2007).

In addition to the challenges mentioned above, teachers perceive different specific challenges that keep them from doing fieldwork (Glackin, 2016). Common reasons include "inflexible and overcrowded curriculum, resource shortage, safety issues, lack of teacher confidence and expertise, poorly designed school grounds that limit use, lack of pupil interest, and unsuitable weather", as described by Fägerstam (2014, p. 59).

1.2 Research questions

Based on the theoretical background presented above, we developed the following research questions:

- How do outdoor lessons influence student teachers' understanding of chemistry as an integrated part of nature outside the chemistry-lab?
- What are the student teachers' expectations and experiences with regards to the fieldwork itself and with regards to integrating it into their future teaching?

2 Method

2.1 The teaching unit

This case study was conducted in an integrated science course, preparing student teachers for teaching years 5-10 of secondary school in Norway. In this country, science, technology and engineering are combined in one subject ("Naturfag") up to 11th grade, (Utdanningsdirektoratet, 2017). Here we follow five student teachers ("students 1-5") and one in-service teacher in continuing education ("student 6") whilst they carry out fieldwork. The student teachers mainly worked in two groups, called group A (student 1-3) and group B (student 4-6).

The case study was embedded in an inquiry-based teaching unit about food chemistry. The summary in Figure 1 illustrates how we integrated the fieldwork into the existing chemistry curriculum by replacing parts of teaching units in the lab with outdoor sequences. The students were set the task of acting as "molecule detectives" and equipped with "chemistry tool bags", which contained the necessary equipment in the form of easy to use test kits, in this case glucose test strips and Lugol's solution (starch test), Figure 2.

The main learning objectives were to find carbohydrates in nearby nature, coupled with reflecting on how to implement similar approaches in their own future teaching practice. Step-by-step guidelines for the outdoor teaching unit are described for use in secondary school in Höper (2017).

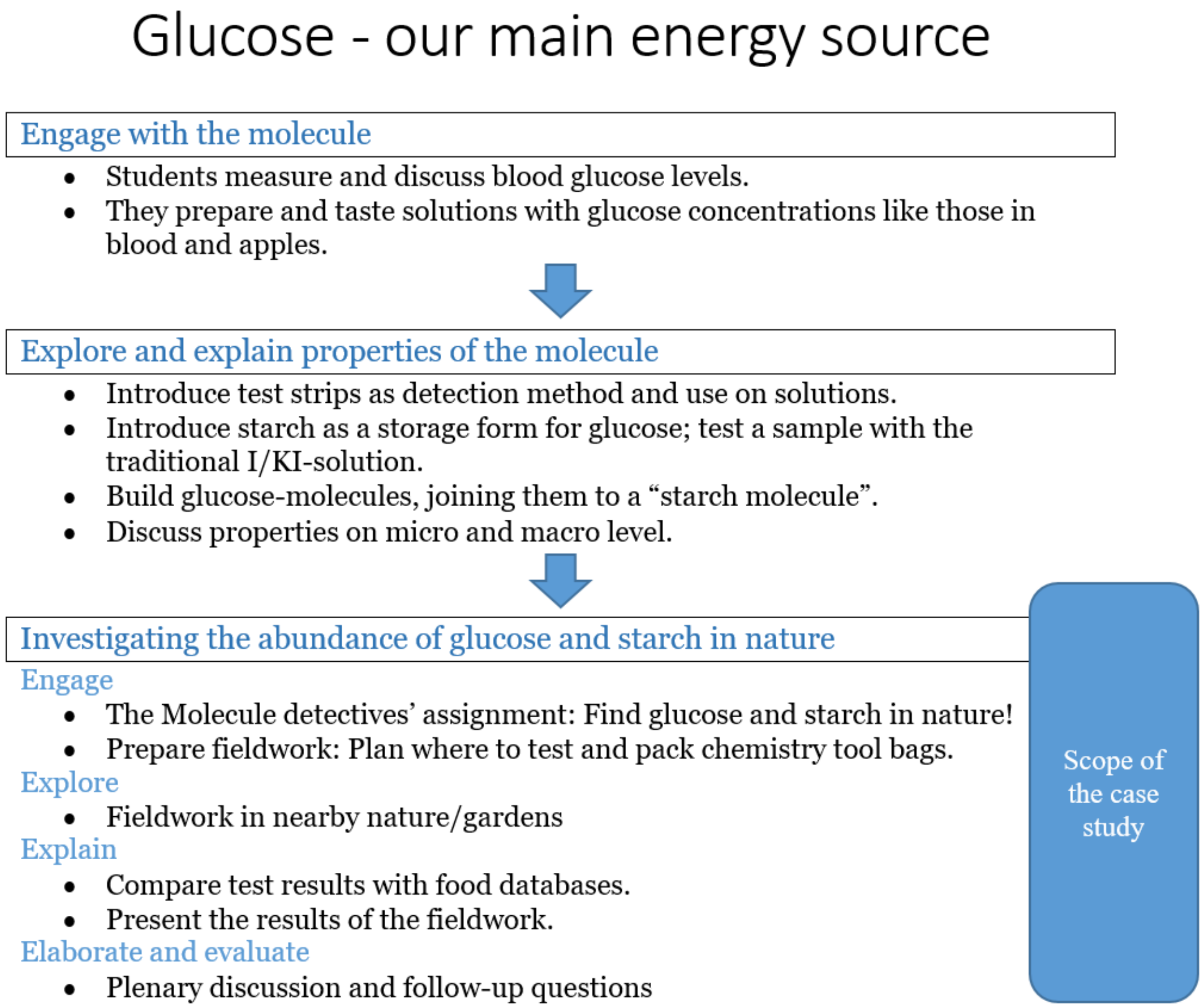

Figure 1. Summary of the teaching unit on glucose and other carbohydrates, based on the 5E inquiry-based instructional model (Bybee, 2009).

2.2 Data collection

To get a better understanding of the student teachers’ perspective, we used a qualitative approach that incorporated data from different sources. We used video observation for a whole-class interview prior to the teaching unit, for the outdoor sequence and for a follow-on teaching sequence. During the outdoor sequence, we used chest mounted GoPro-cameras on one student per group (Frøyland, Remmen, Mork, Ødegaard & Christiansen, 2015). Additionally, we audio-recorded individual, semi-structured interviews after the teaching unit (Kvale, Brinkmann, Anderssen & Rygge, 2015).

The first author, who had been teaching the student teachers and therefore knew them well, continued as their teacher. The second author, who was not involved in this course, acted as an outside observer during the teaching unit and conducted the individual interviews without the presence of the first author.

Figure 2. "Molecule detectives" outdoors, testing for glucose.

2.3 Data analysis

Our data analysis follows a thematic analysis approach (Braun & Clarke, 2006). The analysis is based on 2 hours and 17 minutes of video footage and five individual interviews of approximately 20 minutes each. For practical reasons, it was not possible to interview student 6. We used NVivo to transcribe the data word-for-word in Norwegian, including comments on important nonverbal events in the videos. Not every minute of video footage could be transcribed, though, due to technical challenges, for example when the groups were walking along a noisy road. Translation of quotes to English follows Norwegian closely.

After reading the transcripts, we developed an initial codebook. Intercoder agreement was reached by iteratively double coding parts of the transcripts, followed by comparing and revisiting our codes (Creswell, 2013). The transcripts alone did not cover details of the voices, intonation and other nonverbal activities, which we realized were necessary to set short dialogues into context. Therefore, we compared and discussed remaining disagreements with regards to coding by using the transcripts together with raw footage in NVivo, as this gave us a more nuanced understanding. In addition, we discussed our article with our research group, as suggested by Creswell (2013).

By reading the transcripts repeatedly, comparing the codes and data-extracts with literature shown in the introduction, we thematically classified three themes, divided into eight sub-themes, as summarized in Table 1. The first theme concerns the relevance for the individual and vocational dimensions as defined by Stuckey et al. (2013). The second theme addresses challenges that the student teachers show throughout our material, both during fieldwork and in the interviews. These were comparable to those described in related work (e.g. Fägerstam, 2014). Therefore, we decided to define them being a theme themselves. The third theme contains observations concerning the relationship between school chemistry and real life experiences (e.g. Krischer et al., 2016). In our material, we see link-making (or sometimes a lack of link-making), as defined in Scott et al. (2011), as crucial. The teacher students were establishing links between different domains of knowledge (Abrahams & Millar, 2008).

Table 1. Themes and sub-themes

Theme	Sub-theme
Relevance	Individual
	Vocational
Challenges	Practical and methodological
	Learning outcomes
	Classroom management
Chemistry as an integrated part of nature	Linking organisms to chemical substances and their properties
	Linking the experiments to concepts in chemistry
	Linking organisms to content knowledge in biology

A short example to illustrate the key stages of our analysis is shown in Table 2.

Table 2. Key stages of analysis of a segment of a dialogue. Situation: A group of student teachers discovers a bush of raspberries adjacent to a garden.

Transcript excursion group A:	**Initial coding**	**Sub-themes**
Student 2: Shall we test them immediately? [detaching the glucose test strips from the tool bag]	➔ Hands on/ no challenges	Vocational relevance [easy to use in future teaching practice]
Student 3: Yes. This is, [short pause] but I don't know if it is important how ripe they are? [short pause]	➔ Linking chemistry and food [referring to an earlier dialogue about glucose content in berries]	Linking organisms to chemical substances and their properties
Student 3: Here is the flashback [laughter] stealing raspberries! [whole group laughing] Student 1: Yeah. [smiling]	➔ childhood memories	Individual relevance

3 Results and discussion

Following our research interest, we begin by discussing the student teacher's expectations and experiences, before addressing observations of learning experiences that allowed them to connect chemistry to nature. For the three themes defined above, we assessed combined data from the videos and the student teachers' interviews.

3.1 Relevance

The student teachers in our study perceived the approach to outdoor chemistry as relevant in both individual and vocational dimensions. We found no evidence in our data that the student teachers were preoccupied with the societal dimension of relevance (Stuckey et al., 2013).

3.1.1 Individual relevance

In the interviews, all student teachers described the approach as interesting and exciting:

> Student 4: [...] more fun, you felt a little bit like a chemical Indiana Jones while you are outdoors and testing, bearing your little bag.

Nevertheless, it was not just fun. Most student teachers mentioned explicitly that it helped them to a better understanding of the subject matter:

> Student 5: [...] if I get a question about this in my exam, I will definitely remember it.

> Student 1: I learnt something new on Friday. I am not so strong in chemistry.

The video-analysis of the outdoor sequence supports the findings from the interviews regarding individual relevance. The student teachers generally enjoyed the given tasks and were intrigued by the method of open inquiry. One student teacher had a particularly positive association of outdoor chemistry with his own childhood, repeatedly commenting on stealing raspberries ("bringebærslang"), spreading his excitement to the rest of the group (Table 2). "Bringebærslang" was his own word-creation, adapted from a unique Scandinavian word for children stealing apples in the neighborhood ("epleslang").

3.1.2 Vocational relevance

The student teachers had no previous experience of outdoor chemistry. Outdoor teaching was limited to biology or remembered as something they enjoyed, but without actual science content, e.g.:

> Student 6: Well, I remember we were out a lot. In the forest, or at the beach below. I do not remember what the teaching content was about, but I remember the days clearly, I have very positive memories of being outside with school.

In the interviews carried out after the teaching unit, the student teachers discussed different aspects of the vocational dimension of relevance. They considered this approach as a new, meaningful tool, worth implementing into their own future science lessons:

> Student 4: I now have this in a kind of "toolbox of ideas". I know this is a possibility. Now I will think more like – this is something I could do.

Observations during fieldwork confirmed statements like this. The student teachers eagerly tested the glucose concentration of many different organisms. The different dimensions of relevance in the model are interrelated and partly overlapping (Stuckey et al., 2013). Our data showed that student teachers often combined the individual and vocational dimension of relevance of the outdoor chemistry approach, describing it as personally intriguing and at the same time relevant for their future teaching practice.

3.2 Challenges

We asked the student teachers about the challenges they expect for outdoor chemistry in their future teaching practice, while observing the challenges they encountered during the outdoor sequence. This was particularly interesting as none of the student teachers had previous experiences with outdoor chemistry. In our material, we thematically divided the challenges into three sub-themes.

3.2.1 Practical-methodological challenges

During the outdoor sequence, we observed that the student teachers often focused on practical aspects such as how to perform the tasks correctly and how to document the activities. In the following example, group A discusses how to optimize the documentation of the results, while at the same time considering methodological challenges:

> Student 3: You might place it between them [Referring to the glucose test strip and the patches of the color scale]. It surely is a high value [short pause], but not full score.
>
> Student 2: But, is it visible to the camera now? Exactly how much? Or should you take the picture this way? [trying different angles with a smartphone]
>
> Student 3: We are keeping them, aren't we? [The used test strip] To look at them afterwards?
>
> Student 2: But, they might change, don't they?

The example above confirms Fägerstam's (2014) findings for secondary school teachers that outdoor schooling facilitates experience-based learning. It also underlines the importance of outdoor experiments being easy to conduct. Student 6 (the in-service teacher) was fully aware of this, as expressed in the pre-interview:

> Student 6: The tests have to be very easy if you want to do a lot outdoors, it has to be straightforward. It's no use to take out a lot of stuff.

Our approach seems to meet this criterion, as confirmed in the student teachers' follow-up interviews. Some of them mentioned the outdoor sequence as easier to conduct than expected (see *vocational relevance* above).

3.2.2 Learning outcomes

It is difficult to draw a positive correlation between practical work and learning outcomes (e.g. Abrahams & Millar, 2008; Hofstein & Lunetta, 2004). Some of the student teachers reflected on this issue in their interviews:

> Student 2: I think it can be difficult to ensure learning, learning what you intend for them to learn.

The importance of content knowledge prior to practical work, “to be able to derive meaning from their results” (Köller, Olufsen, Stojanovska & Petrusevski, 2015, p. 43), was evident during fieldwork. Student teachers struggled to make sense of some of the test results. This aspect was also discussed in the interviews. One student explicitly mentioned not being familiar enough with the expected content knowledge.

> Student 3: [hesitates] I don’t grasp this fully, I really don’t, but I understood the main principles.

Suggestions to overcome challenges regarding learning outcomes, as discussed by the student teachers, included adequate preparations, both practical and theoretical. They consider it important to have clear assignments to maintain a focused learning environment in school.

3.2.3 Classroom management

The student teachers were concerned about how to plan and organize outdoor-sequences and stay in control, depending on the size of the school classes and the age of the students. At the same time, they suggested solutions like dividing the class into appropriately sized groups and selecting suitable outdoor locations to ensure a positive learning environment. They also expressed a belief in the benefits of the affective and social dimensions of outdoor learning, which had also been demonstrated in several previous studies (e.g. Fiennes et al., 2015).

All the aspects mentioned above are consistent with the findings of Fägerstam (2014), who investigated the perceived and experienced challenges by secondary school-teachers who participated in a one-year-program to implement outdoor schooling on a regular basis. They, too, expected that ensuring school student discipline would be tricky and indeed experienced this in the beginning, but they overcame this challenge and were able to focus on subject matter after a while.

Surprisingly, in our case study, most of the students did not worry much about time as a limiting factor. This may be due to the students' lack of teaching experience and the positive reputation outdoor teaching has in their biology textbooks. Asked about the reason for not mentioning the issue of time, one student simply suggests combining lessons from science with other subjects to get more time. This pragmatic attitude might work, as we could actually observe it in Norwegian schools in different contexts, e.g. geology fieldwork combined with mathematics and physical education. Moreover, lack of time may not be a crucial issue as teachers can overcome this by reducing extended field trips to the nearby environment or even the school grounds (Fägerstam, 2014).

3.3 Chemistry as an integrated part of nature

We designed the teaching unit to help overcome "the cognitive challenge of linking observables to ideas" (Abrahams & Millar, 2008, p. 1945) through executing chemical tests in situ, i.e. taking the lab out of the classroom, instead of the object of interest out of its context. Hereby, we identified three types of link-making between the domains of observables and the domains of ideas in our material.

3.3.1 Linking organisms to chemical substances and their properties

The main goal of this teaching approach was to link chemistry to nature, which we asked the students to reflect on in the interviews. Here are some examples:

> Student 1: [...] it often becomes very "chemical" in the lab, you don't get any clues where to find these substances and this may be the most important thing: To get an opportunity to learn where to find them in nature.

In our data derived from fieldwork, we found interesting dialogues about where the student teachers expected to find the substances they should test. They also discussed other compounds like vitamins, or why tree bark might be nutritious. A misconception was revealed in group A in the interviews. We see the members of the group surprised about a negative test result for starch:

> Student 2: Ok, but, eh..., we were sure there would be starch here, weren't we?
>
> Student 1: Yes.
>
> Student 3: Time will show.

> Student 2: [We expected] A lot. A lot in such nice food for moose.
>
> Student 1: And... there was none [starch]!

Interesting details were discovered in the following interviews. One student teacher had never thought about the link between chemical substances and plants:

> Researcher: Was there anything extra exciting? Maybe something you didn't know before?
>
> Student 3: There was a revelation; I didn't expect it [bark, expl. note authors] would be made of carbon compounds. I had never heard that living organisms are made of that, trees and such.

Later in the interview, we talked about different carbohydrates:

> Student 3: [...] really, I thought about glucose, that it tastes sweet and would be liquid, that's what I thought. And starch more like...I don't know, maybe I was a little bit confused there...I thought about starch, assumed it would be something solid.
>
> Researcher: Yes, OK.
>
> Student 3: I had this in my mind. I don't think I understood it properly on a molecular level before we went out.

Outdoor sequences can help to identify these kinds of misconceptions, as they may offer an experience "so out of the normal run of experience that it requires a drastic re-appraisal of what we think we know" (Waite, 2017, p. 16).

The student teachers were very surprised about the negative test results for starch, as shown in the dialogue above. They thought that bark is made of starch. Obviously, the student teachers held a misconception, which to some extent was derived from the Norwegian word for starch that one might associate with something being stiff or strong. Student 3 did not consider the concept of chemical substances in living organisms before the outdoor sequence at all. Moreover, students 1 and 2 did not have sufficient knowledge of the differences between common polysaccharides, as the individual interviews showed. These misconceptions were addressed afterwards, and the student teachers realized that their original hypothesis would have made sense if they had expected cellulose instead of starch. All the students in group A achieved a better understanding of biopolymers as the building blocks of organisms. According to Scott et al. (2011), it is important to provide opportunities that foster link-making between real world phenomena and theoretical content. This seems to apply not only for school students, but for student teachers as well.

3.3.2 Linking the experiments to concepts in chemistry

During the outdoor sequence, student teachers were frequently preoccupied with practical issues, as shown in the section about *challenges*. Nevertheless, reflections about concepts in chemistry, such as solubility and concentration, were observed on different occasions. We observed informal and explicit learning processes about the properties of the chemical compounds. When testing resin, one of the students tried to get rid of it by washing it with water and learned hands-on that this wasn't possible. Also, student teachers discussed the solubility of glucose, when thinking about using water on a plant extract to get enough liquid for the test:

> Student 2: But – eh – if we take a lot of water [thinking for a while] doesn't that affect something?
>
> Student 1: Sure. There will be glucose in the water. Water-soluble.
>
> Student 2: Yes. It will be lesser concentrated if we take a lot of water. If we use a lot of water [thinking for a while], we have to take that into consideration.

This quote may serve as an example for one of the suggested approaches to support knowledge building, namely "making links between scientific explanations and real world phenomena" (Scott et al., 2011, p. 9). In this case, it is student 2, who is actively making a new link, as "it is necessary for the learner to carry out the process of link-making for themselves" (ibid., p 4).

Student teachers in group B engaged in discussing the quantitative results and sometimes asked the teacher for help:

> Student 6: [looking at the test scale, comparing colours] How about this one? The 1...ish? Percent, isn't it?
>
> Teacher: Percent, yes.
>
> Student 6: Yes. [thinking for a while] 56. [thinking for a while] Which means 56 mmol/L, yes. [thinking for a while] Yeah, that looks reasonable, doesn't it?

In the last sentence, student 6 was referring to glucose concentrations that had been prepared by the student teachers earlier that day. We also notice the role of the teacher here, as described in Thorsheim et al. (2016). Even if student 6 technically knows the correct answer, confirmation is sought from the teacher before extrapolating from the observation and establishing the link between the visible test results and actual glucose concentrations.

3.3.3 Linking organisms to content knowledge in biology

On several occasions, student teachers talked about species names, trying to remember fieldwork from an introductory course. Some of them revealed a low level of knowledge of biodiversity, talking about "grass" and "all the green leaves", without remembering more than the names of common tree species. At the same time, they are clarifying their own concepts:

> Student 3: Bark, that is spruce and pine, and such things, isn't it? "Never" [birch bark in Norwegian; expl. authors] sure is birch, and...
>
> Student 1: No, it isn't! [Researcher agrees to student 1 by shaking his head.]
>
> Student 3: Is it the same stuff? The same, and only different names for it?

These dialogues emphasize two points. Firstly, much of what is taught in the early stages of teacher training can be categorized as rote learning, which is easily forgotten after the exams (ibid.). Secondly, if we want our students to achieve meaningful learning, including a more holistic understanding of science, repeated excursions in the same environment, with different starting points and relevant assignments, could be useful (Remmen & Frøyland, 2017). This provides opportunities to ensure a deeper understanding by connecting theoretical concepts to a rich learning environment, thereby fostering pedagogical link making (Scott et al., 2011). The dialogue about bark, for instance, continued into a broader discussion about ruminants and bacteria that would help moose, a common animal in Scandinavian forests, to digest bark.

In the end, only student 6 (the in-service teacher) explicitly linked different domains of ideas during the fieldwork:

> Student 6: Thinking about it – there should be glucose in leaves, if, if photosynthesis. If the product of photosynthesis is glucose!

School students, but also student teachers, may need considerable help from their teachers or peers to be able to link the different domains of observables and ideas (Abrahams & Millar, 2008). This applies to chemistry in particular: "This strangeness and lack of connection to real life is greater for chemistry than it is for biology and physics, where students have more immediate and obvious contact with the subject matter" (Childs et al., 2015).

As a final comment, it is of note that seemingly easy concepts raise a number of questions when taken out of the textbook and into a real-life context. The nature of the student teachers' textbook is likely to play a crucial role here, as formulas of carbohydrates were presented without any clear links to a real-life context. This emphasizes the learning potential of integrating fieldwork into chemistry lessons, especially for teachers who will face all kinds of basic questions from school students. This is in line with a statement from Borrows (2006, p. 24): "Even well-qualified chemistry graduates may find they do not have much factual knowledge of their chemical environment but can readily understand and build on it once the ideas are pointed out."

4 Conclusions and implications

The aim of this case study was to analyze how student teachers experienced a new approach to outdoor chemistry teaching.

Concerning the different dimensions of relevance experienced by the student teachers with regards to the fieldwork, many expressed during the interviews that they found both personal and vocational relevance in the exercise, and we found evidence for this when analyzing the footage of the field work. The student teachers perceived the outdoor sequence as personally intriguing whilst also providing a useful method to meet educational demands. Overall, they considered the approach worth taking into consideration when planning chemistry education in their future practice in secondary school.

Furthermore, the student teachers showed a generally critical and realistic attitude towards the different types of challenges they expected from and experienced during the fieldwork in chemistry. They dealt with these in a positive, solution-oriented way.

Finally, in our case study the student teachers linked three different types of domains of observables to domains of ideas. They directly made connections between organisms and chemical substances, linked the experiments to chemical concepts and linked organisms to a spectrum of biological content knowledge. Nevertheless, we also found misconceptions in the students' understanding of organic chemistry in organisms, which would likely never have been articulated and reflected on if they had studied and worked in the lab exclusively.

Findings discussed in this article show that fieldwork in chemistry provides a rich learning environment, enabling student teachers with deep content knowledge to utilize in a new, vocationally relevant context. Other student teachers may get basic, but important insights when connecting chemistry to nature.

This limited case-study shows that introducing small excursions into the chemistry curriculum can be relevant on two levels, both for the student teachers' own understanding of the subject matter and as a tool for their future teaching practice. Additionally, they get the opportunity to reflect on the difference of working with defined chemicals in the lab versus working with real-life reservoirs of the same substances. However, outdoor teaching units have to be followed up with reflective teaching sequences to ensure that they result in intended learning outcomes, as evident from the individual interviews with the student teachers.

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Change of the ideas of science teachers after participation in a training program on the use of non-formal educational places

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Absract: The objective of this study is to understand how the perception of teachers might change after they participate in a training program on the use of non-formal educational places (NFEP). The design of the study is ethnographic and its methodology is qualitative. The study comprehends the analysis of three multiple cases according to the disciplinary area, including teachers of primary education, biology, and physics. The analysis was focused on the discourse of the participants, establishing eight categories which were previously validated through triangulation by time and by instruments. The study concludes that the participants were able to restructure their ideas about the use of NFEP for teaching, showing mainly ontological and epistemological changes, which are discussed in the paper.

Keywords: educational places, non-formal education, teaching of science, teacher training

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1 Introduction

In the last few years, experts have reflected upon how students' learning occurs, both inside and outside the classroom. The learning process tends to be much more significant when it takes place in real, everyday contexts, usually outside the school facilities (Ibáñez & Vincent, 2012). The school is no longer the only place where the learning process happens and it cannot assume the educational role in society on its own.

Similarly, and according to the socioconstuctivist and cultural approaches in education coming from psychology, learning can be understood as a situated and distributed social process (Melgar & Donolo, 2011). Vygotsky recognizes the existence of a zone of proximal development that acts as an area of interaction between the individual, the collective, and the artifacts that are part of the environment, emphasizing the roles of dialogue and joint development of knowledge (Franco-Avellaneda, 2013). In this sense, to consider learning from this broad viewpoint allows to distinguish a variety of contexts for learning and to expand the boundaries of formal education (Melgar & Donolo, 2011).

Melgar and Donolo (2011) identify three types of educational contexts: formal, informal, and non-formal. Non-formal contexts include all those institutions, activities, media, and educational aspects that, while not being part of the educational system, have been created to fulfill particular educational objectives. The Ministry of Education of Chile (MINEDUC, 2009) defines non-formal teaching as every formative process carried out through a systematic program, not necessarily evaluated, which can be recognized and verified as a valuable learning opportunity, with the possibility of obtaining a participant certification.

Therefore, there are different contexts that might contribute to the formation of scientific culture in students (Gerber, 2001). For this reason, the settings in which non-formal learning can be built are diverse, according to the cultural diversity offered by the social context. Some examples of non-formal places of learning are museums, parks, zoos, farms, natural reservoirs, and science and technology centers (Vanegas et al., 2013).

On that basis, the importance of integrating different learning contexts into the school curriculum arises, so that the incorporation of non-formal contexts as part of scientific education is seen as an alternative. This has become a challenge for teachers (Dierking et al., 2003; Guisasola & Morentin, 2007; Pedretti, 2002; Guisasola & Morentin, 2010).

2 Antecedents

The activities in museums play a significant role in the teaching of science, becoming convenient tools for teachers in science education (Sanchez & Marin, 2014). However, the difficulties begin with the type of activities that teachers propose when visiting non-formal educational places, not only because the activities are unconnected from the school curriculum, but also because many times the teachers simply lose track of the pedagogical purpose of the visits and turn them into just a “trip”.

In this sense, the study conducted by Guisasola and Morentin (2010) suggests that the science teacher places a high educational value on the visits, getting involved in the organization of the visits but not in the definition of objectives nor in the preparation of the activities prior, during and after the visits. Griffin (2004) points out different reasons why teachers are not involved in the outings. These reasons include lack of time, logistics, students' needs, and mostly, the little or no training of the teachers in methodological elements that allow them to build bridges between what the museums offer and the school curriculum.

Therefore, the use of non-formal learning contexts should be included in the curriculum, and the activities must be prepared by the teachers, not only paying attention to the organizational aspects but also focusing on the tasks that students will have to carry out before, during, and after the outings (Guisasola & Morentín, 2005, Melgar & Donolo, 2011).

On an international level, several research projects suggest that the ideas teachers have about the use of NFEP for the teaching of science focus on generating motivation and interest in the students, who should be able to enjoy these new learning experiences and to ignore the connection established between the outing and the curriculum (Eshach, 2006). For example, Kisiel (2003) detected that only 50% of the surveyed teachers were able to describe the objectives of a visit to a NFEP, and although most of them stated that going out was a "valuable experience," they did not know exactly where the value lay.

The present study was conducted in Chile because, unlike other South American countries, there is not much research done on the perceptions that teachers have about the use of non-formal educational places and the methodologies they use to work in those places (Bustamante et. al., 2012).

Despite the fact that there are no indexed publications regarding informal educational spaces in Chile, an increased interest on the topic has been seen in the recent Chilean Society of Scientific Education (SChEC) congresses. The papers presented in these instances highlighted clear attempts to use the NFEP for the teaching of science. Although the studies are still incipient, they allow to see the weak points in the preparation of activities for non-formal settings, exposing the fact that Chilean teachers are not prepared to use these places for pedagogical purposes.

For this reason, it is interesting to see the discourse of science teachers as an indicator of the preconceptions that they had of museums and their pedagogical use, according to their personal life stories, teaching subject, and teaching style.

Based on the above, the research problem detected is that teachers do not possess a clear idea of how to use non-formal educational places, and that they are not able to link the non-formal setting with the school program or curriculum. The aim of this study is that teachers, with a continuous training program on using non-formal educational spaces, give different meanings and senses to the use of these spaces, which will allow them to develop strategies and instruments to mediate between the museums and the school curriculum.

3 Theoretical Framework

Different international organizations, such as the National Association of Research in Science (NARST) and the United Nations Educational, Scientific and Cultural Organization (UNESCO), recognize the importance of the experiences of learning in non-formal contexts like museums, since these contexts stimulate positive attitudes toward the sciences and encourage scientific education (Melgar & Donolo, 2011). Likewise, there is evidence that learning is a limited social phenomenon which is boosted when other scientific and cultural scenarios, such as visiting museums, are incorporated to the curriculum. This encourages new learning experiences and methods (Falk & Dierking, 1992; Vanegas & Fonseca, 2010).

In this way, learning becomes an individual process in which the museum provides the student with an active role, offering the opportunity not only to learn individually but by their own choice. This is seen as a non-linear process, whose success increases with the freedom of choice and the personalized pace of each student (Bustamante, 2016; Xanthoudaki, 2003; Bustamante et al., 2012). It is relevant to mention that the use of museums and other similar places establishes a direct relationship between leisure time and education. These places constitute then a scenario in which the reality of the curricular contents related to environmental education, the natural sciences, ethical and civic formation, and the social sciences can be explored (Melgar & Donolo, 2011).

The sociocultural theory of learning of Falk and Dierking (1992; 2010) states that learning is built through personal, sociocultural, and physical contexts that influence the process of negotiation between the ideas presented in the physical context of the museum and the personal ideas of each visitor (Figure 1). The personal context refers to the motivations and expectations of the visitors, and therefore, it is the visitors themselves who control and select what they want to learn and how they want to learn it. This is where previous knowledge, beliefs, and interests interact. Similarly, the sociocultural context has an impact on the intervention or mediation that occurs in the museums, whether it is elicited by a peer, a guide, or a teacher. This creates a bond between the environment and the visitor. Finally, the physical context refers to the museum *per se*, so that the environment, the organization, and the orientation of the space and content presented by the museum affect the visitor's learning.

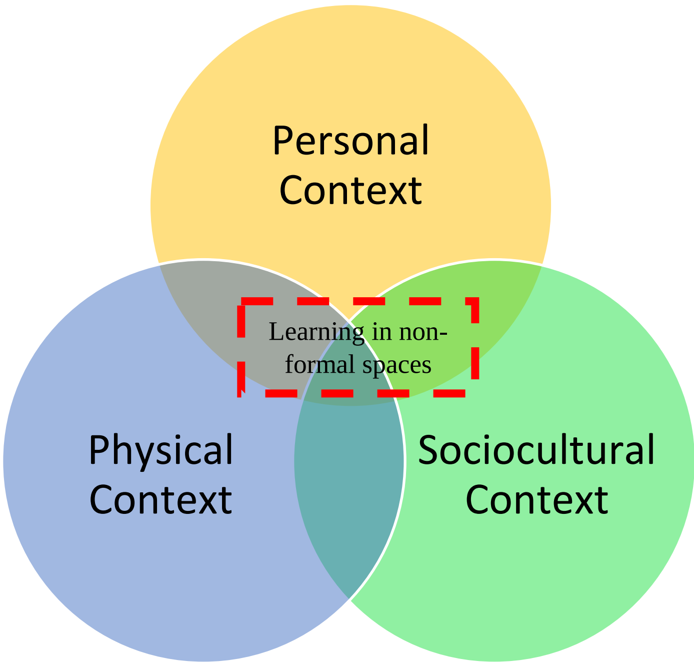

Figure 1. Contexts that intervene when learning in museums (Falk & Dierking, 2010)

The systematic review by Guisasola and Morentein (2010) proposes that the majority of teachers place a great value on the pedagogical outings and the visits to museums, but they are not really involved in the formulation of objectives or the activities done prior, during, and after the visits. This turns the visits into a mere "field trip", since teachers do not usually establish effective teaching strategies and do not connect the outings with the experiences of the students. This prevent the teachers from generating learning processes in non-formal education places, thus delegating that responsibility to the museum (Bustamante et al., 2012). Moreover, Griffin and Symington (1997) claim that teachers often feel intimidated by the visits to museums because in many occasions they do not have a clear learning objective to achieve in said spaces.

This scenario comes along with the need for teachers to understand their role as an agent of change, boosting the learning of each and every student through educational activities within and outside the educational institutions, applying their autonomy to develop scientific competence in their students, and reflecting upon their own performance (Bustamante et al., 2012). Consequently, teachers must design activities based on the criteria of accessibility for everyone, and in particular, for those with special educational needs (Reynoso, 2013.) This makes the teacher a fundamental piece in the communication between the museum and the school (Falk & Adelman, 2003). The role of the teacher is transcendental in the success of the educational outing (Camareo-Izquierdo et al., 2009).

It may be noted that whatever the non-formal educational place the teacher chooses, it is important that they examine and keep in mind some considerations (Chen & Krechevsky, 2000):

- To explore the places beforehand
- To take the students there more than once
- To use the outing as a place to observe the behavior of the students

In the same way, when planning a visit to a non-formal educational place, the teacher must define at least three moments (before, during, and after the visit) to use the NFEP with educational purposes (Table 1). It is also important that prior to the visit, the teacher discusses the experience with the students, encouraging them and problematizing the topic that will be explored at the NFEP. Later during the visit, the activities proposed must be collaborative and based on the observation and manipulation of objects, promoting the collection of evidence and data to be analyzed, and opening the discussion of scientific contents according to what students experienced in the NFEP and the theoretical bases they had learned (Aguirre & Vásquez, 2004). Finally, and after the visit, the experience must be extended and deepened, talking about it, promoting students' metacognition by means of the analysis and reflection upon the activities done, and also verifying the appropriation of the topic discussed in the two previous instances.

Table 1. Use of non-formal educational places. Table adapted from the preparation of a visit to a museum by Aguirre and Vázquez (2004)

Moments	Spaces	Stages	Focus	Processes
Before	School	Preparation	Interrogation	Questioning the topic
During	Non formal educational space	Realization	Collection and analysis of data	Observation and manipulation of the object
After	School	Extension	Analysis and summary	Appropriation of the topic

Aguirre and Vasquez (2004) state that when using a non-formal educational place, three main factors intervene: the student (visitor), the topic (scientific notion to be discussed), and the teacher (intervener). The scientific notion is called the “unifying topic”. This unifying topic comprises the objects found in the museum or science center which have research, exposition, and education purposes. The museum then must have features that are relevant to the content to be discussed. The intervener, or the role the teacher must adopt, should be preferably the role of a mediator between the topic and the students. In this way, the students get involved with the objectives of the visit (Bustamante et al., 2012) and therefore the didactic transposition required to teach the scientific notion is achieved. Figure 2 shows the Legendre triangle applied to NFEP. The figure shows the relationship among the agents involved in the teaching of science in museums: student-visitor, intervener, and topic, all of which constitute the “educational program”.

It is relevant to integrate the class topics with the experiences in the non-formal educational place, connecting the tasks in the classroom with what is studied in the museum. Similarly, the student must participate in the design of problems that could be solved in said space. Therefore, the curriculum should be aligned with the contents of the NFEP in a way that the activities in the museum allow for and stimulate the learning on several cognitive levels, not only of the content as such, but also on affective and imaginative levels, promoting critical thinking, etc. (Griffin, 2004).

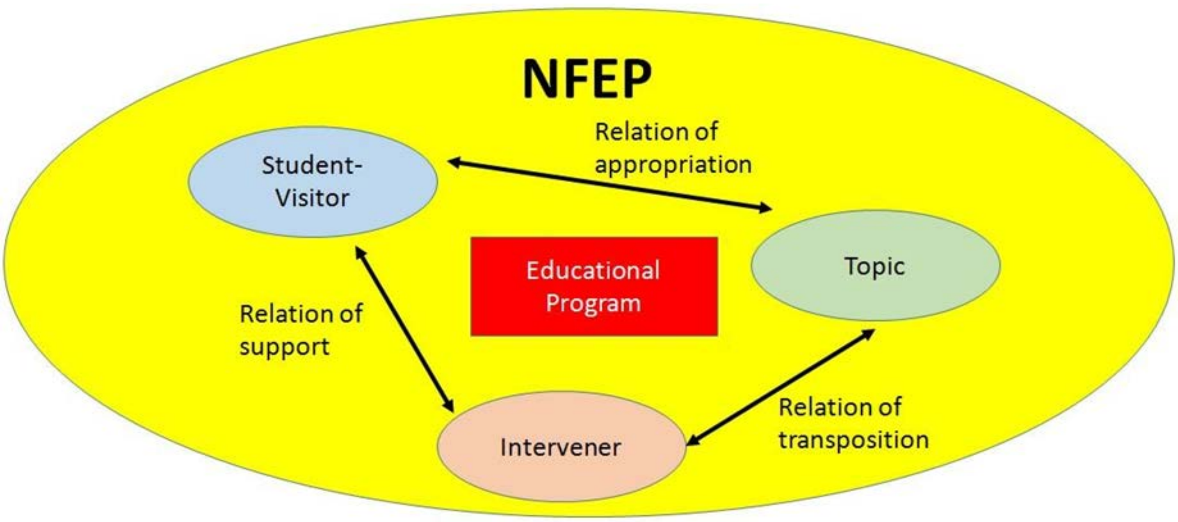

Figure 2. Adaptation of the Legendre triangle applied to museums (Aguirre & Vásquez, 2004)

4 Research objectives

The general objective of this study is to understand how the ideas that science teachers have might change when they participate in a training program on the use of non-formal educational places. Three specific objectives have been identified:

- To identify science teachers' previous knowledge about the use of non-formal educational places.
- To describe possible changes in science teachers' ideas about the use of non-formal educational places.
- To compare science teachers' ideas before and after their participation in a training program on the use of non-formal educational places.

5 Research design

The methodology used was conceived from a qualitative research, with a comprehensive scope, since it not only identifies and describes the preconceptions that teachers have of the use of non-formal educational places for the teaching of science, but also intends to find out how these ideas change before, during, and after the training program (Denzin & Lincoln, 2005; Sandín Esteban, 2003; Yilmaz, 2013). The design is also conceived from educational ethnography, and it particularly corresponds to the study of three multiple cases (Neiman & Quaranta, 2006). The procedures that guarantee the rights established in the ethical framework of educational research were carried out with each of the teachers in all cases.

Case 1: Three primary education teachers. Two of them work in state-subsidized schools, and the other works in a public school. They have been teaching for five, fifteen, and twenty years, respectively.

Case 2: Mixed group composed of three biology teachers, two women and a man. One of the female teachers works in a private school, and the other two teachers work in state-subsidized schools. They have been working for two, seven, and twenty-one years, respectively.

Case 3: Group constituted by three physics teachers. Two of them work in state-subsidized schools and the other works in a public school. This is the least experienced of the three groups, since its members have between two and four years of teaching experience.

This research focuses on the study of the discourse of teachers who participated in a training program on the use of non-formal educational places and how the experiences brought by the program might boost, reconfigure, or change the teachers' previous ideas on the use of NFEP. The selection of the participants was made through an open call to all science teachers in Santiago, the capital city of Chile.

Three phases were considered for the production and collection of the information, which are included in the sessions of the training program the teachers participated in (Table 2).

Table 2. Sessions of the Training Program on the Use of Non-Formal Educational Spaces (26 hours in class and 14 hours of autonomous learning)

Session	Objective	Activities	Class Periods	Place
1 (Phase 1)	To identify previous ideas about the use of non-formal educational spaces.	Questionnaire. Discussion of key concepts based on previous knowledge.	4	University
2 (Phase 2)	To analyze the non-formal educational places from the theory and personal experiences to establish a connection with the classroom.	Definition of concepts. Sharing personal experiences. Discussion of articles.	4	National Museum of Natural History (Quinta Normal Park)
3 (Phase 2)	To build sequenced activities under the constructivist cycle of learning by Jorba and Sanmartí for a non-formal educational place.	Designing activities under the constructivist cycle of Jorba and Sanmartí. Sharing the designed activities.	4	Museum of Science and Technology (Quinta Normal Park)
4 (Phase 2)	To use the non-formal educational place for science teaching.	Outing to a non-formal educational space according to the area of interest of the teacher. Designing a sequence of activities.	6	Case 1: Pochoco Hill. Case 2: Bosque Santiago Park. Case 3: Fantasilandia theme park.
5 (Phase 2)	To discuss the tasks done in the non-formal learning place for science teaching.	Showing the didactic units constructed. Reflecting about the work done by the teachers.	4	Nuestra Señora de Gabriela Park, Puente Alto

6 (Phase 3)	To debate about the importance of using non-formal educational places for science teaching.	Handing in final versions of the didactic units. Lectures and debate about the information among teachers.	4	University

It is worth mentioning that the instruments used to analyze the discourse of the teachers were the products derived from the application of the didactic unit during the whole training program as well as the video recordings of the sessions. In this way, the study was centered in the content of the science teachers' discourse before and after the training program (Tójar Hurtado, 2006). In order to perform the analysis, the following eight categories were established, as shown on Table 3.

Table 3. Description of the categories of the analysis of the teachers' discourse.

Category	**Description**	**Indicators**
Epistemological Commitments	Refers to implicit suppositions shown in the subject's discourse about the relationship between his own knowledge and the environment (Pozo & Gómez, 2006).	- Ingenuous Realism - Interpretative Realism - Constructivism
Ontological Commitments	Refers to the understanding of the world in three categories (states, processes and systems) through the sensitive and experiencing perception of the individual about material and non-material things (Vanegas & Fonseca, 2010).	- States - Processes - Systems
Physical Context	The physical context becomes relevant in the investigation of the scientific area because individuals' preconceptions depend on this space to base their answers and build learning in relation to a specific scientific notion (Flores & Gallegos, 1999; Falk & Dierking, 2010).	- Memory or imagination - Experience - Use
Prior experience	Prior experience is built around aspects that are part of life, therefore, it is important to broaden students' experience to enhance their creativity, recreation, and inventiveness, elements that constitute something new in the subject. This implies combining the old with the new and sets the basis of creation. Besides, the acquisition of new experiences rearranges the previous experiences, so "the new conception takes places and appears to contradict the past experience" (Vanegas & Fonseca, 2010). According to this, the conceptions not only confront but also complement each other.	- Preconceptions - Exemplary situations - Immediate intervention
Teacher's Role	Refers to the role of the teacher when visiting and using the NFEP for science teaching. (Aguirre & Vázquez, 2004).	- Passive - Administrative - Focused on the learning process

		- Focused on teaching
Perception of the Students	Ideas and beliefs that a teacher has about their students when using and visiting the NFEP. (Guisasola & Morentin, 2010).	- Socio-economic status - Behavior - Learning
School-Museum Relation	Role of both institutions (museum and school) with the intention of reviewing the strengths and weaknesses, as well as the complexities and needs of their relationship (Sánchez, 2013).	- Individual - Comparison - Collaboration
Choosing a non-formal learning space (NFEP)	Reasons that the teachers have to choose and use a NFEP for the teaching of science (Meglar & Donolo, 2011).	- Appearance - Playful and entertaining - Attributes that are coherent to the objective - Space of learning

Two types of qualitative triangulation were used in the analysis: triangulation by time and triangulation by instruments (Benavente, 2009). The triangulation by time consisted in comparing the results obtained before, during, and after the continuous training program. For the triangulation by instruments, the transcription of the sessions (discourse) was contrasted with what the teachers wrote in the different activities of the training course. In addition, the KAPPA reliability analysis was made (Benavente, 2009) which indicated a good index of reliability (0,64) and 81,76% of agreement among researchers.

6 Results

The results of each of the cases are summarized below:

6.1 Case: Primary Education Teachers

In the first session, the ideas referring to the teacher's role in the use of NFEP were identified. These ideas mainly correspond to the administrative aspect and the planning of the activities. This is why their discourses are based on previous experiences they had with students, giving more than once examples of "educational outings" that turned out to be effective for them. The teachers also emphasized that the educational outings are important to their students because the students have a low cultural level and are socioeconomically vulnerable, and claimed that these non-formal contexts are "more entertaining". Likewise, the teachers highlighted that an important part of planning a visit to a NFEP is the previous motivation given to the students. In consequence, epistemological commitments of an ingenuous and interpretative nature as well as ontological commitments of state appear.

By the end of the course, the teachers kept the idea that NFEP are playful and entertaining, but that their attributes should be coherent with the Chilean school curriculum in order to perform specific tasks with their students. Moreover, the teachers identified their role as mediators in the learning process, emphasizing that they must "dare" to use the NFEP with previously planned activities, without fearing their students' behavior. Additionally, they warned that the museum must not become a school, since their students need to "change the context," and also recognized that there is a need for a connection between the schools and the museums in order to generate a culture of visits to NFEP. In this sense, their discourse provides examples of experiences lived during the course and experiences lived during the making of the didactic units. Ultimately, the epistemic commitments move toward a constructivist and interpretative nature and toward ontological commitments of system.

6.2 Case: Biology Teachers

The biology teachers compared the school and the museums more than once, characterizing the latter as more playful and entertaining than the classroom. The teachers emphasized the poor behavior of the students, but at the same time, they mentioned how significant "field trips" can be for students' learning. Similarly, the role of the teacher is regarded as organizational and administrative, giving a lot of importance to the legal aspects that visiting a NFEP involve.

Conversely, at the end of the training program, the biology teachers expressed that the role of the teacher lays on the creation of activities to be used in the NFEP, which should be connected to the curriculum.

> I mentioned that it was necessary to review the additional material, I mean, apart from what is in the museum, to incorporate a work guide with information we could better relate to what is exhibited in the museum. Sometimes we need to do a didactic adaptation and to modify a bit the contents that we want to teach. (Teacher 5)

In this respect, the teachers' discourse contains personal experiences lived in the course, providing examples that allow to see the NFEP as places of learning, so the choice of such space must be made by the teacher. They also recognized that schools are like “islands”, and that in agreement with the upcoming public policies, links between the schools and the museums and science centers should be fostered. Likewise, they highlighted that the NFEP should not only be used for the teaching of science, but also of other school subjects, thus making interdisciplinary visits to the museums. In conclusion, the initial epistemic commitments are ingenuous and tend to be interpretative. Similarly, the ontological commitments change from state to processes.

6.3 Case: Physics Teachers

The physics staff mentioned that the places to be visited with their students must be selected according to the contents taught in class. They warned that the role of the teacher is not only organizational but also pedagogical, and therefore they must generate activities with a defined learning objective, something that could only be done if the teachers know the place. The teachers gave examples of “educational outings” made by them. They also recognized that their students are socioeconomically vulnerable, and as a result, this type of spaces favors their learning. Additionally, they regarded these “outings” as an extracurricular resource and not as directly attached to the school curriculum or the annual planning, since they think that the visits should be presented as work projects. The teachers showed ontological commitments of process and epistemic commitments of an interpretative nature.

However, after participating in the training program, the discourse of the physics teachers is characterized by the identification of the lack of connection between the schools and the museums, highlighting the importance of a collaboration between the two.

> Maybe the visits I make are not very structured, then the option I got with this class is to develop a dynamic that truly promotes learning, because until now, the outings mostly distract the student, they get to leave the classroom for a moment, but we’re not guiding them exactly to the content we want them to learn. Now we have the tools to give a sense and a structure to the use of non-formal educational places. (Teacher 9)

Furthermore, the teachers exemplified the importance of the NFEP with situations lived during the course, situations where the teacher must have a “technical” approach to the creation of activities, always connecting them to the Chilean school curriculum. However, they mentioned that the museums and science centers should not be turned into schools, but remain as another type of "resource" or "didactic approach" to teaching science. Therefore, every visit to a museum or similar place must focus on the "pedagogical sense". In consequence, constructivist epistemological commitments and ontological commitments of system are shown.

7 Conclusions

Consistent with the objective of this study, it was evident how the teachers of science in each discipline managed to restructure their perceptions after the training program on the use of NFEP for science teaching.

At first, the teachers, and just like Guisasola and Morentin (2010) mention, attached a high formative value on the outings, getting involved in their organization but not in the definition of the objectives, let alone the activities before, during, and after the visits. This is explained mainly because none of the participating teachers had training in teaching science in NFEP.

In the first session, the teachers talked about the use of NFEP for science teaching mainly with ingenuous epistemic commitments and ontological commitments of realism and reduction. The teachers mentioned that the visits to this type of spaces are beneficial for their students because they are playful and entertaining. However, the physics teachers established interpretative epistemological relations and ontological relations of process focusing the purpose of the visit to a NFEP on the school curriculum. In this sense, there is a diversity of interpretations in relation to the role that teachers have in the educational outings.

Likewise, the teachers talked at first about their own experiences of outings organized in their schools, basing their arguments mainly on the type of student they had and the behavior that the students showed. However, by the end of the study, the teachers justified their ideas from different theoretical bases, which can be attributed to the training program.

At the beginning of the study, the three groups acknowledged that the museums and schools are independent from each other, and that they are only linked when the schools visit the museums. After the training program, all the three groups recognized the importance of a collaborative relationship between museums and schools, discussing current educational public policies. It is worth mentioning that primary science teachers and physics teachers highlighted the importance of not schooling the NFEP.

At the end of the training program, the teachers were more able to create didactic units which were coherent with the Chilean school curriculum, mentioning that it is necessary to take into account the individual attributes of the NFEP for science teaching. According to this, the role of the teachers goes from passive or administrative (at the beginning of the program) to mediator of learning and planner of the activities (at the end of the program). The teacher must be able to select the place to be visited according to their pedagogical purpose and the attributes of the NFEP.

Based on the previous point, and in relation to the objective of this investigation, we can state that science teachers were able to acquire some abilities and the knowledge needed to design outings to museums and science centers. Such visits might produce significant learning in the students, both in the affective, social, and procedural aspects (Guisasola & Morentin, 2007). Likewise, we can state that the participants' preconceptions were modified, linking their previous experience to the training program, becoming new ideas that can be used for future experiences on NFEP for science teaching.

This study has various limitations which prevent the generalization of the conclusions to all science teachers: The number of the teachers who participated was small, there were no chemist teachers involved, and elements like age, years of teaching experience, and the gender of the teachers were not taken into consideration. Nevertheless, the study provides enough evidence to pose challenges to the initial and continuous training of teachers in Chile: How to intend learning processes that allow science teachers to articulate the school curriculum with the possibilities offered by the NFEP? What abilities do training programs and teacher trainers have to provide learning opportunities in NFEP? How to generate articulation among the NFEP, the universities, and the schools to improve teacher training?

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Non-formal science education: The relevance of science camps

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Abstract: Non-formal science education means goal-oriented learning outside of school. The use of out of school learning environments (e.g. science camps) has been found to increase motivation and interest in natural sciences. In this study, the relevance of non-formal science education in science camps has been analyzed from the perspectives of children and families, which has not been studied before. The analysis of relevance has been based on the relevance theory developed by Stuckey, Hofstein, Mamlok-Naaman & Eilks in 2013. The study focuses on the 46 science camps organized by the University of Helsinki LUMA Centre in the years 2015 and 2016, involving more than 900 schoolchildren and some of their parents (N=124). The study examined also the impact of children's gender and children's earlier interest in science on the relevance of chemistry related science camps. Survey and theme interview were both used as research methods.

The results of the survey show that non-formal science education in science camps is relevant according to both the children and the families, mainly at the level of individual relevance, with emphasis on present and intrinsic dimensions of relevance. The tasks related to the camp themes, for example in chemistry camps, experimental work in the laboratory, and friends made in the science camps are the most relevant for children. The chemistry science camps are individually most relevant to those children who didn't have much earlier interest in chemistry. Boys are more confident about their own interests at the individual relevance level than girls. At the level of societal relevance, boys are more focused on present-day relevance than girls when girls also consider the future. The levels of societal and vocational relevance were only slightly visible in the answers of the survey. However, based on theme interviews, camps were considered as relevant for all relevance levels of the relevance theory.

The results of this research can be utilized in the development of out of school learning environments, especially in the development of science camps and in further research.

Keywords: non-formal education, out of school learning, relevance, science camp

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1 Introduction

One of the most important tasks of science education is to support the student's personal interest. An interest in the subject will substantially affect how the student works or what choices he or she does in his or her life. (Krapp & Prenzel, 2011) The importance of non-formal science education has increased in recent years and, as a result, the supply of various non-formal learning opportunities has also been significantly expanded. (Affeldt, Tolppanen, Aksela & Eilks, 2017). Non-formal science education includes, among others, various science clubs and camps, science labs and laboratories operating at universities and all kinds of science fairs.

Many studies show that studying natural sciences - especially chemistry, physics and engineering - is not popular among students. (e.g. Osborne, Simon & Collins, 2003; Dillon, 2009; Hofstein, Eilks & Bybee, 2011; Stuckey, Hofstein, Mamlok-Naaman & Eilks, 2013). Pupils are not interested in studying chemistry, and one of the frequent reasons for this is that chemistry learning is not considered relevant for their everyday life or even for society. The modification of teaching to be more relevant was already at 1980's (Newton, 1988) considered to be the way to motivate students and to make them more interested in learning science. (Eilks & Hofstein, 2015)

Despite the fact that more relevant teaching is continuously offered as a solution to weaker learning outcomes, the relevance of teaching has been studied very little compared to, for example, motivation and interest research. To enable the most relevant teaching, research data on what relevant teaching really is and which factors make the lesson relevant, is needed. The model published in 2013 by Stuckey et al. provides a means of studying the relevance of teaching, and this model has also been used in this study. According to the model, relevant teaching is not just about increasing interest, because taking into consideration the pupil's interests increases the relevance of teaching only on a personal level. According to Stuckey et al. (2013), teaching should be relevant both at the individual, societal, and vocational level. Relevant learning also includes both intrinsic and extrinsic dimensions, as well as present and future relevance.

Non-formal teaching has been discovered to increase the motivation of pupils and improving their attitudes towards natural sciences (Jarvis & Pell, 2005, Orion & Hofstein, 1991, Nadelson & Jordan, 2012). Consequently, non-formal learning environments can be seen as a solution to the decreasing interest in learning science. However, non-formal education has been studied quite little compared to formal school education, so new information on the subject is needed so that, for example, the teaching in science camps can be developed as closely as possible to meet the needs.

Recent research shows that non-formal learning environments, especially participation in science camps, has increased the children's motivation and interest in natural sciences (e.g. Davis & Hardin, 2013; Hayden, Ouyang, Scinski, Olszewski & Bielefedlt, 2011). Research has shown that science camps also enable more profound and detailed themes than formal school education, or shorter workshops, such as clubs (Nugent et al., 2010). Participation in science camps is claimed to increase the interest and motivation of children to consider the future career in the natural sciences. (Mohr-Schroeder et al., 2014).

The aim of this study is to look at the relevance of non-formal science education in science camps from the point of view of children attending the LUMA Centre camps at the University of Helsinki. Along with the children's perspective, the perspective of families is studied. The paper examines also whether children' and families' views about relevance in science camps agree with each other.

2 Theoretical framework

The theoretical framework in this study includes the theory of non-formal science education and previous research data as well as the relevance theory through which non-formal science education in science camps was studied in this study.

2.1 Non-formal education

Non-formal science education has been defined by many different actors, but with the same principles. Singh (UNESCO GUIDELINES, 2012) defines non-formal learning as follows: Non-formal learning is learning that is carried out in addition to or instead of formal learning. In some cases, non-formal learning can be structured, but it is always more flexible than formal learning. Non-formal education is often organized by various social organizations and takes place in communal spaces.

According to Werquin (2007), non-formal learning means goal-oriented learning, but without formal learning goals. In practice, this means that the learning objectives for non-formal learning are the responsibility of the party providing the teaching, and the objectives are not defined, for example, in national curricula. Non-formal learning can, based on the definition of Werquin (2007), happen at workplaces, museums, science centers, and various science circles or academic libraries. Eshach (2007), in turn, draws the distinction between non-formal and formal teaching that, although non-formal learning can be tied to formal school activities, the environment is always less formal than in the normal school teaching. According to Eshach (2007), non-formal learning is generally not evaluated, and learning goals are not defined according to any formal plan.

2.2 Relevance in science education

When discussing the relevance of teaching, the term Relevance is used to describe the student's interest (Childs, 2006, Ramsden, 1998) and how meaningful everyday life phenomena appear to individuals and society. An example of this is the application of science and technology through sustainable development to socio-economic, environmental and political issues (De Haan, 2006; Hofstein & Kesner, 2006). Relevance also explains how well the pupils perceive the usefulness of using everyday contexts in teaching (Gilbert, 2006; King, 2012; Lyons, 2006; Mandler, Mamlok-Naaman, Blonder, Yayon, & Hofstein, 2012) and it has been used as a synonym for importance, usefulness and needs (Keller, 1983; Simon & Amos, 2011).

Stuckey et al. (2013) created a coherent model for the concept of relevance. According to this model, the relevance of education should be evaluated on three different levels: individual, societal, and vocational relevance. The validity of this classification is supported by the fact that Van Aalsvoort has already described the concept of relevance in a similar way in 2004. In addition to the above mentioned three levels, Stuckey et al. (2013) model takes into account the intrinsic and extrinsic relevance of teaching and whether learning is relevant to the pupil's life right now or in the future.

Stuckey et al. present a model diagram for evaluating the relevance of science teaching. This model diagram can be utilized for example in the designing of teaching. The principle of the model has been simplified in Figure 1 below.

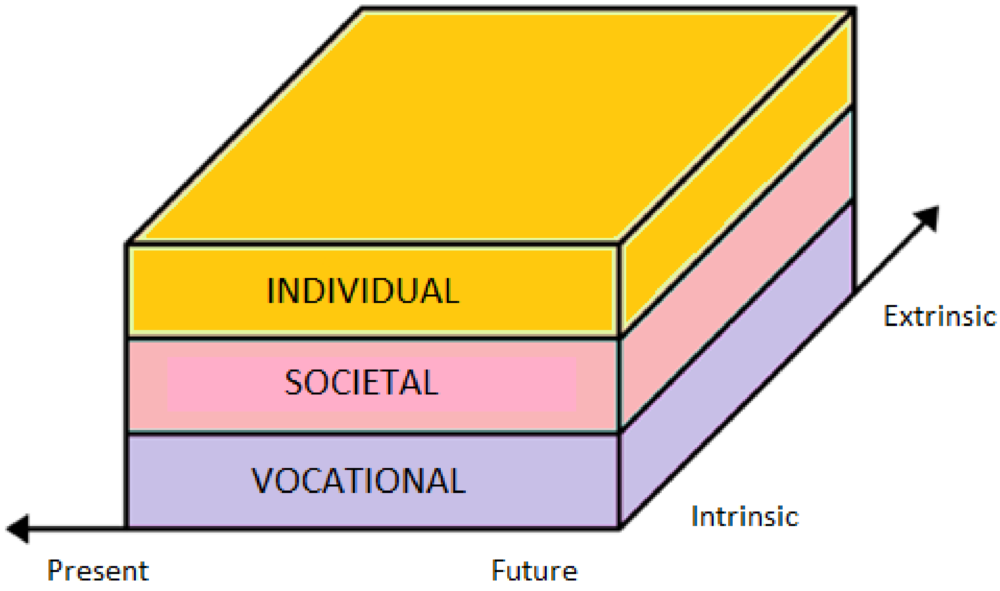

Figure 1. Levels and dimensions of relevant education

According to the model presented above, the effects of the most relevant science education on the learner can be diverse and yet equally relevant. The article (Stuckey et al., 2013) briefly states that science education becomes relevant for education, when learning has positive effects on the learner's life. Relevance should be a concept used by curriculum designers and teachers so that they can assess the relevance of their own hourly plans. (Newton, 1988) The model is designed specifically for the purpose of allowing teachers to actively analyze their hourly plans and possibly modify them so that teaching is as relevant to the learner as possible. (Stuckey et al., 2013)

Stuckey et al. (2013) have used the model in teacher training. It has been used, among others, as a tool for reflection of the relevant science education objectives and as a tool for evaluating different teaching methods. The model has also been utilized in research in science education, for example in science competitions and MOOC (Massive Open Online Course) –related research (Mutanen, 2015; Aksela, Wu & Halonen, 2016). Earlier studies have shown that the level of individual relevance is emphasized in student responses compared to societal and vocational levels.

2.3 Science camps as a non-formal learning environment

Science camps have been organized for many years around the world with the aim of providing children and young people with non-formal activities where they are free to access natural sciences, technology and mathematics. Science camps also aim to introduce children and young people to LUMA-experts in an authentic working environment. The purpose of this activity has been to show career opportunities and the hope that children and young people would be more likely to consider a career in natural sciences. (Mohr-Schroeder, Jackson, Miller, Walcott, Little, Speler, Schooler & Schroeder, 2014)

Although the relevance of science education in a science camp environment has not been studied very much, the pupils' interest and motivation towards natural sciences has been studied. Recent studies show that participation in science camps has increased the children's motivation and interest in the natural sciences and possibly also the interest towards a career in natural sciences (e.g. Davis & Hardin, 2013; Hayden, Ouyang, Scinski, Olszewski & Bielefedlt, 2011; Nugent, Barker, Grandgenett, And Adamchuk, 2010). Science camps also allow more profound and more detailed themes than formal school education or shorter workshops such as clubs (Nugent et al., 2010). It is alleged that participation in science camps and non-formal activities in general is raising the interest of children and motivating them towards natural career options (Mohr-Schroeder et al., 2014).

2.4 Research questions

Which levels of relevance are emphasized in science camps according to the children?

a. Does previous interest in natural sciences affect the relevance of science camps?
b. Does gender affect the relevance of science camps?

Which levels of relevance are emphasized in science camps according to the families of the children attending the science camp?

a. Do the families have a similar opinion about the relevance in science camps than the children?

3 Research methodology

During this study, in the years 2015 and 2016, the University of Helsinki LUMA Centre organized a total of 46 (23 + 23) science camps during the summer holiday season under different mathematical and scientific themes. More than 900 primary school children and some of their guardians (N = 124) participated in this study. The camps lasted for five days, and the daily program contained many activities. Mathematics camps solved various codes and puzzles, programming camps made their own games etc. In addition to the actual learning tasks, all the camps contained different kinds of games and fun which also played a part in learning about the theme of the day.

The research was conducted mainly as a survey, but it also included some theme interviews. The open questions of the questionnaire were mainly analyzed by theoretical content analysis. Structured questions were addressed both in qualitative and quantitative terms. Spearman correlation coefficient was used to illustrate the correlations, as it is well suited to illustrating correlations of discrete variables that were present in this study. Theme interviews were transcribed, and also analyzed by theoretical content analysis.

Tables 1. and 2. present some examples of the theoretical content analysis in question number 7: What were the best things at the camp?

Table 1. Example of content analysis in question 7 (children)

Original answer	Classification
I may have found a new friend	Friends
I learned new things	Learning
Going to a museum	Fieldtrips
To build a tall tower from marshmallows and spaghetti	Theme-related tasks

Table 2. Example of content analysis in question 7 (parents)

Original answer	Classification
Trips	Fieldtrips
Miroscoping	Theme-related tasks
Doing experiments	Theme-related tasks
My son loved the experiments where he could build and design	Theme-related tasks

3.1 Research reliability and validity

In this study the internal validity of the research has been increased with triangulation of the methods. (Cohen et al., 2007) The material for this study was collected with both questionnaires in two years and with theme interviews. Research questions have been approached from different points of view when questionnaire and interview questions are drawn up to answer the question as fully as possible. Questions on the questionnaire have also been drafted by several people so that the researcher's personal views are not over-emphasized in the layout of the questions.

In order to be as reliable as possible to classify the sections derived from content analysis into the levels of relevance theory, reliability was studied through peer classification. In the peer classification, another researcher carried out the same classification on the basis of the relevance theory without seeing the original classifications. The peer classification is calculated by Cohen's kappa value, which describes the consensus among scientists.

The Cohen's kappa values obtained for the peer classification were separately calculated for classifications made for children and parents, although the ratings were very similar. The obtained kappa values were also almost the same with each other as expected: kappa(children) = 0.82 and kappa(families) = 0.83. Both kappa values ranged from 0.8 to 1.0, which corresponds to very good compatibility between classifications (Landis & Koch, 1977). The calculated kappa values therefore confirmed the reliability of classifications.

4 Results

The following sections present the results of the research by research questions.

4.1 Individual level of relevance was emphasized in the children's answers

Table 3. presents the children's answers to question number 6: Why did you participate in the camp? Table 4. presents the children's answers to question number 7: Which were the best things at the camp?

Table 3. Why did the children participate in the camp – children's answers

Claim I participated because...	**Relevance dimensions**	**Yes (%)**	**Maybe (%)**	**No (%)**	**No answer (%)**
A. I'm interested in the theme	Individual Present Intrinsic	69,1	22,0	4,4	4,5
B. I wanted to make new friends	Individual Present Intrinsic	28,5	41,7	25,2	4,6
C. I wanted to learn more	Individual Present Intrinsic	55,8	29,0	10,6	4,6
D. I learned something that's useful in the future	Individual Future Extrinsic	54,7	32,8	7,5	5,0
E. I learned something that's useful in school	Individual Present Intrinsic	39,5	43,2	12,5	4,9
F. I learned something that will help me get the job I want	Vocational Future Extrinsic	23,1	50,9	20,2	5,8
G. I learned to cooperate	Societal Present Extrinsic	41,1	36,7	16,1	6,1
H. My parents wanted me to	Individual Present Extrinsic	53,9	30,4	10,8	4,9
I. My parents thought it would be useful	Vocational Future Extrinsic	47,3	41,7	6,0	5,1

J.	I want to make a difference in the well-being of the world and people	Societal Future Intrinsic	41,7	42,3	11,1	5,0
K.	I want to learn how to take care of the world	Societal Future Intrinsic	35,4	43,7	15,8	5,2
L.	I want to work in this field in the future	Vocational Future Intrinsic	25,6	54,36	14,7	5,3

Table 4. The best things at the camp – children's answers

Classification	**Answer**	**Relevance level**	**Number of answers**
Activities	Theme-related tasks	Individual	756
	Playing (outdoors)	Individual	191
	Free time	Individual	152
	Fieldtrips	Individual	138
	Learning	Vocational	89
	Experimenting	Individual	45
	Drawing	Individual	21
	Hand-on activities	Individual	20
	Problem solving	Vocational	6
	Competitions	Societal	4
Social	Friends	Individual	128
	Group work	Societal	16
	Instructors	Societal	61
	Getting help	Societal	3
	Rules	Societal	2
Other	Camp theme	Individual	86
	Food	Individual	61
	Everything	Individual	57
	Laboratory	Vocational	30
	Getting to know the building	Vocational	8
	Videos	Individual	6
	I don't know	Individual	6
	The end of the camp	Individual	5
	Nothing	Individual	2

More than 91 percent of the campers thought that individual interest in the subject was, or at least perhaps, the reason for participating in the science camp. In addition to interest, the desire to learn more about the camp was highlighted in the answers. Almost 85 percent of campers responded as a reason, or as a possible cause, to participate in the camp with the desire to learn new. Both of these alternatives are represented in the relevance model by Stuckey et al. (2013) as the individual, present and intrinsic level of relevance.

The vocational level of relevance was the least emphasized of all the three levels of relevance. Only a little over 23 percent of respondents felt certain that they had learned something in the camp that would help them get to the job they wanted in the future. On the other hand, over 50% of respondents thought that they might have learned something in the camp that would help them get to the job they wanted. The answer to this and possibly the gap between the answers is most likely to be the fact that most of the campers were so young that they probably have no idea what they want to do in the future.

The most support of the dimensions at the societal level got the desire to influence the future of the planet and people's well-being in the future. More than 41% of the children chose this as one of the reasons for participating in the camp and over 42% felt that this was perhaps one of the reasons for participating in the camp. According to Stuckey et al. (2013), this alternative is in the societal, future and intrinsic level of relevance.

Questionnaire question 7 was an open question asking campers to find the nicest and most unpleasant things in the camp. The level of individual relevance was most pronounced in the nice things -answers, for example in the form of new friends and tasks in the camp. There was some societal and vocational relevance in the responses. “Learned something new” appeared in the responses 89 times. It was considered to present a vocational level of relevance.

To illustrate the correlation between the different dimensions of the relevance theory, the Spearman correlation coefficients between dimensions of different relevance were calculated with the SPSS program. The correlation coefficients were clearly greater than zero, most in the range of 0.0 to 0.5, and correlations were significant mostly at 1% and 5% at significance levels. There was therefore a weak positive correlation between the different dimensions of the relevance, which means in this case that the campers who chose a particular option to assert their choice were quite likely to choose the same option for another claim. From the point of view of relevance, this can be interpreted so that those campers who considered the camps as relevant on one level considered them relevant at other levels as well.

In the theme interviews with families, the same questions were asked from both parents and campers themselves. The questions represented equally all levels of relevance. Interviews showed that the campers experienced the participation of the camp as relevant at all levels. The campers did not feel that the camps in any case had any negative impact on any level of relevance. In particular, the level of vocational relevance seemed to be emphasized in campers' responses.

4.2 Impact of previous interest towards natural sciences to the relevance of science camps

Interest, in this case, means either an earlier interest in chemistry or an interest in science, mathematics or information technology in general. In this section, the research material was limited to the data obtained from chemistry camps (109 responses), so relevance in this case is the relevance of participating in the chemistry camp.

Spearman's correlation coefficient for chemistry, and the relevance for chemistry camps was -0.288, and correlation was significant at 1% significance level. From this it can be concluded that relevance has a weak negative correlation with respect to the campers' interest in chemistry before participating in the camp. Children who have previously been interested in chemistry consider the camp less relevant than those who were less interested in chemistry before.

Spearman's correlation coefficient between general interest and chemistry camp relevance was -0.423, and correlation was significant at 1% significance level. This means that the relevance still has a weak, but somewhat stronger, negative correlation with respect to the children's interest in chemistry before participating in the camp. It can therefore be concluded that campers who were interested in natural sciences have considered the camps even less relevant than those who were interested in only chemistry before the camp.

4.3 Impact of gender to the relevance of science camps

Table 5. presents the answer percentages in boys' and girls' answers in question 6.

Table 5. Differences in boys' and girls' answers

Claim	Relevance dimensions	Answer	Boys (%)	Girls (%)
A	Individual	Yes	65,0	62,1
	Present	Maybe	23,8	34,5
	Intrinsic	No	7,5	3,4
		No answer	3,8	0,0
B	Individual	Yes	22,5	17,2
	Present	Maybe	52,5	44,8
	Intrinsic	No	22,5	34,5
		No answer	2,5	3,4
C	Individual	Yes	50,0	51,7
	Present	Maybe	40,0	34,5
	Intrinsic	No	7,5	13,8
		No answer	2,5	0,0
D	Individual	Yes	55,0	55,2
	Future	Maybe	30,0	37,9
	Extrinsic	No	11,3	6,9
		No answer	3,8	0,0
E	Individual	Yes	51,3	51,7
	Present	Maybe	28,8	41,4
	Intrinsic	No	17,5	6,9
		No answer	2,5	0,0
F	Vocational	Yes	17,5	17,2
	Future	Maybe	55,0	65,5
	Extrinsic	No	23,8	17,2
		No answer	3,8	0,0
G	Societal	Yes	37,5	34,5
	Present	Maybe	30,0	37,9
	Extrinsic	No	28,8	24,1
		No answer	3,8	3,4
H	Individual	Yes	65,0	48,3
	Present	Maybe	22,5	41,4
	Extrinsic	No	10,0	10,3
		No answer	2,5	0,0
I	Vocational	Yes	42,5	41,4
	Future	Maybe	50,0	44,8
	Extrinsic	No	5,0	13,8

		No answer	2,5	0,0
J	Societal	Yes	37,5	48,3
	Future	Maybe	43,8	44,8
	Intrinsic	No	16,3	6,9
		No answer	2,5	0,0
K	Societal	Yes	36,3	44,8
	Future	Maybe	42,5	51,7
	Intrinsic	No	18,8	3,4
		No answer	2,5	0,0
L	Vocational	Yes	22,5	27,6
	Future	Maybe	66,3	58,6
	Intrinsic	No	8,8	13,8
		No answer	2,5	0,0

Only chemistry-related camps were selected for this research question. The sample of this question was 109 respondents in total, of which boys 80 and girls 29.

Responses to individual relevance related claims were fairly similar regardless of gender, but in four of the six allegations, girls had chosen the maybe option more often than boys. With respect to individual relevance the effect of gender seems to be mainly related to the fact that boys are more confident about what is individually relevant to them, and what is not. However, statistically the differences are not particularly significant.

On the statements regarding societal relevance, there is a small difference between the genders. It can be concluded that boys are slightly more interested in present-day events, while girls pay attention to the future, even though the p-value of the claims was more than 0.05, meaning the result is actually not statistically significant.

Also, in these claims regarding vocational relevance, as claimed by societal relevance, the gender distribution was statistically insignificant ($p > 0.05$). Most of the boys and girls have responded “maybe” to all the claims regarding vocational relevance, probably indicating that issues related to vocational relevance are still far in the future.

4.4 Individual relevance emphasized also in the parents' answers

In the parents' answers, like the children, the individual level of relevance theory was emphasized. More than 80 percent of parents thought that their children participated in the camp, as the child themselves was interested in the theme of the camp/camp theme. Interestingly, 79 percent of parents admitted that their children attended the camp, because the parents wanted it. These two statements illustrate the individual level of the relevance theory, but the difference is that the former represents intrinsic relevance, while the latter is extrinsic.

The parents of the children, who participated in the camp, were asked in the questionnaire, which in their opinion were the three best things in the camp and which were the three worst things. The question did not really specify whether parents should answer from their own or from their child's point of view. In the answers of the parents, the significance of friends representing the level of individual relevance was most emphasized. Many campers had, according to parents, gotten new friends in the camp, but many campers were also attending the camp with a friend who was already familiar to them. Overall, the answers were fairly in line with the children's equivalents, as the camp program and the theme-related tasks received praise from the parents. According to the theme interviews, parents felt that the levels of individual and vocational relevance were especially emphasized in the camps.

Table 6. presents the parents' answers to question number 6: Why did your child participate in the camp? Table 7. presents the parents' answers to question number 7: What were the best things at the camp?

Table 6. Why did the children participate in the camp – parents' answers

Claim I participated because…	**Relevance dimensions**	**Yes (%)**	**Maybe (%)**	**No (%)**	**No answer (%)**
A. he/she is interested in the theme	Individual Present Intrinsic	82,3	12,9	2,4	2,4
B. he/she wanted to make new friends	Individual Present Intrinsic	8,1	39,5	46,8	5,7
C. he/she wanted to learn more	Individual Present Intrinsic	62,1	29,8	3,2	4,8
D. he/she learned something that's useful in the future	Individual Future Extrinsic	40,3	41,9	12,1	5,7
E. he/she learned something that's useful in school	Individual Present Intrinsic	36,3	37,1	21,0	5,7
F. he/she learned something that will help them get the job they want	Vocational Future Extrinsic	8,1	40,3	45,2	6,5
G. he/she learned to cooperate	Societal Present Extrinsic	25,0	49,2	18,6	7,3
H. I wanted him/her to	Individual Present Extrinsic	79,0	12,1	6,5	2,4
I. I thought it would be useful	Vocational Future Extrinsic	73,4	18,6	4,0	4,0
J. he/she wants to make a difference in the well-being of the world and people	Societal Future Intrinsic	31,5	50,0	12,9	5,7
K. he/she wants to learn how to take care of the world	Societal Future Intrinsic	25,0	48,4	20,2	6,5
L. he/she wants to work in this field in the future	Vocational Future Intrinsic	82,3	12,9	2,4	2,4

Table 7. The best things at the camp – parents' answers

Classification	Answer	Relevance level	Number of answers
Activities	Program	Individual	42
	Experimenting	Individual	25
	Going outdoors	Individual	14
	Playing	Individual	8
	Fieldtrips	Individual	7
	Contents	Individual	1
Social	Friends	Individual	44
	Instructors	Societal	26
Other	Learning	Vocational	16
	Food	Individual	14
	Interesting subject	Individual	12
	Interesting environment	Individual	8
	Location	Individual	5
	Courage to get interested in natural sciences	Vocational	4
	Challenges	Individual	4
	I don't know	Individual	2
	The feeling of success	Individual	1

4.5 Children's and parents' thoughts about the relevance of science camps are similar

Parents' and children's answers were quite similar, with a few exceptions. According to the respondents, the campers have experienced a little bit more than their parents that they learned skills in the camps that benefit them in school, but the result is not statistically significant on the basis of the t-test, as $p > 0.05$. Parents, on the other hand, have more often felt that their children have been involved in the camp because they (the parents) wanted them to. For this statement was calculated $p < 0.001$, so the result was also statistically very significant.

The campers considered the camps more societally relevant than their parents. In every claim regarding societal relevance, campers have chosen the yes option more often than their parents, while the parents have opted for the option "no" more often than campers. Regarding vocational relevance, the children considered the camps to be a little more vocationally relevant than their parents.

Based on the theme interviews, the views of parents and their children on the relevance of science camps were very similar. In some of the interviews, the parents seemed to think that they had to guess about the views of their children, but after the child's interview it became apparent that the views were very similar. In particular, the question of societal relevance in relation to the group work skills of the camp seemed to be very challenging for many parents, and most of the time, they also mentioned the issue as difficult. The campers did not consider the issue as difficult.

5 Discussion

This chapter presents the results in the light of previous research findings, as well as the importance of research and further research topics.

5.1 The relevance of non-formal learning environments from the children's perspective

Although science camps have been researched in the past both internationally and in Finland (e.g. Tolppanen & Aksela, 2014; Mohr-Schroeder et al., 2014), camps specifically for children have not been studied through the relevance theory. The results obtained will open up a new perspective for research on science camps and their development.

Both the survey and the theme interviews revealed that the level of individual relevance was very strongly represented in science camps. This supports earlier research results obtained from science camp research, in which the children's interest towards science increased during a science camp (e.g. Davis & Hardin, 2013; Hayden et al., 2011; Nugent et al., 2010), as interest is most often handled with the level of individual relevance. The results of this study thus support the premise that non-formal learning environments have a positive impact on the interest in natural sciences. Since the relevance theory considers not only the personal relevance, but also the other two levels of relevance, new dimensions of societal and vocational relevance are entirely new to the development of non-formal science education.

Studying societal relevance proved to be challenging as the issues seemed to be fairly strange for elementary school children. Theme interviews studied societal relevance through teamwork skills, but the results were not particularly illustrative, as all respondents felt that they already had very good teamwork skills before the camp. However, the outcome of theme interviews was positive for the sake of societal relevance, as opposed to the material collected by the questionnaire. Only a small fraction of children had responded positively to the questions related to the vocational relevance. However, theme interview made it clear that vocational relevance was at least to some extent detectable in the camp.

Non-formal science education is being studied in order to develop it more and more to support learners and the results of this study showed that at the levels of societal and vocational relevance the science camps still need to be developed.

5.2 The relevance of non-formal learning environments from the parents' perspective

The vast majority of parents, such as children, highlighted the level of individual relevance. On the other hand, societal and vocational relevance were both equally weak in parental responses. Such a division between the answers is very similar to the general idea that children participate to the camps mainly from personal interest.

Parents were also asked to tell about their own interest in science, and this could also be an excellent subject of research, even though it was excluded from the scope of this study. Parents' own interest in science may have something to do with how relevant they experience non-formal science education in their child's life. Parents' role in non-formal science education is an interesting matter that could be considered a potential topic for further research. The importance of families to childhood education is high, according to previous studies (e.g. Solomon, 2003; Jeynes, 2005), so it would be sensible to continue researching the role of parents in the future.

The views of children and their parents on the relevance of science education were really similar to each other. This is not surprising since previous studies (e.g. Jeynes, 2005; Crowley & Callanan, 1998) show that parents and their opinions play a great part in how their children are concerned with studying natural sciences.

5.3 The importance of the research

According to recent studies, the knowledge and motivation to learn science is decreasing (e.g. Braund & Reiss, 2006). Non-formal learning environments have been shown to have a positive impact on pupils' interest and motivation for studying natural sciences, so it is expedient to explore and develop these learning environments even better. Studying is meaningful and motivating to the learner when it is relevant to the life of the learner, both on the individual, societal and vocational level. In order to develop relevant education that covers all levels of relevance, one must first find out what kind of things the learners consider relevant. This mapping has been done in this study.

This research has shown that current non-formal learning environments are effective at the level of individual relevance. On the other hand, the levels of societal and vocational relevance are either not sufficiently achieved in the science camps or, alternatively, the theory should be better developed to fit children. As such, a survey questionnaire formulated on the basis of the relevance theory was unlikely to be the best possible for the target group and it would be appropriate to test the form first with children in the future so that the form of the questions would be as easy as possible for children's own life.

The research has been carried out in almost every camp at the University of Helsinki Science Education Centre in two years, and in the coming years, the corresponding research on the development of non-formal education will be done. When designing renewed camps, we will look at the information obtained from this study on what types of camps have previously been missing. This way, camps are likely to be more motivating and interesting, and more and more children can be enthusiastic about learning natural sciences.

While this research focuses solely on the study of non-formal science camps, the results of the research are justifiably meaningful, at least in the case of science clubs, and even in the case of formal school education. The results cannot, as such, be directly transferred to formal teaching, but they can be applied. In an ideal situation all forms of education: formal, non-formal and informal, support each other so that the learner gets the best support for learning.

In this study, the children attending the camps have been researched as well as their families. In the future, it would also be interesting to research the impact of these science camps on the camp instructors. In the case of science education at the University of Helsinki, the camp instructors are often future science teachers and it can be assumed that instructing a science camp has at least some kind of effect on their teacher identity.

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Building natural science learning through youth science camps

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Abstract: This study focuses on a youth science camp for pupils in sixth to ninth grades that is organized annually by the University of Jyväskylä, Finland. The main idea of the science camp is to learn to do guided inquiry in nature. The study investigates the significance of science camp for encouraging young participants to learn science and how the camp supports their learning. The research method used was a survey. Altogether, 47 youth participated in the camp in 2012 and 2013. The results show that the participants wanted to learn more about science than secondary school could offer, and science camp had a positive impact on their interest in science. It was possible to introduce important concepts of chemistry and biology in a comprehensible manner through experimentation in an authentic context. The participants worked as researchers in a positive and non-formal learning environment and they received concrete experience with the various phases of scientific research.

Keywords: narrative research, non-formal learning, non-formal science education, science camp, scientific inquiry

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1 Introduction

The development of scientific literacy is one of the main goals of science education in many countries (Khishfe, 2008; Leblebicioglu, Metin, Yardimci & Berkyurek, 2011a). The key element in scientific literacy is to understand the nature of science (NOS), science practices and researchers' activities (Vesterinen, 2012). Science camps help to develop scientific literacy (Foster & Shiel-Rolle, 2011) and inspire youth to study natural sciences by offering an alternative learning opportunity to formal learning in a freer environment. According to Robbins and Schoenfisch (2005), science camps can motivate youth to learn science by helping them to see that they have the potential and ability to become natural scientists. The students are highly motivated to learn in camp. Adding the component of being in nature and investigating phenomena may add authenticity to students' experience (Leblebicioglu et al., 2017). According to Kong, Dabney, and Tain (2014), science camps have been studied from two different perspectives: (1) the science camps themselves and what the participants have learned during the camp, and (2) the extent to which camps affect the future interest of participants in the natural sciences. In this study, science camps are studied as a form of non-formal science education. Attention is also paid to the scientific inquiry education.

1.1 Non-formal science education

The importance of informal learning has increased in the teaching of natural sciences. Fields (2009) argues that a little-studied form of informal learning in natural sciences are science camps where pupils spend a relatively short but intense period (e.g., Foster & Shiel-Rolle, 2011). Science camps include informal learning, but they could be better suited to meet aspects of non-formal learning. Informal learning mainly means everyday learning which is not organized (Coll, Gilbert, Pilot & Streller, 2013) and applies to situations in life that come about spontaneously (Eshach, 2007). Non-formal learning means voluntary learning that is organized (Leblebicioglu et al., 2017) and which takes place in a systematic but highly adaptable manner in situations beyond the spheres of formal or informal education. In science camp there is a program and a schedule of activities. However, the experience occurs outside of a formal school setting (Leblebicioglu et al., 2017). The motivation for learning may be fully intrinsic to the learner even though non-formal learning shares the characteristic of being mediated with formal education (Eshach, 2007).

1.2 Scientific inquiry education

Scientific inquiry (SI) is considered the centerpiece of science teaching (Antink-Meyer, Bartos, Lederman & Lederman, 2014; Williams, Ma, Prejean, Ford & Lai, 2007). Until about 60 years ago, the term *inquiry* had a prominent role in middle and secondary school science (Hassard & Dias, 2009). In practice, the term inquiry is used to refer to (1) SI, (2) inquiry learning and (3) inquiry teaching (Anderson, 2007). SI is defined by Schwartz, Lederman and Lederman (2008, p. 3) as "the characteristics of the processes through which scientific knowledge is developed, including the conventions of development, acceptance, and utility of scientific knowledge" (see also Hassard & Dias, 2009, p. 35; Schwartz, Lederman & Crawford, 2004, p. 612). Hassard and Dias (2007) express that inquiry learning refers to the process of learning science by methods. Those methods emulate those of scientific reasoning and inquiry is something that students do, not something done to them. In other words, inquiry learning is something whereby students gain understanding of phenomena via scientific ways of knowing (Hassard & Dias, 2007).

The knowledge and practice of SI include the following: (1) asking scientific questions, (2), informing those questions through methodologically relevant means, (3) analyzing data, and (4) utilizing, modifying, and creating scientific models (Antink-Meyer et al., 2014). Hofstein, Kipnis, and Abrahams (2013) highlight that asking relevant and scientifically oriented questions is an integral part of SI (e.g., Chin & Osborne, 2008). Hofstein et al. (2013) add that the formulation of a good question is at the heart of what doing science is all about. For example, questions from students indicate that (1) they have been thinking about the ideas presented, and (2) they have been trying to link them with other things they know (Chin & Osborne, 2008). At science camp, almost all of the aforementioned phases of SI take place in experimental work. By doing scientific research, it is also possible to develop an understanding in the students of the nature of the sciences.

1.3 Science camps at the Konnevesi Research Station

The Department of Chemistry at the University of Jyväskylä, Finland, has organized science camps for teenagers since 2010 at the Konnevesi Research Station. The Konnevesi Research Station is part of the Department of Biosciences and Environmental Science at the University of Jyväskylä. Science camps are part of the science, technology, engineering and mathematics (STEM) activities organized by the Department of Chemistry. The number of participants in the science camps has ranged between 10–25. The organization of the science camps started with the idea of providing meaningful activities for those youth who are interested in the natural sciences. The aim of the science camp was to support youth scientists to better understand the nature of the natural sciences. Youth are offered an opportunity to develop scientific thinking in the form of versatile experimental work. The phases of the scientific research are emphasized. The ultimate idea was to provide youth with a camp in which they might build a learning community. An additional aim was to open experiments of natural sciences through study of the surrounding nature. The goal of the camps was to reach high level thinking skills of Bloom's taxonomy (Krathwohl, 2002). Permanent topics of science camp include nature, water and the environment, while other topics have varied annually. In recent years, topics have become increasingly integrated with chemistry and biology. The themes are closely related to the nature surroundings of the research station. Science camps have been made more versatile by sharing the teaching responsibility between the chemistry and biology students who are teaching.

2 Research

The study approach is a case study, as it was desirable to study the same phenomenon in an actual context as deeply as possible.

The research was guided by the following research questions:

1. What is the significance of science camp for encouraging youth to learn science?
2. How does science camp support youth learning of the natural sciences?

Section 2.1 explains what a case study means. Section 2.2 explains the procedure of the research and section 2.3 introduces the target group. Quality of the research is presented in Section 2.4. The results of the research are presented in Chapter 3 as a single report on the meaning of the science camp. Finally, Chapter 4 provides a summary of the study accompanied by conclusions.

2.1 A case study

A case study is considered to be more of an approach than a data collection or analysis method (Eriksson & Koistinen, 2005). It explains a single case, seeking to understand the phenomenon in its context (Kananen, 2013). In a case study, the connection between the phenomenon and the context is not quite clear. Such a method of research is chosen when it comes to understanding a real-life phenomenon, but such understanding demands important contextual aspects (Yin, 2009). The researcher has the ability to determine what the case means in his/her own research field (Patton 2015). The case can deal with an individual, group, institution or community (Kananen, 2013; Patton, 2015).

According to Eriksson and Koistinen (2005), a case study is selected as a research approach if one or more of the following conditions are met:

- The question words 'what,' 'how,' and 'why' are the key points.
- The researcher has only a small chance of controlling events.
- There is little empirical research on the subject being studied.

- The research topic is a real-life, contemporary phenomenon.

2.2 Implementation of the research

The first author of this report served as the primary researcher and took primary responsibility for data collection, analysis, and interpretation. The second author planned and taught the science camp and also took responsibility for implementation, research analysis and interpretation.

The qualitative data, collected in 2012 and 2013, consists of questionnaires (N = 47) and interviews ($N_{interviews}$ = 10, respondents 18). The interviews were conducted as individual and group interviews. Analysis of narratives and narrative analysis were used. Narrativity is divided into two categories of material handling: narrative analysis and analysis of narratives. According to Patton (2015), narrative analysis focuses on how stories, especially texts that tell stories, are interpreted. Narrative analysis produces a new report on the basis of collected reports, which highlights the themes of the data. In analysis of narratives, the focus is on the categorization of reports (e.g., by case types, metaphors or categories; Heikkinen, 2010). Narratives and stories reflect the experiences of individuals, social structures and how the world is understood (Patton, 2015). Stories can be constructed as a typical event or a typical story can be presented as a whole from them (Eskola & Suoranta, 2008). Narrative research uses a linear, analytical case study reporting methodology (see Eriksson & Koistinen, 2005; Yin 2002), which outlines the starting points, material and methods of research, results and conclusions. In this study, the analysis included direct quotes from open responses and interviews in order to provide additional explanations for the answers. The narrative approach was chosen for the analysis phase because the focus was on adolescents' authentic stories (Heikkinen, 2010).

The participants received a cover letter and a study permission form by post before the camp, and they returned the permission form signed by a parent before attending the science camp. Instructions for completing the questionnaire were provided orally on the spot by the researcher. The questionnaire was answered anonymously. The problem with using questionnaires is that there is no chance to ask further questions. For this reason, an interview was used in 2012 in addition to the questionnaire. The amount of questionnaire data was small, but saturation was seen in the second year.

The research material was compiled so that the questionnaires were distributed to the campers at the beginning and end of the camp and they returned them to the researcher anonymously. It took about 15 minutes to complete the questionnaire, which contained open and closed questions. Due to the narrative approach, only open questions were taken into account in this research analysis.

An interview study was also conducted in 2012. At first, interviews were implemented as groups. Due to the effect of other groups members in the interview situation, the rest of the interviews were done individually. In this case, the interview can be classified as a thematic interview. The interview form was used because researchers sought additional insight on the questionnaire replies. The results of the interviews confirmed the results from the questionnaire. However, the interviews did not take place the following year, because it was observed that the answers failed to provide substantial additional value compared to the questionnaire. Two researchers independently analyzed the research data, and after the discussions, researchers came to a similar conclusion regarding which topics emerged the most from the answers.

2.3 The target group

In 2012, 25 youths participated in the camp, and one did not participate in the survey. In 2013, 25 youths participated in the camp; two did not participate in the study. The average response rate was 94%. The questionnaire consisted of three sections. In the first section, the respondent's background information was asked. The second part contained statements about science camp. The third part contained open questions related to the experiences gained from the science camp.

Respondents (N = 47) were aged 12 to 16 years. Most of the campers were 14 years old (40%, 19/47). While 59% of respondents (27/46) were girls and 41% (19/46) were boys, one did not answer the question about gender.

Attending the camp were youth from primary school, upper secondary school and vocational education institutions. Most of the participants were seventh- or eighth-graders (see Figure 1).

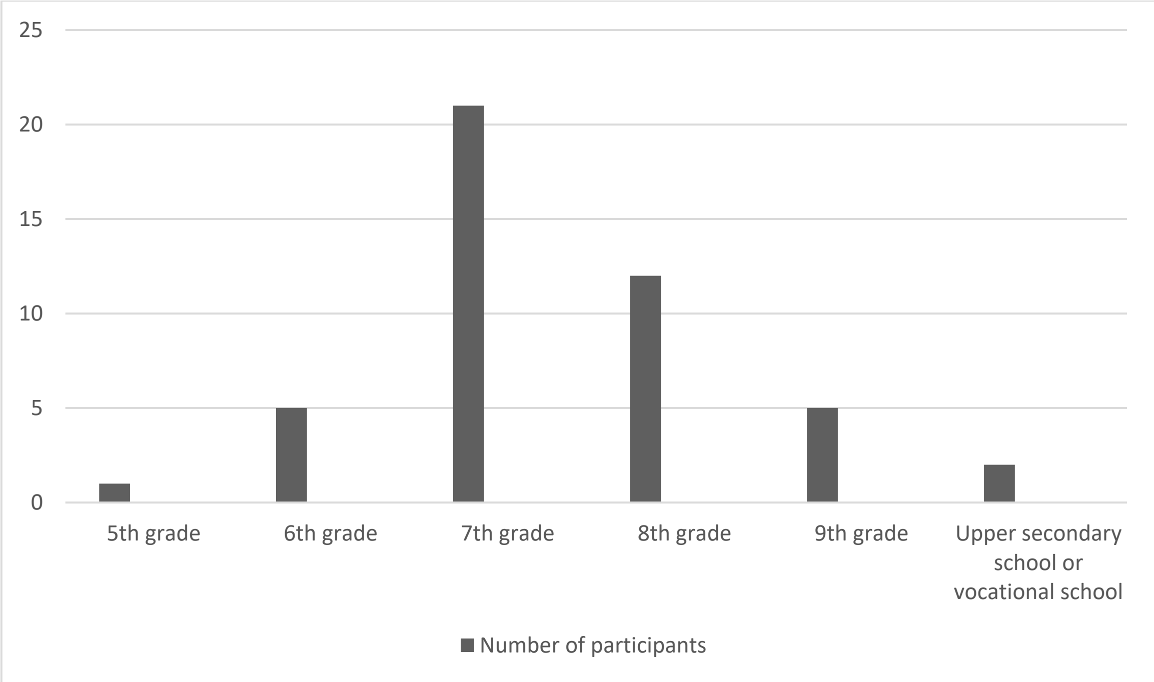

Figure 2. Campers' grade when they completed the school year.

2.4 Quality of the research

The advantage of interviews is that the interviewee has the opportunity to raise issues about his own perspective as extensively as desired. However, an interview contains many potential sources of error, which arise from both the interviewer and the interviewee. Reliability may be weakened by the interviewee's tendency to provide socially desirable answers (Hirsjärvi & Hurme, 2011). Interviews included one person or groups of two or three people. In this study, group interviews posed a special challenge. It was evident that respondents responded to each other's responses. Respondents mingled with each other's answers. As a result, the rest of the interviews were conducted as individual interviews and only those responses were taken into account in the direct quotations of the analysis of the material. The identification details were properly discarded after the study was completed.

According to Heikkinen (2010), the reliability of narrative research can be viewed in light of the traditional concepts of trust in concepts of modernity: validity and reliability. Generally, validity means how the research results correspond to the actual state of facts and reliability means the extent to which random factors potentially affected the results of the research (Tuomi & Sarajärvi, 2013). Efforts have been made to increase the credibility of the research. Describing the reports of the campers has aimed at fairness. This has been done by trying to treat the campers and their stories equally. In addition, all stages of the research process have been introduced as accurately as possible to give the reader a clear idea of their content. For narrative research, it is essential that the story opens to the reader. This has been done by adding enough direct quotations from the research material in the produced report. The research was carried out according to the guiding principles of scientific research, so the question of dependence on research was realized. The research data was small, but rich: data provided an in-depth look at the research questions. In a narrative case study, it is not relevant how many pages texts contain but their number of narratives (Partanen, 2011). Efforts were made to increase the validity of the research by highlighting critical aspects in the data. Also, the use of multiple coders in analysis phase and different type of research material may be seen as a form of triangulation. Triangulation, in this study the use of both interviews and questionnaire as a research method, adds credibility and validity to a research. (Tuomi & Sarajärvi, 2013.) The independent analyses of two researchers and common conclusions reached after discussions also add to the reliability of the analysis. In a consensus-based theory of truth, people can create a "truth" by arriving at a consensus (Patton, 2015; Tuomi & Sarajärvi, 2013).

3 Results

In the study, the data from questionnaire and interviews is presented using combined types. The story is built on the basis of both questionnaires and interviews. At the beginning of the data analysis, data was classified into types and different story types were examined. Attempts were made to look for temporal organization. The analysis was further extended and the answers were constructed to represent one typical tale in its entirety. (Eskola & Suoranta, 2008.) Eskola and Suoranta (2008) distinguish three different ways of forming types. An authentic type contains one example of wider material describing the typical story of the material. The combined type is the most general and contains the things that occur in either a large percentage or all of the responses. The widest possible type includes content of the data presented in a variety of ways. This means that some of the things involved may have occurred in only one answer. The essence of such a type is its internal logic: the type is possible, although it is unlikely as such.

The study conformed to the widest possible type in order to highlight the unique features of the stories. This study will help to further develop the science camp in the future, and it will also serve to protect the identity of the investigators. The report can be described as a kind of summary in which certain elements of the responses were collected and arranged. Some of the issues were mentioned in only one answer, others in quite a few. (Eskola & Suoranta, 2008.) Themes and stories construct the story and thus act as a turning circle of the plot.

Iisa, Oona and Paavo appear in the report and they are pseudonyms. Iisa and Oona are 14-year-old girls who were at the camp for the first time. Paavo is a 15-year-old boy who participated in the camp two times. Iisa, Oona and Paavo tell the story of why they wanted to go to the camp, what they expected from it, what was done at the camp and how the camp could be improved in the future. The themes reveal the main findings of the story. A report was built on the data, which proceeds chronologically from the beginning of the science camp to the present.

4 The story about participating in the science camp

4.1 Before the science camp

From Iisa, Oona and Paavo's responses it was apparent that the most important issues in science camp were related to learning content and cooperation. Youth felt they learned new things in both biology and chemistry. Iisa mentioned, for example, the calculation of water oxygen content, the identification of cloud forms and the use of a microscope. Paavo, in turn, told that he was motivated by the study of lake water, insect and stone studies, and the production of a layered drink. Youth also felt that there was a good time to rehearse of what had been learned earlier in school.

> ...I want to be a chemist as an adult. (Oona)

4.2 Youth learned at the science camp...

Iisa, Oona and Paavo wanted to join the science camp because they were interested in natural sciences and because the topics that were in the program during the participation year were interesting. As examples from those topics, Iisa and Paavo mentioned crime scene investigation and the Amazing Race competition.

> The fact that I learn different things about science, like various measurements, and so on... (Oona)

The camp supported group work. Cooperation has many good aspects: it helps in grouping, and peer support during experimentation is of paramount importance for many youths. Oona highlighted the importance of grouping in relation to other people's lives. Oona said that the most important thing in the camp for her own life was that she learned to interact with complete strangers.

> The most important thing for my life was that I learned to interact with complete strangers. It has been difficult for me earlier. (Oona)

4.3 Thoughts about the successes and weaknesses of the science camp

Iisa, Oona and Paavo considered the good aspects of the science camp from many different perspectives. The campers gave positive feedback regarding various factors related to camp life. The answers showed the importance of being together. The camp brought together similar kinds of thinking youth with a shared interest in natural sciences. The science camp was considered to be a more diverse camp than other camps usually are because science is learned and actually done.

> I got new friends and learned all about new things in chemistry and biology. (Oona)

> I think this is a really good group, with everybody being a bit with everyone. (Paavo)

Paavo pointed out tolerance and that it was nice to do research together with other campers. Campers did experiments in different groups, varying their workload. This helped them to get to know other campers better. New friends and nice teachers were an inspirational factor in creating team spirit.

Experimental work in the science camp differs from work done in secondary school by taking advantage of the nature environment at the research station as much as possible. The genuine nature environment provides many new opportunities for teaching that traditional classrooms cannot offer. At the camp, a lot of new experiments were performed in the field of nature. Paavo told that the assignments were interesting, and he felt it was important that they were adequate. However, it is good to remember that mere experimentation is not sufficient to understand natural phenomena. Students should also correctly understand the content of the work. (Clough, 2002.)

> It is always fun to do hands-on experimentation. Most of the campers were really enthusiastic about the topics and so were the teachers. There was a DNA story told late in the evening at the request of campers. (Iisa)

> ...biology and the Amazing Race may be the nicest program, and leisure was really nice, with sauna + swimming. (Oona)

> ...got to go to the lab to investigate insects. (Oona)

Iisa, Oona and Paavo's thoughts regarding the negative aspects of the camp were mainly related to practical arrangements. Iisa and Paavo reported that many campers thought that there was nothing wrong with the camp. Some youth criticized the contents of the curriculum. For example, Oona felt that the material was not adequately covered after the study.

> The only minus was the nature trail. Rushing in the woods and the long walk were not very nice to do. (Paavo)

Iisa mentioned that she was annoyed because there were less chemistry studies than expected. In 2013, biology was more integrated into the teaching. Oona, on the other hand, felt a little uncertainty about her own subject knowledge. Paavo felt that the experiments were too easy. The campers' age range was originally from the seventh to ninth grade, but sixth-grade youth participated in the camp if there was still room for them.

> That you did not at times know all the things... (Oona)

> Part of the program works seemed to be oriented to younger people than the camp's age limit was. (Paavo)

Campers would have liked to choose the groups themselves and they thought that the groups should have been smaller. Youth felt that self-selected groups may have worked better than those selected for them. Teachers assembled groups that were varied, so that campers could learn more about each other. Iisa, Oona and Paavo felt that in some situations the group was too big for older students to get to know the other campers.

> Groups could have chosen themselves so they might have worked better. (Paavo)

4.4 The science camp had an impact on interest in biology and chemistry

The aim of the science camp was to increase interest in natural sciences. Iisa and Oona's answers reflected the importance of the camp to enhance enthusiasm and interest. The youth who came to the camp were already interested in science. The science camp offered an opportunity to explore new things and it enhanced motivation.

> I am interested in biology and chemistry more because I like to learn new things and this science camp has helped me to learn new things. (Oona)

According to Paavo, the camp had no effect on increasing interest in natural sciences. Paavo justified this by saying that he could not be more interested than presently. In science camp was possibility to apply the knowledge in new learning contexts.

> It opened different perspectives on things and that affected positively. (Iisa)

4.5 Youth gave development ideas for the future

Iisa, Oona and Paavo hoped for more chemistry and biology content-related things in the camp. Youth hoped for chemistry-related laboratory work. Also, there was a perceived need for more theory and deeper knowledge of different things. Youth may be seen as experiencing things superficially. In addition, they thought that the difficulty of the subjects being discussed could be increased, because the camp is targeted at secondary school students.

> More theory, deeper knowledge about different things... (Oona)

Oona thought that the camp could also introduce other natural sciences. Integration of physics, mathematics and geography could be possible in the future. Youth would have wanted more work with their own group. Also, they wanted more experiments in nature. As the eldest in his group, Paavo noted that in the future it would be nice if there could be a camp for people of different ages, such as high school students.

> I would have wanted freedom of choice and variety in the groups! (Paavo)
>
> More days! (Iisa)

5 Summary and conclusions

The study explored how youth can be encouraged to learn science through a science camp. The study also examined how youth experience science camp as supporting their learning of the natural sciences. When youth came to the camp, they were interested in natural sciences and wanted to learn new things about chemistry and biology. However, the science camp managed to increase enthusiasm and interest in natural sciences (see also Bhattacharyya, Mead & Nathaniel, 2011). Participants had a chance to learn science in new contexts and there were new friends and teachers encouraging them to learn science. Lindner and Kubat (2014) have also found the same kind of conclusions: science camp participants in Germany and Denmark both show the same tendencies. A five-day camp increases the interest in science. The majority of participants (70%, N = 52) report an increase of interest in science and technology (Lindner & Kubat, 2014). Science camps can be said to be the type of extracurricular learning environment that develops positive feelings towards the natural sciences.

Youth are more motivated to study natural sciences if they are offered new learning experiences in an authentic context. This has a positive impact on learning outcomes (Hofstein & Lunetta, 2004; Watson, Swain & Robbie, 2004). In science camp there is a small amount of teacher-led instruction, which helps students to understand new concepts and things. Most of the experimental work involves hands-on experiments. The campers felt that the science camp positively influenced their interest in natural sciences: the topics were interesting and there was enough experimentation that was connected to the real world.

Most of the campers perceived that experimentation was the most sensible way of studying chemistry. Interesting experimental work deepened youth's knowledge of chemistry and biology. Experimentation can be seen as an important aspect of learning natural sciences because it provides personal experience (see Bradley, Durbach, Bell & Mungarulire, 1998). This was seen in, for example, Iisa's comment after our science camp: "It is always fun to do hands-on experimentation. Most of the campers were really enthusiastic about topics..." Phenomena were examined in authentic contexts and thus youth were introduced into phenomenal learning. Although experimentation played a central role in the camp, it was even more desirable to have learning contents related to the camp and laboratory work. The camp served as a good reinforcement of what had been learned earlier in school, and through using experimentation, group work and discussions it helped to develop critical thinking skills.

The study shows that science camp can lead to a better understanding of the nature of information obtained from SI. The science camp utilizes various types of learning styles to encourage youth to conduct scientific research. This helps different kinds of learners to find their own best way of learning science. Science camps organized by the University of Jyväskylä have played a major role in bringing experimental, research-oriented science and science-oriented youth closer together. It was possible to introduce important concepts of science in an understandable manner through experimentation in a natural environment. The camp imitates an authentic research situation in a non-formal learning environment where youth work as researchers. Extracurricular contexts can stimulate pupils to think more deeply about science and provide new connections to science (Braund & Reiss, 2006). According to the research literature, the camps help to develop scientific thinking (Leblebicioglu, Metin, Yardimci & Cetin, 2011b) and campers are excited to ask more questions (Sterling, Matkins, Frazier & Logerwell, 2007).

Campers came to the science camp from all over Finland, and many campers were alone in a new situation. Shared leisure time allowed the campers to get to know each other better. Working in a group was considered an important issue: youth were placed in teams to solve common problems and tasks. Regarding cooperation, it is important that campers support each other in doing the tasks and that the research conclusions are made together (see Auno et al., 2016). It became clear in this study that youth dared to ask questions of concern and questions were considered together by other youth and instructors. Asking relevant and scientifically oriented question is an integral part of SI (Hofstein et al., 2013). Cooperation with other campers and instructors supports a positive socialization experience (Fields, 2009; Kong et al., 2014). The camp was felt to be a functional and positive extracurricular learning environment in which youth shared the same interests.

Eventually, the camp might be developed to target elementary or older students. During the years studied here, the campers were mostly in sixth to ninth grade. That difference in age is too wide for activities to be suitable for all campers. The chemistry knowledge of sixth graders is not very advanced yet, and in turn, maintaining ninth graders' interest is challenging if a lot of the work is too easy for them. Martinez and Hibbs (2003) studied summer camps and they came to the conclusion that seventh to twelfth grade is too large of an age gap to keep the twelfth graders interested without losing the seventh graders. In this research, the interest of older students in the camp involved the responsibility of taking younger campers into consideration. Camps have emphasized an openness to experimentation and providing space and time for campers' questions and personal interests. These will advance campers' knowledge of the natural sciences.

The youth science camp supports the learning of chemistry and attracting interest in STEM subjects by providing youth with new learning experiences in a genuine context. Youth's answers highlighted the positive feedback. It can be concluded from this that the science camp is a functional entity. The results here can be utilized in the development of this and other science camps. In addition, researchers hope that this could encourage other teachers and universities to organize science camps for youth. During science camp, it is worthwhile to reserve enough time to work in groups and to make inquiries. There should also be teacher-led instruction in science camp settings and time for questions and discussion by young people. Science camp works when there are motivated, science-oriented young people and an interesting learning environment.

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Research-based exhibition development: Illustrating the invisible nanoworld

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Abstract: Informal learning environments such as exhibitions in museums and science centres have the potential to promote public engagement in the societally important fields of nanoscience and nanotechnology (NST). This study contributes to research-based development of an NST exhibition by mapping educational, communicational and museographical challenges in illustrating nanoscale science. For the methodological framework, the study employs a previously suggested model based on the Model of Educational Reconstruction. Potential visitors' perspectives were analysed by reviewing research literature on NST learning, and by interviewing science centre visitors. On the basis of the results, the study suggests strategies for illustrating the nanoscale in an exhibition: ways of supporting visitors' scale conceptualisation, presenting images and visualisations deliberately, and using scale models and macroscopic analogies. The study examines how the educational role of science centres may be enhanced by informing exhibition development with visitor-oriented research.

Keywords: exhibition development, model of educational reconstruction, nanoscale, nanoscience education, research-based development, scale conceptualisation, visualisations

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1 Introduction

The fields of nanoscience and nanotechnology (NST) continue to develop rapidly and bring about societally and environmentally significant applications and implications. These emerging fields have also gained growing public interest and media attention. However, and perhaps paradoxically, results of surveys and polls have shown that despite the public's interest in and somewhat positive attitudes towards NST, people's awareness and knowledge of the fields has remained at a rather low level (Crone, 2010; Sahin & Ekli, 2013; Waldron, Spencer, & Batt, 2006). Citizens have no firm foundation for understanding NST due to the many conceptual challenges, e.g. concerning relative size of the nanoscale and nanoscale interactions (Schönborn, Höst, & Lundin Palmerius, 2015). This state of affairs has aroused some concerns, since it is likely that in the near future, citizens will have to make more and more decisions on NST-related issues – both at the personal level, as consumers, and also at the societal level (Jones, Blonder, Gardner, Albe, Falvo, & Chevrier, 2013). Therefore, it has been suggested that some level of understanding of these fields is relevant concerning scientific literacy (Gardner, Jones, Taylor, & Forrester, 2010; Gilbert & Lin, 2013; Laherto, 2010; Sabelli et al., 2005; Stevens, Sutherland, & Krajcik, 2009). In these suggestions, the ambiguous concept of scientific literacy takes a functional and contextualised interpretation, focusing on citizens' ability to identify, to form opinions about and to make reasoned decisions on personal, social, and global issues related to science and technology. Such an emphasis appears in the highly influential PISA definition of scientific literacy (OECD, 2007), recommendations for European science education policies (European Commission, 2015; Osborne & Dillon, 2008), and "Vision II" for scientific literacy proposed by Roberts (2007; cf. Roberts & Bybee, 2014). In accordance with these, both the public's awareness of NST and the public's engagement in NST has been called for. In particular, the important ethical issues related to these fields have given rise to the need to engage the public in a deeper discourse on NST and its relations to society (e.g. Cameron & Mitchell, 2007; Jones et al., 2013).

Consequently, methods and strategies for public communication on NST have been increasingly discussed in the fields of social sciences, science education and science communication (e.g. Gardner et al. 2017; Sweeney & Seal, 2008). It has been suggested that informal learning environments such as exhibitions in museums and science centres have significant potential not only to educate the public about emerging science and technology, but also to contribute to the science-technology-society dialogue (Castellini et al., 2007; Crone, 2010; Gilbert & Lin, 2013; Zenner & Crone, 2008). Given that such high educational value flow from science centres and museums, the process of developing exhibitions – typically governed by practical and financial aspects and constraints – should be informed by educational knowledge and expertise. In particular, educational research might support the educational function of those learning environments (see Laherto, 2013, for further discussion).

This paper draws on and expands on a research project that created a design framework[1] Edelson, 2002) for the development of an exhibition on NST. The purpose

[1] According to Edelson, design frameworks are a type of theory design research can develop. Design frameworks "describe the characteristics that a designed artefact must have to achieve a particular set of goals in a particular context" (Edelson, 2002).

of the project was to analyse the fields of NST from an educational perspective, in particular from the viewpoint informal learning settings, in order to find well-grounded approaches for exhibition design. The present paper focuses specifically on the issues related to “the nanoscale”. A literature review and an empirical survey were carried out to map the challenges in understanding “the nanoscale”, and to find effective approaches for illustrating it in an exhibition. The term “nanoscale” here refers not only to measurement units but essentially also to its objects and phenomena, the tools with which the nanoscale (or the “nanoworld”) can be accessed, and the models that describe the phenomena at that scale (cf. Stevens, Sutherland, & Krajcik, 2009).

Size and scale are only a few of the several educationally significant features of NST. In fact, it can be argued that the most essential ideas – involving the important applications and implications of nanotechnology – involve scale only indirectly (see Kähkönen, Laherto, Lindell, & Tala, 2016; Laherto, 2011; Laherto, Tirre, Parchmann, Kampschulte & Schwarzer, in press; further discussion on this follows in the paper). However, since the scale and the smallness of “nano-objects” pose several communicational and museographical challenges regarding exhibition development, they are worth focusing on in this paper.

2 Framework

To find research-based guidelines for illustrating the “nanoworld” in an exhibition, the study employed a previously suggested methodological framework (Laherto, 2013) for informing exhibition development through educational research. That framework builds on the Model of Educational Reconstruction (MER) (Duit, 2007). The MER, associated with the design research tradition, combines analytical and empirical educational research with development of practical educational solutions. It consists of three closely interlinked components: 1) analysis of content structure, 2) research on teaching and learning, and 3) design of learning environments. One of the fundamental ideas of the model is that the content structure for instruction cannot be taken directly from science content structure (that is also a human construction), but has to be specially (re)constructed by paying attention to the educational goals, as well as learners’ cognitive and affective perspectives (Duit, 2007; Komorek & Duit, 2004). The methodological framework (Laherto, 2013) adopts the MER for the purpose of informal learning environments.

The present paper focuses on the second component of the MER, i.e. research on teaching and learning, to find strategies for illustrating NST in an exhibition. However, due to the close interplay between the components in the model, other part-studies are first briefly introduced here. Figure 1 presents content-oriented and visitor-oriented educational research conducted in order to support the choices made in the development of the learning environment.

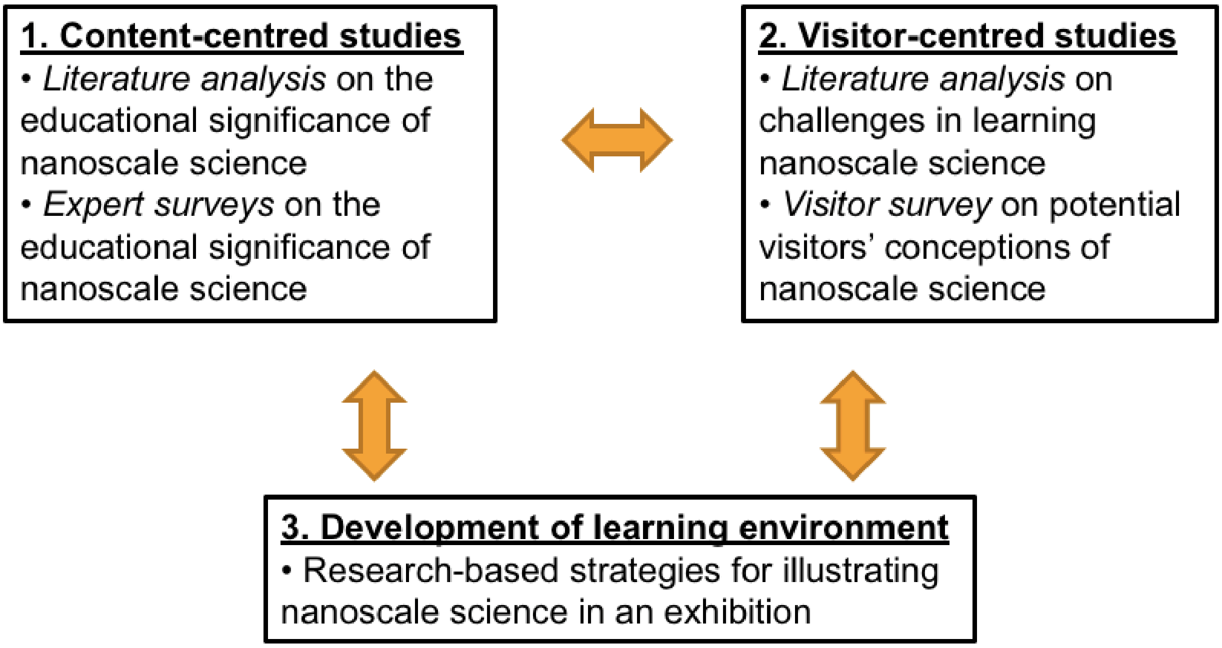

Figure 1. The part-studies of the wider research project, situated within the Model of Educational Reconstruction.

Component 1 of the research project (see Fig. 1), corresponding to the "Analysis of content structure" component in the MER (Duit, 2007), included studies focused on the scientific and technological content of the exhibition, i.e. NST. While there has been a lot of museum research focusing directly on the visitors and their experiences in an exhibition, the absence of content-centred studies in the field of museum education has been pointed out by many (e.g. Gilbert & Stocklmayer, 2001). In the approach employed in this study, analysis of content structure plays a crucial role in setting the "target" of the exhibition, i.e. the scientific and technological ideas to be presented in the exhibition (Laherto, 2013). The part-studies supporting this process included literature analyses on NST from an educational perspective (Laherto, 2010; Kähkönen et al., 2016), two surveys on science teachers' views on the educational significance of NST (Laherto, 2011; Kähkönen, Laherto, & Lindell, 2011), and an interview study on nanoscientists' views on the nature of NST and its public communication (Laherto et al., in press).

The present paper, instead, focuses on the second component in Fig. 1, corresponding to the "Research on teaching & learning" component in the MER (Duit, 2007), aimed at understanding the potential visitors' perspectives and learning processes in the context of NST and then using those findings to make recommendations for illustrating the field in an exhibition. In the literature on museum education, knowledge about the audience is nowadays considered equally important to the knowledge of the objects to be presented (Hooper-Greenhill, 1994; Laherto, 2013). A successful audience-responsive approach requires that the staff members do not only rely on their own view when choosing a subject for an exhibition, but that they carefully study the audience's perspectives and interests. As with the content-centred component, the visitor-centred component also involved both theoretical and empirical analyses.

3 Methods

The literature analysis on learning the concepts of nanoscale science (Fig. 1) involved science education research literature on teaching and learning the nanoscale concepts, including studies on typical learning difficulties and educational challenges related to this content. A limited (although rapidly growing) amount of such research has been published. The analysis spanned a comprehensive book on NST education (Sweeney & Seal, 2008) and three review articles (Hingant & Albe, 2010; Jones et al., 2013; Kähkönen et al., 2016), and all the science education research publications these reviews refers to. A few common themes clearly emerged from the literature, and the analysis focused on these.

The empirical part of the visitor-centred component consisted of a survey in order to get a grasp of potential visitors' perspectives on NST. The survey was conducted in the form of a standardized open-ended interview (Patton, 1990). The sequence of questions is presented in Appendix A. The beginning of the interview aimed to determine the level of awareness of the respondent about NST. Since public awareness of these emerging fields was presumed to be quite low, in the latter part of the interview some descriptions were given to the respondents in order to help them to consider the meanings of NST. These descriptions, given to each respondent, are also presented in Appendix A. Furthermore, the aim of the survey was to learn about the specific communicational challenges related to the use of visualisations of nanoscale objects. To that end, an image generated with a scanning tunnelling microscope (STM) and a video of a computer simulation were shown to the respondents, with some verbal explanations and questions (see Appendix A). In addition to the interview, the respondents were asked to provide background information in a brief questionnaire: gender, age, educational background, general interest in science, and general interest in technology (the latter questions had a four-point scale "very interested", "quite interested", "not very interested", "not at all interested").

Interviews were carried out in the lobby of the Heureka Finnish science centre. The interviewees were selected randomly from among the adult visitors. The interviews averaged about ten minutes, including completion of the background questionnaire. The number of the interviewees was 28, with 15 women and 13 men. The age of the respondents varied from 20 to 62 years, with a quite even distribution. The educational background varied from secondary school to university level. The great majority (93%) were at least "quite interested" in both science and technology, as could be anticipated for science centre visitors.

The interviewees' responses were analysed by identifying a few answer categories per question and categorizing the respondents' answers in these categories (Miles & Huberman, 1994; Patton, 1990). Due to the small sample, no strong generalisations can be made concerning the general public nor even the visitors to the science centre. However, in conjunction with the results of the literature analysis, the results are useful in gaining tentative insight into the awareness and interest of laypersons regarding NST and some idea about the educational and communicational challenges concerning nanoscale issues. In this paper, only the interview results that deals with an understanding of the nanoscale have been reported. Questions about the applications and implications of nanotechnology are beyond the focus of this paper.

4 Results

4.1 Literature analysis

Analysis of the literature on NST teaching and learning revealed that various studies have pointed out quite coherently certain challenges in understanding the nanoscale and its concepts. Several studies have shown that people of all ages have major problems in understanding the scale of NST (Castellini et al., 2007; Tretter, Jones, Andre, Negishi, & Minogue, 2006; Taylor & Jones, 2008). Furthermore, this does not concern only children and the young; it is natural that all humans – including also scientists working in related fields – have difficulties in conceptualising at the nanoscale because of the change in reasoning it requires (Jones et al., 2013). These challenges are elaborated in what follows, as well as strategies for addressing them.

In their study on the understanding of the size and scale of objects among students (of various ages) and experts, Tretter et al. (2006) concluded (not surprisingly) that students tend to have greater problems with scales for which they have no direct experience, especially microscopic and sub-microscopic scales. Prevalent misunderstandings seem to surround the size of the nanoscale (Schönborn, Höst, & Lundin Palmerius, 2015). However, the size conceptualisation seems to be easier using relative comparisons than absolute sizes. Taylor and Jones (2008) suggested that by strengthening these relative size perceptions, science education can support qualitative understanding of scale. Quantitative size differences may be added later as mathematical skills develop with age and education. Moreover, size landmarks, or points of reference, seem to be an important tool for anchoring perceptions of the spatial scale (Tretter, 2008). The size of a human appeared to be the clearest reference point, the other common ones being e.g. the width of a hand, the size of an ant, the thickness of a piece of hair or grain of rice, continuing to submicroscopic landmarks like the size of an atom. However, the younger the children are, the lower is their ability to use microscopic and especially the submicroscopic landmarks. In order to solidify these landmarks, education should provide a variety of experiences and reinforcements (Taylor & Jones, 2008).

An efficient strategy of conceptualising scales that are normally inaccessible to humans, such as the nanoscale, is unitizing. Unitizing means using existing objects to mentally create a new unit that can then be used to measure some other object (for examples, see e.g. Tretter et al., 2006). In order to develop such unitizing skills, science education should provide proportional reasoning abilities (Taylor & Jones, 2008; Tretter, 2008).

Besides the fact that the scale itself is difficult to comprehend, an additional challenge in NST communication arises because the public does not have a good grasp of the terminology and concepts regarding atoms and molecules and lacks knowledge of the atomic structure of matter (e.g. Crone, 2010). It is common to conceptualize matter as being continuous rather than particulate (Margel, Eylon, & Scherz, 2008). Children use the terms “atom”, “molecule”, “cell” ambiguously, and have many misconceptions (Murriello, Contier, & Knobel, 2006; 2009). Additionally, students tend to use "scaling" erroneously and assume that atoms/molecules have the same properties as the macroscopic substance they are part of. The use of macroscopic models for nanoscale phenomena may also contribute to the perception of atoms/molecules as shrunken versions of their macroscopic manifestations (cf. Margel, Eylon, & Scherz, 2008).

Castellini et al. (2007) argue that one of the fundamental challenges in the public communication of NST is that scientists and also educators tend to assume erroneously that lay people are familiar with the basic ideas of the structure of matter and able to comprehend the size scale. An understanding of nanoscale phenomena, however, can only be built on a comprehension of atoms as building blocks, and the size of them. Therefore, although it may be argued that the most essential ideas of NST involve scale only indirectly, learners need to familiarize themselves with the basics of the scale and the structure of matter before going into actual topics of NST.

Furthermore, the relationships between nanoscale concepts and the observable world can be counterintuitive (e.g. Jones et al., 2013). Since the behaviour of nanoscale particles is governed by quantum effects, discussion of this behaviour in proper terms requires highly sophisticated concepts. This certainly poses educational challenges and the risk of generating misconceptions (Sabelli et al., 2005). Careless simplification of the sophisticated concepts of NST, especially in quantum mechanics, leads to superficiality and the risk of misrepresentation.

The extensive use of images in communicating nanoscale objects and phenomena has recently also become an educational research interest (e.g. Landau, Groscurth, Wright, & Condit, 2009). The common perception of nanoscience "making atoms visible" is alleged to be problematic (Pitt, 2004), since the microscopy used in nanoscale research is epistemologically not an outright continuation of instruments such as the telescope or light microscope. The scanning force microscope, the atomic force microscope and the scanning tunnelling microscope simply do not portray the visible properties of an object in the sense of geometrical similarity and realistic depiction of colours. Rather, these techniques serve certain theoretical models, but do not generate an empirical database in the same sense as telescopy and light microscopy do (Brune et al., 2006; Pitt, 2004). Brune et al. (2006, pp. 53–57) also argue that the discourse on NST in general is replete with apparent confusion of models with descriptions of reality due to nanoscientists who tend not to emphasise that their representations are relevant only in the framework of certain theories, models, methodological decisions and purposes. Consequently, models are confused with what is being modelled.

In order to learn about the NST-related learning challenges that are specific to exhibitions, publications concerning nano-exhibitions were also searched for to be included in the literature analysis. While several exhibitions on NST topics have been launched in museums and science centres all over the world, there are few publications reporting on the experiences of those projects from an educational viewpoint. When discussing the Brazilian “NanoAventura” exhibition, Murriello, Contier and Knobel (2006; 2009) stress that the most important museographical and communicational challenge in designing exhibits on NST relates to the fact that the objects the fields are based on are invisible to naked eye. Exactly the same notion is stated in the evaluation of “It’s a Nanoworld”, a travelling exhibition on NST funded by the National Science Foundation in the U.S. (Batt, Waldron, & Trautmann, 2004). While NanoAventura solved the dilemma of displaying nano-objects in an exhibition by using computer games and virtual representations, “It’s a Nanoworld” employed concrete macroscopic models and analogies. In the following, these two approaches among some others are discussed.

On the basis of the literature analysis on the related learning challenges, it can be recommended that an exhibition should provide visitors with opportunities to familiarize themselves with the basics of the scale and the structure of matter before going into actual topics of NST.

4.2 Visitor survey

The results of the small survey (n=28) carried out in the lobby of a science centre provided additional insights into the aforementioned findings of the theoretical analysis.

Almost all of the respondents (96%) had heard of or had at least read something about nanoscience and nanotechnology, with the mass media (newspapers, television and popular science magazines) providing the most important sources of information. The respondents associated NST mostly to physics (71%), chemistry (43%) and computer science (25%), but technology, medicine, astronomy, biology, materials science and mathematics were also mentioned. When asked about their perception of the meaning of “nanoscience and nanotechnology” (question 5, Appendix A), 71% of the respondents coupled the terms with some kind of “smallness”. Every fourth interviewee even mentioned the level of atoms or molecules here. On the other hand, 50% of the respondents associated NST with new technological products, e.g. faster computers, stronger materials and tiny robots.

As the visitor survey was expected to provide additional insight into the educational and communicational challenges discussed in the literature analysis, the questions regarding visitors' perceptions of the scanning tunnelling microscope image[2] see Appendix A) were of special interest. Firstly, without any explanation, the respondents were asked to interpret what is depicted in the image (question 8). Only 25% of the interviewees named any nanoscale objects (molecules, atoms etc.), whereas most of the respondents associated the image with either macroscopic objects (35%) such as "an island" or "a waterdrop" or microscopic objects (29%) such as "a cell". After the respondents were told that there is a ring of iron atoms on a copper surface and the diameter of the ring is ca. 7 nanometre, 25% of the respondents knew that the image was created with an electron microscope, whereas 36% suggested that it was made by computer modelling, without experimental instruments (question 9). After this, the interviewer explained that it was a scanning tunnelling microscope (STM) image, and briefly explained the operating principle of STM, and then asked the respondent to say something about the iron atoms or the copper surface. Even after this attempt for a contextualisation, in question 10 most of the respondents (57%) came up with false, macroscopic conclusions about the image, for example suggesting that the copper surface is "rough", "soft" or "jelly-like", or that the iron atoms are "sharp" or "rusty", or that "iron is warmer than copper". Still, many respondents reached correct conclusions about the nanostructure, stating e.g. that iron atoms are of equal size and symmetric, or that it is possible to manipulate matter on an atomic scale. In the next question, 43% suggested that such images could be used in studying the structure of matter or the behaviour of atoms, 28% said that the STM images are helpful in manipulating matter and developing materials, 7% mentioned the purposes of communication and popularisation, and 21% were unable to answer to the question.

In the next phase of the interview, a video of a computer simulation was shown to the interviewees, together with a verbal description as explained in the "Methods" section and in Appendix A (question 12). The respondents were asked to compare the methods and techniques behind the STM image and the simulation. The idea behind

[2] The image shown was of the "quantum corral", available e.g. at http://www.almaden.ibm.com/vis/stm.

the question was to see how clear the fundamental difference between these two visualisations, one based on a simulation and the other on empirical methods, is to the respondents. 36% of the respondents mentioned this difference in some way, while the others responded with some other differences or similarities, e.g. that in the video, the bodies are moving while in the image they are not. 14% did not provide any answer.

Question 13 proved to be too difficult: 54% of the respondents could not say anything about it. On the other hand, even 32% of the respondents were able to provide an answer that is perfectly compatible with the scientific conception, e.g. “the laws change near the atomic level”, “at different scales there are different rules”. Finally, 68% of the respondents were interested in learning more about NST (question 25). Most of the respondents (71%) were especially interested in applications, 21% in scientific results and methods, and 7% in knowing the risks (question 26).

These results bring out the point that discussing the nanoscale and its phenomena seems like a natural and necessary starting point for the exhibition, although the potential visitors are probably interested in nanotechnological applications too. Special attention is needed when using visualisations of the nanoscale in order to convey the right epistemological ideas with them.

5 Discussion: strategies for illustrating the nanoscale science in an exhibition

Based on the results from the above-reported studies, some strategies that could support illustrating nanoscale science in an exhibition are suggested. These presented strategies are all related to “the nanoscale” but they relate to the two aspects of the issue in terms of their goals. Some of the strategies focus on supporting visitors’ (geometrical/spatial) scale conceptualisation as such, whereas others address the scale only indirectly. The aim of the latter strategies is to illustrate “the invisible” – the nano-sized objects that cannot be observed as such because of their smallness. It is argued that both approaches are needed to help museum visitors to come to grips with nanoscale and its objects.

5.1 Illustrating the continuum of scales & providing size landmarks

As both the literature review and the empirical survey pointed out, the "smallness" of the nanoscale and its counterintuitive phenomena are very difficult to conceptualise. In education, therefore, they should not be considered in isolation. Instead, an exhibition should guide visitors there by starting from the macroscopic scale, advancing through the microscopic range and finally to the nanoscale. This relative approach may help visitors to construct a continuum of scales and integrate their views of matter across scales. This was also one of the main approaches discussed in the comprehensive workshop reported by Sabelli et al. (2005).

An effective way of displaying this continuum in an exhibition is a scale spectrum with carefully chosen anchoring objects as size landmarks from each scale. Proportional reasoning can be employed by illustrations such as "if a football would be the size of the Earth, then a fullerene would be the size of a football". Besides pictorial presentations, even more effective way of supporting scale conceptualisation is provided by the "powers of ten" videos[3], recommended also e.g. by Tretter (2008), Castellini (2007) and Sabelli et al. (2005).

If a visitor understands the linear scale continuum from the macroscopic world to the nanoscale, it does not yet mean that (s)he has an understanding of any of the key ideas of NST, such as the size-dependent properties of matter. However, the visitor has a good foundation on which to situate later insights of nanoscale objects and phenomena.

5.2 Using images and visualisations

The research reviewed for this paper showed that personal experiences are essential in understanding scales. As discussed above, people have major difficulties in conceptualising size scales which they do not have experience of. Since it is not possible to obtain direct experiences at the nanoscale, and quantum phenomena cannot be replicated at the macroscale, images, visualisations and simulations must be used instead. Furthermore, several studies pointed out that visual models are crucial in students' understanding of sophisticated concepts (see e.g. Tretter, 2008). Therefore, abstract nanoscale concepts should also be taught with linkage to pictorial representations.

[3] There are many popular videos available, see e.g. http://www.powersof10.com.

Accordingly, images and visualisations are used extensively in NST communication. These methods are also natural for museums and science centres – e.g. virtual representations have been common in science museums for a long time (see Hooper-Greenhill, 1994). For an example of an NST exhibition relying completely on virtual representations, see Murriello, Contier, & Knobel (2009).

The power of visual representations in communicating NST also entails pitfalls. The public's understanding of these images and the impact of the images on the public's perceptions has become a research interest (e.g. Landau et al., 2009). The literature review found several articles that presented discussion of the risks of causing misconceptions – for example, it is questionable indeed what "seeing atoms" is by using a scanning tunnelling microscope (STM) or an atomic force microscope (AFM) (cf. Pitt, 2004; Robinson, 2004). Our empirical findings support the conclusion of the literature review, implying that special attention should be paid when communicating the nanoscale using such images, in order to avoid misleading learners into false models of direct sense perception and epistemological misunderstandings.

5.3 Using scale models and analogies to macroscopic objects

Another strategy for illustrating nanoscale objects in an exhibition is to use macroscopic scale models and analogies. They are popular in public communication of NST, especially in models of the structure of matter (with macro objects modelling atoms and molecules for example), as well as in macroscopic models of electron microscopy (e.g. "LEGO-AFM", see Sabelli et al., 2005). An American exhibition on NST entitled "It's a Nano World" relied solely on macroscopic analogies and "enlargement models" (Batt et al., 2004).

These models and analogies are powerful tools for anchoring the issues in learners' everyday experiences. This is especially crucial in informal learning environments: because of the free-choice-learning nature of them, it is a necessity to address visitors' needs and interests in an exhibition in order to gain any contact. Therefore, macroscopic points of comparison should be chosen so that they are relevant to visitors.

Demonstrating nanoscale phenomena by using macroscopic analogies is tempting indeed. It should be noted, however, that they do not reflect the discontinuous change of properties at a certain size, or any other quantum phenomena. Consequently, there is a major risk of causing misconceptions and, even, contradicting the major learning goal: properties of objects change discontinuously at a certain size. This important learning goal may become blurred when objects of a macroscopic nature and behaviour are used to demonstrate the nanoscale phenomena that do not obey macro laws. Due to these concerns, exhibits of this kind should be evaluated before being used in an exhibition, in order to find out the potential misconceptions they may generate. The nature and the limitations of the analogy should be pointed out.

Still, analogical models may be especially helpful in illuminating "scaling effects" (as suggested by Taylor and Jones, 2008). These effects mostly follow from the simple and classically understood way how a change in the size of an object affects the ratio of its surface area to volume. In studies on reasoning patterns, it has been found out that students find understanding scaling effects to be challenging. Macroscopic analogies may help this: for an example, surface-area-to-volume experiments with differently sized pieces of ice to illustrate heat loss.

5.4 Accessing nanoscale by instruments

Instead of drawing solely on visualisations and macroscopic analogies, it is both useful and possible to provide visitors with a "real" access to nanoscale phenomena, for example by using a scanning tunnelling microscope (STM) or an atomic force microscope (AFM) (also suggested by Sabelli et al., 2005). By using real instruments to make measurements on real nanoscale samples may support visitors' understanding of the connection of the nanometric world to its manifestations and representations in the macroscopic world. Reasonably-priced instruments are available for educational purposes, and applications for remote access to an AFM placed in a university laboratory are also available. Furthermore, the use of a haptic interface has shown promise in visitors' learning about molecular interactions (Bivall, Ainsworth, & Tibell, 2011). These methods have even been used in classrooms (see e.g. Fraundorf & Liu, 2008; Jones, 2008), and the resources are better again in museums.

6 Conclusion

Informal learning environments have a significant potential to contribute to public understanding and engagement in emerging fields of science and technology such as NST. The study presented here connects to a wider project on research-based development of such settings (Laherto, 2013). The Model of Educational Reconstruction (Duit, 2007; Komorek & Duit, 2004) has been used as the basis, drawing on both content analysis of the subject matter and studies on learners' perspectives. In this paper, educational, communicational and museographical issues related to the scale of NST have been scrutinised in order to find well-grounded strategies for exhibition development. The challenges and the recommended strategies are summarised in Table 1.

Table 8. Challenges in illustrating the nanoworld, and corresponding strategies for exhibition development.

Challenge	References	Recommended strategies
invisible nano-objects: challenge to the "presence culture" in exhibitions	Batt, Waldron, & Trautmann, 2004; Murriello, Contier, & Knobel, 2006; 2009; Taylor & Jones, 2008	• macroscopic models and analogies (especially in illustrating scaling effects) • computer games and virtual representations • shifting to the "meaning culture": societal significance of NST
no experience of sub-microscopic scales	Bivall, Ainsworth, & Tibell, 2011; Fraundorf & Liu, 2008; Jones, 2008; Murriello, Contier, & Knobel, 2009; Sabelli et al., 2005; Tretter et al., 2006; Tretter, 2008	• images, visualisations and simulations • real access to nanoscale with instruments (remote or actual educational AFM/STM) • haptic interfaces
difficulties in scale conceptualisation	Castellini et al., 2007; Sabelli et al., 2005; Schönborn, Höst, & Lundin Palmerius, 2015; Taylor & Jones, 2008; Tretter, 2008; Tretter et al., 2006	• relative comparisons instead of absolute sizes • size landmarks • continuum of scales
difficulties in proportional reasoning	Castellini et al., 2007; Sabelli et al., 2005; Tretter et al., 2006; Taylor & Jones, 2008; Tretter, 2008	• unitizing • proportional illustrations • "powers of 10" videos

difficulties in understanding size-dependent properties	Sabelli et al., 2005; Taylor & Jones, 2008	• illustrations on surface-volume ratio • multiple examples and representations
misconceptions: matter as continuous rather than particulate	Castellini et al., 2007; Crone, 2010; Margel, Eylon, & Scherz, 2008; Murriello, Contier, & Knobel, 2006; 2009	• discussing the structure of matter • illustrating size and scale
misconception: atoms/molecules having the same properties as the macroscopic substance	Jones et al., 2013; Margel, Eylon, & Scherz, 2008; Sabelli et al., 2005	• discussing counterintuitive quantum effects
risks of images and visualisations: epistemological misunderstandings, false models of direct sense perception	Landau et al., 2009; Brune et al., 2006; Pitt, 2004; Robinson, 2004	• explaining the methodological and epistemological issues • careful front-end evaluation of visualisations for potential misconceptions
risks of scale models and macroscopic analogies: confusion of models with reality; misusing "scaling", missing the discontinuous change of properties	Batt et al., 2004; Brune et al., 2006; Sabelli, 2005	• discussing scientific modelling • pointing out the limitations of analogies • careful front-end evaluation of exhibit models for potential misconceptions

In general, exhibitions seem to fit well as learning environments on NST. Contrary to formal education, in museums and science centres, there are no disciplinary boundaries or other curriculum constraints that do not cohere with the interdisciplinary nature of NST (cf. Kähkönen et al., 2016). Also, the instrumentation required for experimental work and "seeing" invisible nano-objects may be unattainable for classroom purposes, but the resources are better in museums and science centres. Moreover, given the needs discussed in the Introduction, exhibitions can provide a quick response to the growing public interest. Yet, informal learning environments such as exhibitions certainly bear some additional educational challenges too. Because of the fragmental nature of the learning environment, it is difficult to learn structured information at an exhibition. This poses major challenges for conceptual learning, considering also complex and sophisticated concepts and knowledge structure of NST. Moreover, due to the diversity of learners in a science centre, it is complicated to take visitors' preconceptions and other perspectives into account in exhibition development.

The axiomatic fact that nano-objects are neither visible nor tangible constitutes an interesting museographical challenge. In the traditional view, it makes nanoscale science a problematic topic for a museum, since it does not fit in with the idea of materiality and "presence culture" that is considered the essence of museums (Söderqvist, Bencard, & Mordhorst, 2009). Nanoscale objects cannot be collected and displayed in an exhibition as such. An exhibition can include NST instruments and macroscopic objects that nanoparticles are part of, showing the macroscopic manifestations of nanoscale phenomena. Such exhibits, however, do not present the scientific essence (for a discussion on the same issue in the context of biomedicine, see Söderqvist, Bencard, & Mordhorst, 2009). Yet, this museographical challenge of the "presence culture" is even wider and concerns all contemporary fields of science in which social and cultural aspects are typically deeply connected to the "scientific content". Representing these social and cultural phenomena in an exhibition cannot be done in traditional museographical ways, since they usually do not manifest themselves through material artefact. This development has shifted the focus of museums from "presence culture" towards "meaning culture" (Söderqvist, Bencard, & Mordhorst, 2009). Due to the important social implications of nanoscience and nanotechnology, and the limited opportunities for "presence effects", focusing on the meanings seems like a reasonable starting point for a nanoscience exhibition. Accordingly, the study reported here focused on the communication of one of the meanings of NST, i.e. an understanding of the nanoscale. Given the societal and educational significance of NST, it should be acknowledged that social and cultural meanings are at least equally important aspects of an exhibition.

In this paper, it has been argued that scale-related issues are a natural starting point for development of an informal learning environment on NST. Despite several educational challenges highlighted by the study, there are reasonable strategies to illustrate the nanoscale and its objects in an exhibition. Supporting visitors' scale conceptualisation by presenting scales as a continuum with size landmarks, using images and visualisations, as well as using macroscopic models and analogies (only in the context of scaling effects!) are effective tools for that. However, each of these approaches also entail some pitfalls, so they should be used only deliberately. Also, it should be noted that an exhibition should not focus too much on the scale itself, but on the properties of matter that are the essence of NST. If visitors only learn to "scale down" their macroscopic experiences, they will end up with wrong conclusions about the nanoscale. The discontinuously changing properties of matter should be kept in mind.

Indeed, it remains debatable if size and scale itself is in fact the very essence of NST. Either way, when taking an educational perspective, size and scale are definitely important. Scale conceptualisation is an important interdisciplinary theme of science education in general, and also plays a significant role in scientific literacy (as defined in the introduction; see also Gardner et al., 2010; Kähkönen et al., 2016; Tretter, 2008). It has also been suggested as one of the "Big Ideas of Nanoscience", and its incorporation in school curricula has been recommended (Sabelli et al., 2005; Stevens et al., 2009). Thereby the conceptualisation of scale is nevertheless a natural starting point for public communication and informal education in NST.

The guidelines suggested in the paper can be considered as a design framework (Edelson, 2002) for the development of such learning environments. Creating a prescriptive, generalized set of design guidelines such as the one in this study is a typical theoretical outcome of design-oriented research. Besides being applied in the research project this study is connected with, the results could also be used in research and development on other educational solutions.

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Appendix A: Questions of the interview: science centre visitors' perspectives on nanoscience and nanotechnology (translated from Finnish by the author)

4. Have you heard or read about nanoscience or nanotechnology (NST)?
5. Where did you hear/read about NST?
6. Have you studied NST, or has your work experience concerned these fields?
7. In your opinion, what fields of science is NST related to?
8. In your opinion, what does NST mean?

When the respondent has responded to question 5, the interviewer provides a simple definition of NST: "Nanoscience and nanotechnology concern the research, manipulation and construction of very small structures. According to a common definition, the structures of NST are in the size range of 1–100 nanometres, at least in one dimension (length, breadth or thickness). A nanometre is one millionth of a millimetre. This means that the structures of NST can be as small as a few molecules or atoms. At this scale, matter gains new properties that depend on size. These properties can, for instance, be mechanical, electrical or optical."

9. Do you know any applications or products that exploit nanotechnology?
10. Here I have talked about nanoscience and nanotechnology. Do you think that there is a difference between them?

The interviewer shows a scanning tunnelling microscope (STM) image of a nanoscale structure. ["Quantum corral", image originally created by IBM Corporation and available at the STM Gallery, http://www.almaden.ibm.com/vis/stm/gallery.html. The image is also on the cover of the printed version of this dissertation.]

11. What do you think is presented in this image?

After the respondent has answered question 8, the interviewer explains that there is a copper surface, in which a ring is constructed out of single iron atoms. The diameter of the ring is ca. 7 nm.

12. How and with which instruments was this image created?

The interviewer explains that the image was created with a scanning tunnelling microscope. STM has a sharp tip that is slowly moved across the surface, measuring the properties of the surface.

13. On the basis of this image, what can you say about the iron atoms or the copper surface?
14. For what purpose do you think images of this kind can be used in nanoscience?

The interviewer shows a computer simulation and gives the following explanation: “In this computer simulation a small, spherical carbon structure collides with a tubular carbon structure.”

15. When you think of the creation of this video and the recent image, what similarities and differences come to your mind?

After the respondent has answered question 12, the interviewer explains: “The carbon nanotube shown in the video is one important structure studied and applied in NST. It has interesting properties: a carbon nanotube is extremely strong, and it conducts electricity and heat very well. It is a good example of a central idea of NST: below a certain size, matter may exhibit totally new and even revolutionary properties.”

16. What do you think these new properties result from?
17. Generally speaking, what potential benefits do you think will follow from nanotechnology?
18. What disadvantages and risks will follow from nanotechnology?
19. Which do you consider more significant, the benefits or the disadvantages/risks?

After the respondent has answered question 16, the interviewer says: “Finally, I will read some statements. Please respond on the scale 1...5 depending on how much you agree with the statement. ‘1’ means you do not agree at all, and ‘5’ means you completely agree. You can also respond ‘I cannot say’.”

20. The general public should be heard when making decisions about the development of NST.
21. Decisions on NST should be made on the basis of expert views and advice.
22. Decisions on NST should be made on the basis of views of average citizens.
23. Decisions on NST should be based on scientific knowledge of the risks and benefits.
24. Decisions on NST should be based on moral and ethical considerations.
25. Citizens should be told about NST and be able to decide independently whether they want to use products developed with these methods.
26. Although nanotechnology may bear some unknown risks, it is an inevitable part of our future, so we should just make sure that it is used as safely as possible.
27. NST should be regulated and supervised more strictly than before.
28. I am interested in knowing more about NST.
29. What interests you the most about NST?

The relevance of non-formal Biology Olympiad training for upper secondary school students

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Abstract: Science competitions, such as the International Biology Olympiad, are non-formal education targeted to upper secondary school students with high abilities. However, there is little knowledge about what is the relevance of training for a science competition. In this study, Finnish Biology Olympiad training participants were researched in the context of relevance of science education. In total, 28 students filled in questionnaires and participated in interviews. It was found out that the students experienced the training to be especially individually relevant for them, and there was no significant difference between genders. Based on the results, vocational and societal topics should be taken into more account in designing Olympiad trainings.

Keywords: high ability students, non-formal education, relevance, science education, science competitions, out-of-school learning

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1 Introduction

The decline of interest and engagement in science as well as growing need of skilled scientists have aroused concern in many Western countries (Osborne, Simon, & Collins, 2003; Vihma & Aksela, 2014). Non-formal, out-of-school education might help to engage young students to math and science (STEM) careers (Tolppanen, Vartiainen, Ikävalko, & Aksela, 2015; Vihma & Aksela, 2014) and understand scientific inquiry (Antink-Meyer, Bartos, Lederman, & Lederman, 2016). The development of non-formal education is also promoted by the European Union (European Union, 2015).

Most science competitions pursue to promote interest in science and scientific careers, but it is still unknown whether those objectives can be fulfilled. According to earlier research, science competitions have been identified to help the students realize their talent (Campbell, Wagner, & Walberg, 2000). In addition, competitions can reinforce career choices and interest in science, but personal topics of interests, teachers and parents also have a big effect on future vocational choices (Krapp & Prenzel, 2011; Sahin, Gulacar, & Stuessy, 2015). According to Campbell et al. (2000), it is assumed that competitions are important because the schools rarely have differentiated curriculums for advanced students. It is also assumed that students with high abilities are attracted to taking part in competitions and they are motivated by these activities (Campbell et al., 2000). These assumptions have not been confirmed, as science competitions have received little scientific interest (Abernathy & Vineyard, 2001). Most studies about science competitions have been conducted in Western countries, and various cultural factors have been neglected (Lim, Cheah, & Hor, 2014). Especially, the long-term effects of the science competitions are poorly known. Because of the lack of educational research on this field, defining the aims, purposes and objectives of the competitions can be challenging.

The participants of science Olympiad and other science competitions have been researched in a few studies. It has been shown that the participants of these events are likely to choose a scientific career and succeed in academic life (Campbell et al., 2000). Family support and not fearing failure are important predictors of students' success (Urhahne, Ho, Parchmann, & Nick, 2012), as well as parents' educational level (Tirri, 2000). Participants also consider that both ability and effort are needed to succeed in competitions (Tirri & Nokelainen, 2010).

Science Olympiad training has been researched by Oliver and Venville (2011), who found that the students participating in science Olympiad training had a higher attitude towards science compared to other students of this age. It was also discovered that the students experienced science to be an easy school subject and didn't pursue to learn it. To support those students, there should be more challenges in science as well as academic support in science learning process. (Oliver & Venville, 2011) Biological competitions might also be a meaningful tool to improve young students' interest in science and enabling to maintain and stabilize it (Staziński, 1988). However, it is yet to be defined what kind of effects these competitions and training courses have on interest or motivation or how the students value the competitions and training.

The International Biology Olympiad (IBO) is a yearly competition for secondary school students interested in biology. During the competition, both practical skills and theoretical knowledge are tested. The objectives of the IBO competition are to 1) stimulate active interest in biological studies, 2) promote networking and understanding between biology students, and 3) promote and exchange ideas about biology education' (IBO Coordinating Centre, 2015).

Most countries taking part in the IBO competition also arrange a national Biology Olympiad or competition and a training course for the students. In Finland, students can participate in the National Biology Competition. Based on the competition, approximately ten students with the highest scores are selected for the IBO training, consisting of an online training course and two training weeks at university. To help the students orient towards the training, the Campbell's Biology textbook is sent to the students, and the students receive online training questions to help learning the material. Training weeks consist of laboratory experiments, designing and executing a small research project, as well as research laboratory visits and a final exam. In the end of the training, four students are selected for the IBO team to represent their country in the IBO competition, based on their score on the final exam.

2 The Relevance of Science Education

Science education is often experienced to be irrelevant for the students (Dillon, 2009), and hence students may not become interested in scientific topics. To make students develop positive attitudes towards science, science education should be relevant for students in the individual level. In addition, it is important that science education is relevant for the society and the future vocational life of the students. (Cleaves, 2005; Hofstein, Eilks, & Bybee, 2011; Osborne et al., 2003) Advanced students consider science to be relevant for them individually, but also for society and their future vocation (Vesterinen, Tolppanen, & Aksela, 2016), which should be taken into account when designing education for students with high abilities.

The relevance of science competitions hasn't been researched, even though various science competitions are organized every year. Relevance is widely used concept in educational policies and research, but there has been ambiguity in the definition (Newton, 1988; Stuckey, Hofstein, Mamlok-Naaman, & Eilks, 2013). There are various examples of studies where *'relevant'* is interpreted synonymous for *'interesting'*, *'motivating'*, *'needful'* or *'meaningful'* (Holbrook, 2008; Levitt, 2001; Simon & Amos, 2011; Sjøberg & Schreiner, 2010). Sometimes real-life effects on students or society are used to assess the relevance of education (Hofstein & Kesner, 2006). Stuckey et al. (2013) argue that there are differences in relevance and interest as science education can be relevant for the students even though it wouldn't be interesting to them. Interestingness is not the only criterion for relevant science education, but educators should also consider including vocational and societal aspects of relevance in their teaching.

The relevance of science education is also discussed by Roberts (2007), who presents two visions for scientific literacy: On the one hand, science education is relevant in developing scientific thinking skills and fostering growth of future scientists (Vision I); on the other hand, it's also relevant in everyday life and society (Vision II). (Roberts, 2007; Roberts & Bybee, 2014) The definition of the relevance of science education also depends on who decides what is relevant. Academic scholars have traditionally defined what is relevant in science education. However, ordinary people also face science-related problems in their everyday life; employers emphasize working-life skills in science education; the media makes people become interested in scientific topics; experts who are concerned with general public have also interest in science education; and students themselves may be interested in scientific topics as well. (Aikenhead, 2006, p. 32) In conclusion, the relevance of science education is a multifaceted issue debated by multiple interest groups with conflicting views.

Based on literature on the relevance of science education, Stuckey et al. (2013) have synthesized a theoretical framework, in which relevance is defined to have a 1) temporal component, 2) an intrinsic-extrinsic component and 3) three different dimensions of individual, societal and vocational relevance (Figure 1). They also have pointed out that relevant science education should have positive effects on a life of a student, but this effect can be related to the individual interests of a student or to the societal or vocational needs. All three dimensions, individual, vocational and societal relevance, should be present to achieve the goals of science education.

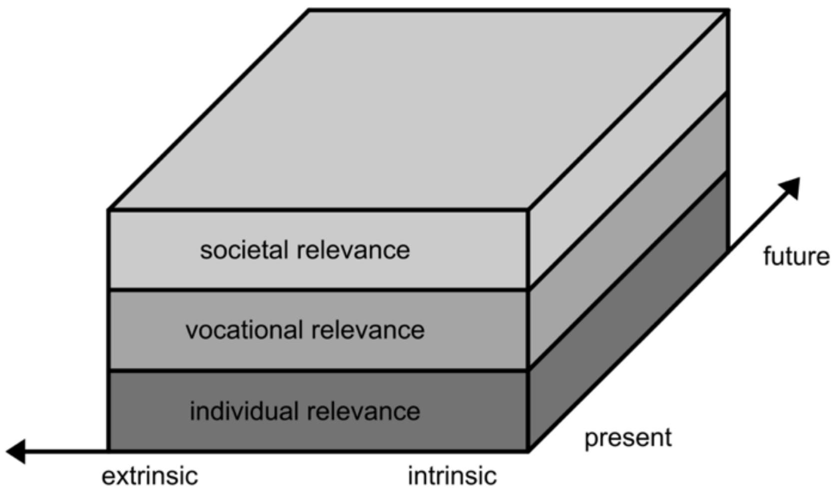

Figure 1. The components and dimensions of relevant science education, according to Stuckey et al. (2013).

Science Olympiad training can be classified as *non-formal education* (Eshach, 2007) because it has some features of both formal education (e.g. a curriculum and learning objectives) and informal education (e.g. voluntariness). The requirement of relevant science education does not apply only to formal education, but also to non-formal and informal education. The relevance of non-formal science education has gained little scientific interest, but e.g. Tolppanen et al. (2015) have analysed the relevance of non-formal STEM education in Finland, and found that non-formal, out-of-school science education can be relevant for the students individually, vocationally and societally, and relevance should be taken into account when designing science education for high ability students.

In this study, the participants of Finnish Biology Olympiad training courses were researched to examine the relevance of the training. In addition, participants' views on the relevance of biology education were researched to get more knowledge of the relevance of the training. Secondly, students' aims and expectations and their learning experiences were explored to get more knowledge to develop more relevant training for the participants. The research questions were:

1. How is Biology Olympiad training relevant for the participants?
2. How is it possible to make Biology Olympiad training relevant for the participants?

3 Materials and Methods

In the first part of this research, the relevance of the training was examined by analysing the experiences of the previous participants. In 2014, an online questionnaire was sent to the previous participants from years 2008–2014 (65 participants in total). 35 previous participants (54 %) answered the questionnaire: 49 % of the respondents were male and 51 % female, and 49 % were selected for the IBO team. 83 % of the respondents were studying in the university (Bachelor's or Master's level), 6 % were PhD students and 11 % were in other position. 31 % of the respondents had chosen biosciences, 40 % medicine, and 29 % other disciplines.

The questionnaire contained background information fields (gender, year of participation, and current discipline of studies or vocation) and 15 statements about the relevance of the training (see Table 1). For each statement, the participants had to choose a value from a five-point Likert scale ranging from 'do not agree at all' to 'strongly agree'. To assess the reliability of each dimension, Cronbach's alpha was calculated for each dimension.

Table 1. The questions in questionnaire sent to the previous Finnish Biology Olympiad training participants.

Number	Statement	Dimension of relevance
1	The experiences I got during the training have been memorable.	Individual
2	The knowledge and skills, that I learned during the training, helped me to choose my future studying place.	Vocational
3	The knowledge and skills, that I learned during the training, have been useful in my everyday life.	Individual
4	The training helped me to develop my social skills.	Societal
5	I learned knowledge and skills that are useful in vocational life.	Vocational
6	The training made me better in solving problems.	Individual
7	The training helped me to understand, what's the meaning of science to the society.	Societal
8	The training helped me to get connected to other people who think like me.	Vocational
9	The training helped me to understand societal issues connected to science.	Societal
10	The knowledge and skills, that I learned during the training, have been helpful in my studies.	Individual
11	The training was interesting.	Individual
12	The training affected or strengthened my career choice.	Vocational
13	The training helped me to understand science better.	Individual
14	The training gave me a good insight into jobs in science.	Vocational
15	I learned to work with different people during the course.	Societal

Based on the results, a sum score was calculated for each dimension. The sum scores of each dimension and the year of participation were compared by calculating the Spearman correlation coefficient (see Table 5). The effects of background factors were examined by conducting Mann-Whitney U-tests.

To examine the effects of the training, a qualitative study was carried out, the subject being the Finnish IBO training during 2014 and 2015. During this period, two student groups took part in the training: the first group was trained for the IBO competition organized in 2015, and the second group was trained for IBO 2016. An online questionnaire containing open-ended questions was sent to the students before and after the two training weeks. In addition, the students were interviewed after the training weeks (semi-structured interviews). In total, 28 students filled in the questionnaires and participated in the interviews.

Before the training week the students were asked why they are interested in biology and what kind of aims and expectations they have for the course. After the training week, the students were asked what kind of topics they learned during the week.

A qualitative content analysis approach was applied to analyse the qualitative data and both inductive and deductive approaches were used: In inductive content analysis, the content is reduced to different themes based on the data, whereas a theoretical framework sets the direction for the analysis in deductive content analysis (Elo & Kyngas, 2008). First, the questionnaires and interviews were analysed, and different themes were created based on the data. Secondly, the previously formed themes were classified in bigger groups based on deductive content analysis. In this case, the theory of relevance of science education (Stuckey et al., 2013) was applied as the basis of deductive analysis phase.

Thus, the whole process included both inductive and deductive phases:

- The inductive phase

1. Reading through the data and identifying the relevant excerpts.
2. Forming the initial groups based on the data.
3. Classifying the excerpts in the initials groups.
4. Checking the initial groups and refining them. Forming new groups, if necessary. Reclassifying the excerpts if necessary.
5. Classifying groups in bigger themes, if applicable.
6. Re-reading and re-discussion of the data.

- The deductive phase

1. Classifying the themes in the theoretical framework.
2. Checking the themes, groups and original excerpts and checking their applicability in the theoretical framework.
3. Re-forming the inductive phase classification, if necessary.

When analysing the reasons to be interested in biology, after the inductive analysis process, the data were classified in nine themes. In the deductive content analysis phase, the previously formed themes were classified to belong to individual, vocational or societal relevance, based on the description by Stuckey et al. (2013). The classification of the data is presented in Table 2. The excerpts are translated from Finnish into English.

Table 2. The classification of students' reasons to be interested in biology.

Dimension of relevance	Theme	An example
Individual relevance	Understanding the nature	*'biology helps you to understand the World around you, and environment'*
	Practical applications of biology	*'practical applications [of biology] are useful'*
	Consistency of biology	*'[biology-related topics] are more logical and can be deduced rather than memorized'*
	Understanding oneself	*'you can understand the functions of your own body.'*
	Hobbies and free time activities	*'knowing species is important as a hobby'*
Societal relevance	All-round education / general, layperson knowledge	*'knowing biology is a part of all-round education'*
	Topicality of biology	*'biology can be used to explain many important current topics'*
	Caring about environment and nature	*'I want to take care of environment and nature'*
Vocational relevance	Future studies / vocation	*'They are likely to be related to my future studies'*

Using the previously described content analysis process, the aims and expectations of the students were analysed. The aims and expectations were classified in 15 themes in the inductive phase of the process, and these themes were classified as individual, vocational or societal relevance in the deductive phase. The classification is presented in Table 3. The excerpts are translated from Finnish.

Table 3. The classification of students' aims and expectations for the training.

Dimension of relevance	Theme	An example
Individual relevance	Getting to know new people	*'I want to – – get to know new people'*
	Learning practical skills	*'learning to use new devices'*
	Getting new experiences	*'to learn and have a novel experience'*
	Learning to apply knowledge	*'different methods, and testing – how can you apply it in practise'*
	Deepening knowledge in a special topic of interest	*'learning microbiology in detail'*
	Research-related topics	*'[to learn] about modern research topics'*
	Performing well	*'managing to do my research'*
	Reviewing one's knowledge	*'Recalling what I've learned before'*
	Getting to the IBO team	*'to get to the [IBO] competition'*
Vocational relevance	Matriculation exams	*'learning things preparing for the matriculation exams'*
	Future studies	*'Broaden the views – – what's learning a subject in the university'*
	Getting to know companies / industry	*'Visiting the companies – – would be interesting'*
	Getting a course for the studies	*'Having a course [for the upper secondary school]'*
Societal relevance	A good working environment	*'[how to] work without pressure'*

Similarly, the learning experiences from post-training questionnaires and interviews were analysed. During the inductive phase, the learning experiences were classified in 11 groups, and these groups were further reduced into 6 themes. In the deductive phase, the 6 themes were classified to represent either individual, vocational or societal relevance. The classification is presented in Table 4. The excerpts are translated from Finnish.

Table 4. The classification of students' learning experiences.

Dimension of relevance	Theme	Group	An example
Individual relevance	Learning practical work	How devices work / using devices	*'a little bit – – how devices work'*
		Learning practical methods	*'having the courage to do practical work'*
	Learning theoretical knowledge	Theoretical knowledge about a biological topic	*'I learned most about microbiology, but also plant physiology was really a new topic'*
		Connecting theory with practise	*'learning new ways of thinking, from a theoretical perspective, such as how the size of a molecule affects it filtration [in biochemistry]'*
	Learning about research	Research funding	*'[understanding the] price of everything, such as an electron microscope – – could be worth of millions'*
		What's research like	*'You can do whatever you like if you find – – your own project'*
		How to apply scientific knowledge	*'the importance of PCR in all medical research et cetera'*
Vocational relevance	Getting help to succeed at studies	Succeeding in the matriculation exams	*'the matriculation exam could have a special question about this kind of practical work'*
	Science as a vocation	Understanding the nature of a scientific career	*'wherever you end up – – as a career – – you get to know what's going on in this field of research'*
		Learning skills needed in vocational life	*'things that you might need – – in your vocation'*
Societal relevance	Science and society	The importance of science for the society	*'the meaning – – of biology to the society'*

In the classification process, all the answers given by a single student were combined, and based on the classification, it was marked down whether the student had mentioned a specific theme in their interviews or questionnaires. Finally, the results of the three training weeks were combined, and the percentage of students who mentioned the theme was calculated.

The number of participants of this study is relatively small, as it was selected to focus on the Finnish Biology Olympiad training. As there are only about 10 students participating in this course every year, it is challenging to involve large groups for this kind of study. To address this issue, different levels of triangulation were applied: 1) time triangulation, 2) investigator triangulation and 3) methodological triangulation. First, data were collected from previous Olympiad training participants, and also from three different training weeks after the refinement of the training. Second, to improve the reliability and validity of results, a second researcher used the described classification to classify the data. The inter-rater agreement was assessed by calculating Cohen's kappa value (J. Cohen, 1960). Third, both quantitative and qualitative approaches and different kinds of data collection methods were used to get more reliable data about the phenomenon (L. Cohen, Manion, & Morrison, 2013, p. 196).

4 Results

In the quantitative part of this study, the three dimensions of relevance (individual, vocational and societal) of the Biology Olympiad training were measured by using a questionnaire developed in this study. The reliability index of Cronbach's alpha was 0.75 for individual relevance (statements 1, 3, 6, 11 and 13), 0.79 for vocational relevance (statements 2, 5, 10, 12 and 13) and 0.84 for societal relevance (statements 4, 7, 8, 9, and 15). The participants gave higher absolute values to the individual relevance dimension compared to the other two dimensions, which can also be seen in Figure 2. There was moderate correlation between different dimensions of relevance, but little correlation between the year of participation and experienced dimensions of relevance (Table 5).

Table 5. Spearman correlations between the dimensions of relevance experienced by the participants of Finnish Biology Olympiad training, and their year of participation.

	Individual relevance	**Societal relevance**	**Vocational relevance**
Societal relevance	0.535 (p=0.001**)		
Vocational relevance	0.668 (p<0.001**)	0.495 (p=0.003**)	
Year of participation	0.239 (p=0.166)	0.335 (p=0.049*)	0.310 (p=0.070)
**p < 0.05. **p < 0.01*			

According to Mann-Whitney U-tests, there were no significant differences between genders and their experiences of individual, vocational and societal relevance (p=0.610, p=0.193 and p=0.454, respectively). If a student had been selected for the IBO team, they experienced that the training was more relevant for them both individually, vocationally and societally (p=0.002, p=0.045 and p=0.014, respectively). The means of sum variables for these groups are displayed in Figure 2.

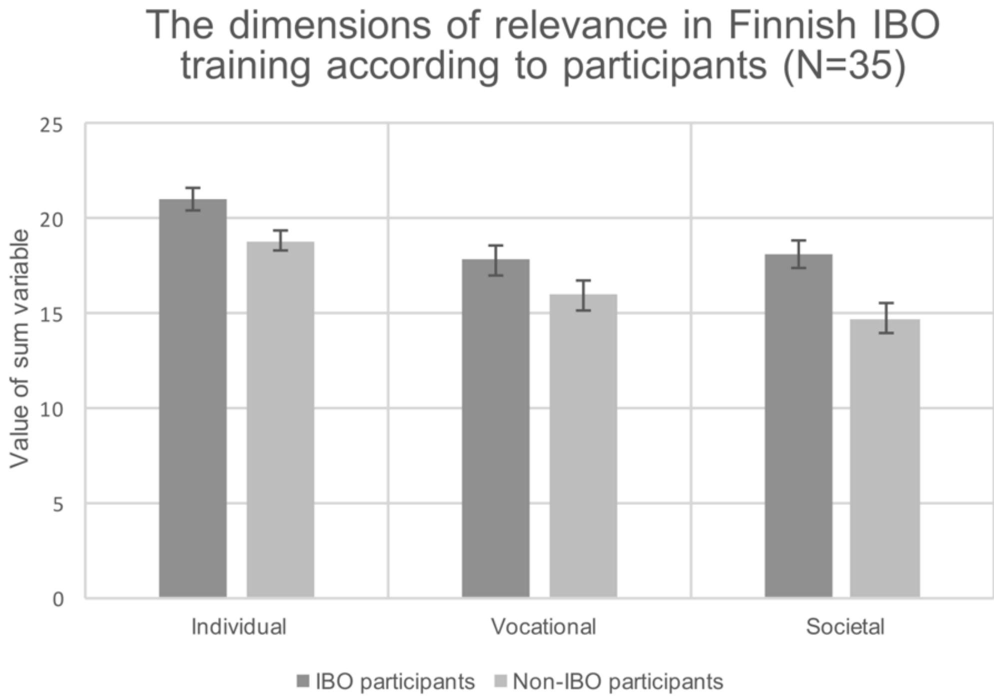

Figure 2. The mean sum scores of the dimensions of relevance in Finnish Biology Olympiad training, according to participants (years 2008–2014, N=35, error bars = SEM). The figure shows the differences between students who were selected for the International Biology Olympiad (IBO) and students who didn't qualify.

The students participating in refined Finnish IBO training (N=28) gave various reasons to be interested in biology. The most common themes were 'understanding the nature' and 'future studies or vocation', which almost half of the students mentioned in their open-ended answers. In total, the students mentioned themes belonging to the individual relevance dimension the most, but also societal and vocational relevance dimensions were prevalent (Table 6).

Table 6. Students' reasons to be interested in biology (N=28).

Dimension of relevance	**Theme**	**The amount of students (N=28) mentioning the theme**	
		Rater 1	Rater 2
Individual relevance	Understanding the nature	11	
	Practical applications of biology	7	9
	Consistency of biology	3	3
	Understanding oneself	1	1
	Hobbies and free time activities	1	1
Societal relevance	All-round education / general, layperson knowledge	5	8
	Caring about environment and nature	4	4
	Topicality of biology	2	3
Vocational relevance	Future studies / vocation	11	11

Cohen's kappa value for inter-rater agreement was 0.805.

The students' aims and expectations for the refined training were mostly classified to belong to the individual dimension of relevance. The most common aims and expectations were 'learning practical skills' and 'deepening knowledge in a special topic of interest'. Only a few themes could be classified to represent vocational or societal relevance (Table 7).

Table 7. Students' aims and expectations before the training week (N=28).

Dimension of relevance	**Theme**	**The amount of students (N=28) mentioning the theme**	
		Rater 1	Rater 2
Individual relevance	Getting to know new people	6	5
	Learning practical skills	17	19
	Learning to apply knowledge	3	3
	Deepening knowledge in a special topic of interest	11	9
	Performing well	4	4
	Research-related topics	6	8
	Getting to the IBO team	4	4
	Getting new experiences	3	4
	Reviewing one's knowledge	1	3
Vocational relevance	Matriculation exams	7	7
	Future studies	1	5
	Getting to know companies / industry	3	3
	Getting a course for the studies	1	1
Societal relevance	A good working environment	1	7

Cohen's kappa value for inter-rater agreement was 0.803.

The prevalence the individual dimension of relevance was even clearer when analysing the students' learning experiences from the refined training. Almost all the students experienced that they had learned theoretical knowledge, and most students mentioned also practical skills. However, only a few students experienced that they had learned something belonging to the dimension of vocational or societal relevance (Table 8).

Table 8. Students' learning experiences after the training week, based on the post-training questionnaire and the interview (N=28).

Dimension of relevance	**Theme**	**The amount of students (N=28) mentioning the theme**	
		Rater 1	Rater 2
Individual relevance	Learning theoretical knowledge	26	24
	Learning practical work	19	18
	Learning about research	7	9
Vocational relevance	Getting help to succeed at studies	2	4
	Science as a vocation	2	2
Societal relevance	Science and society	2	3

Cohen's kappa value for inter-rater agreement was 0.820.

5 Discussion

This study answered to the two research questions through the quantitative and the qualitative parts of the study:

5.1 The relevance of Biology Olympiad training for the participants

In the quantitative part of this study, the aim was to examine the theoretical framework of relevant science education (Stuckey et al., 2013) used also in the qualitative part of this study. To measure the dimensions of relevance by Stuckey et al. (2013), an instrument was developed and tested to operationalize and measure relevance, but it should be refined and tested in further studies. Based on the results, the theoretical framework of relevance of science education (Stuckey et al., 2013) might be useful for qualitative analysis in these kinds of contexts. It was discovered that the three dimensions of relevance (individual, vocational and societal) are tightly connected: the students who considered the training to be relevant for them individually are more likely to experience it to be relevant also vocationally and societally.

Based on the results from the quantitative analysis, the difference between genders in any of the dimensions of relevance was not statistically significant. In many studies, gender has been observed to be an important factor predicting the achievement in biology (Britner, 2008), interest and motivation (Gedrovics, Wäreborn, & Jeronen, 2006; Prokop, Prokop, & Tunnicliffe, 2007; Uitto, Juuti, Lavonen, & Meisalo, 2006), self-efficacy beliefs (Zeldin, Britner, & Pajares, 2008), observed relevance of biology

(Schreiner & Sjøberg, 2004) and choosing biological career (Lavonen et al., 2008; Uitto, 2014). However, the effect of gender may be different among students with high abilities. It would be important to research the effect of gender on high ability students to get more knowledge about this issue.

It is important to consider that only some of the students participating in the training were selected for the IBO. Participating in the IBO was a significant factor predicting the experienced individual, vocational and societal relevance of the training. The reason might be that 1) the students that experience the training to be more relevant for them will be more likely to be selected for the IBO team, 2) the students not qualifying for the IBO team develop negative views on the training, or 3) the students selected for the IBO team were unable to distinguish the effect of the training and the competition from each other, and actually the IBO competition itself affected their views.

To get more knowledge about the relevance of the training, students were also asked why biology (as a school subject) is relevant for them. The students considered that biology is a relevant subject to study and learn in itself, and in their reasoning, they expressed individual, vocational and societal dimensions of relevance. This is in accordance with the theoretical framework of relevance by Stuckey et al. (2013), and implicates that it is important to include all the three dimensions in relevant biology education, both in formal and out-of-school (non-formal) contexts.

5.2 Possibilities to make Biology Olympiad training relevant for the participants

To make science competitions more relevant for the participants, it is important to research their aims and expectations. According to the students, studying biology is relevant individually, vocationally and societally. However, students' aims and expectations did not evenly contain all the dimensions of relevance. In fact, most of the students expected the training to be only individually relevant for them, which may result from students' preconceptions about science competitions and training. Scientific competitions (e.g. IBO Coordinating Centre, 2015) are planned to be relevant in many ways, and it's useful to explain to the students what are the aims of the competition and training. According to Campbell et al. (2000), science competitions are expected to promote motivation and lead the students to contribute to society. Therefore, science competitions should not only promote interest in science, as relevant science education should also anticipate the future needs of the students (Stuckey et al., 2013), including vocational and societal aspects.

Students' views on the relevance of the training was also examined by asking what they had learned during the training. Students' learning experiences represented almost entirely the individual dimension of relevance, which is in accordance with their aims and expectations. However, it should be taken into account that when asking about learning experiences, the students tend to give concrete answers, which were classified to represent the individual dimension of relevance. In addition, the students may be unaware of their learning as learning may be informal: it is invisible, the learned knowledge is tacit and difficult to explain in detail (Eraut, 2004). However, assessing the relevance of non-formal science education might not be possible by analysing learning experiences, but those educational activities should be evaluated in their entirety (Tolppanen et al., 2015).

Moreover, students' aims and expectations are mostly related to the present or near future (e.g. 'getting to the IBO team', 'matriculation exams' or 'getting a course for the studies'). Notably, students' aims and expectations for out-of-school Olympiad training are primarily short-term, which might also explain the lack of vocational and societal components of relevance in this part. In addition, students' learning experiences reflect the same phenomenon: most of the learning is related to the individual dimension of relevance.

The vocational and societal dimensions of non-formal education may easily be neglected, unless this issue is addressed when developing such activities. In addition, if participants' aims and expectations only direct the development of Olympiad training, activities may only be individually relevant. All participants are not specifically aiming to study the specific discipline of the training, which is another reason to take vocational and societal relevance into account. In addition, we found out that biology is a relevant school subject for the participants of the trainings, individually, societally and vocationally. Hence, the science Olympiad training should be developed by taking these viewpoints into consideration as well.

This is a preliminary study to shed light on complex issues about developing non-formal education for young students. That's why it is needed to conduct similar studies in other contexts, such as in different countries and science disciplines to make further recommendations about developing non-formal science education and the Olympiad trainings for students with high abilities.

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Mathematics and outdoor photography experience – exploration of an approach to mathematical education, based on the theory of Dewey's aesthetics

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Abstract: Based on Dewey's theory of art, aesthetics, and experiences and photographer Barnbaums' writing about expanded perception through photography, we conducted a one-day experimental mathematics education unit. Using photography in outdoor conditions had a positive impact on teacher students' perception of the use of photography for teaching mathematics. To study the changes in students' visual attention deeper, we used gaze-tracking to analyse one student's visual attention when walking outdoors after the activity. The gaze data indicated that more visual attention was given to objects he had photographed or discussed during the group activity in comparison to other objects.

Keywords: aesthetics, mathematics, photography, teacher education, visual attention

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1 Introduction

It has been suggested (Kramer, 2013, p.11) that adventure and experimental education should be used more in mathematics teacher education, both inside and outside the classroom. Extraordinary experiences will be remembered and can give fulfilling satisfaction (Barnbaum, 2010). Dewey made a distinction between ordinary experience and *an* experience, which Pugh and Girod (2007, p.10) further elaborated, saying that science has the potential to enrich life through such experiences. The approach of Pugh and Girod, based on Dewey's aesthetics (Dewey, 1958), emphasises both outdoor experiences and re-seeing. For them *re-seeing* means looking at ordinary objects from a new perspective.

It is well known that we need to look and see in-depth when we want to take a photograph. This is the opposite to the casual everyday seeing when we "... allow visual input to slide in and out of our eyes and brain all the time" (Barnbaum, 2010, p. 58).

What we really see depends on our background. Barnbaum stated that the more knowledge, training, and experience we have the more and deeper we will see. He used the metaphor of a detective viewing the room of a crime scene. The detective will see many more details than an ordinary person.

Visualisation, both as a process and a product, ought to become more visible in mathematics education, Arcavi claimed (2003, p. 215). He emphasises the creation, interpretation and reflection upon pictures and images.

The first author of this paper is developing a teaching unit in the spirit of design-based research (Gravemeijer, Akker, McKenny, & Nieveen, 2006). In this unit, photography is used to develop the way students perceive mathematics in their environment. They get the task to be on the lookout for images of mathematics around them, out of school. They capture those images with their mobile phone, analyse the mathematics underlying one of them and discuss their thoughts, both in small groups and in the whole class. This paper reports an evaluation of the second iteration of this teaching unit.

Our approach is supported by an earlier study (Munakata and Vaidya, 2012), which indicates that the use of photography encourages students and increases creativity. Everyday life outdoors and science/ mathematics can be connected in a meaningful way through the experience of photography.

2 Research questions

To explore the effect of photography-based teaching we had the following questions:

1. How would photography-based teaching influence students' interest in and valuation of visual approaches in mathematics learning?
2. How would this influence students' perception of mathematics in everyday objects?

3 Theory

Our theoretical framework is mainly based on Dewey's theory of art, aesthetics and experience (Dewey, 1934; 1958). Our work is also influenced by Pugh and Girod (2007) who constructed an alternative pedagogy that emphasises transformative aesthetical experiences in everyday contexts. Moreover, the writings of photographer

Bruce Barnbaum (2010; 2014) will add theoretical ideas about perception in photography.

In the field of education, Dewey's work is well known for learning through experiences, but Pugh and Girod (2007) argue that his concept of experiences through learning is equally important. Dewey's writings on art and aesthetics give us insight into "how learning concepts can foster enriched experience – not just in the classroom, but in everyday life" (Pugh & Girod, 2007, p. 10).

Wong and his colleagues (Wong, Pugh, & The Deweyan Ideas Group at Michigan State University, 2001) gave an explanation about what Dewey meant by that kind of experience. According to them, for Dewey the central goal of education is "to help students to lead lives rich in worthwhile experiences" (p. 319). Dewey makes a distinction between ordinary experience and an experience. We all have ordinary experiences all the time, but there are distractions, interruptions, we are tired or lazy and the experience ends without developing. The experience on the other hand "runs its course to fulfilment ... A piece of work is finished in a way that is satisfactory; a problem receives its solution; a game is played through .... Such an experience is a whole and carries with it its own individualizing quality and self-sufficiency. It is an experience" (Dewey, 1958, p. 35). Just such a deep satisfaction photographer Barnbaum derived from each step of his process, from discovering something worth photographing to the final print. He wrote that anything that can produce an emotionally fulfilling experience, painting, literature, music and photography, is a form of art (2013, p. 283). Dewey (1958) connected art with this kind of experience and used the term "aesthetical experience" in his writings.

Deweyan scholar Jackson (1998. p. 124) explained: "The arts, above all, teach us something about what it means to undergo *an* experience..." Here, art is not linked to beauty and a subjective matter of taste, but represents idealized experience. It arises when a person interacts with an object and it merges to a whole from varied parts. "Like a drama, an experience is an event that has its own completeness ..." Pugh and Girod (2007, p.11) wrote. While Dewey himself never explicitly discussed the implications of aesthetics for education, Pugh and Girod (2007) developed an educational approach, based on Dewey's thoughts. They stated that students would see the world in a new transformed way, through making their own experiences, especially in outdoor conditions. Students can get a renewed interest, excitement and clarity in mathematical concepts. The term "creative", as it is used in this paper, is related to this new way of seeing mathematics content. We will focus on the expansion of perception on outdoor mathematics, increasing interest, meaning and clarity in mathematical thinking.

To perceive means both to view the world with fresh eyes and to be fully alive in *an* experience (Wong, 2001, p. 329). Photography might be a tool to accomplish both, *re-seeing* and to have *an* experience in the sense of Dewey. Deep perception, the *art of re-seeing*, must be taught (Barnbaum, 2010; 2014).

According to Barnbaum (2010, p. 58), the making of a photograph starts with visualisation. In depth looking and seeing, *re-seeing*, is the starting point of the process that leads to the product, the final print. This process can have a completeness and self-sufficiency in Dewey's sense (1934, p. 35).

"You and your eyes are not just wandering aimlessly..." Barnbaum continued. We will start to see things in areas we would have overlooked previously. We will analyse everything, learn more about our objects and provide deeper meaning to what we are seeing. "Seeing the unseen" was the leitmotif of Arcavi's writing about the role of visual representation in the learning of mathematics (Arcavi, 2003, p. 216). While visualisation for Barnbaum is the starting point of the photographer's process, Arcavi (p. 217) stated that visualisation is both the process and the product of creation, interpretation, use of and reflection upon pictures. He analysed various roles of visualisation in mathematics education with the goal of developing previously unknown ideas and advancing understanding in mathematical education. Visualisation becomes a tool for learning mathematics.

4 Methodology

Firstly, we will first describe the principles and design of the teaching activity in detail. In the next section we will present the survey and thirdly the gaze-tracking methodology. Finally, we reflect on the ethical issues encountered in this study.

4.1 Particicants

The participants in this study were fifty in-service teacher students at their first two-day meeting on a course for further education at Volda University Collage. They had varied backgrounds: some of the students were working as teachers; some had been teachers in mathematics for a long time, without enough formal education. Others had a teacher education, but were not practising right now. The course brings together elementary teachers (1–7 grade) and middle school teachers (5–10 grade). Both groups were roughly equal in size, 26 in 1–7 group and 24 in the 5–10 group.

In the elementary teacher group we chose two students to wear eye-tracking glasses (Figure 1) and microphones during three short walks outside school (one walk before, one during, and one after the photography activity) and during the group discussion. In addition, we made video recordings of the group activity and whole class activity. After the activity, we had stimulated recall interviews with these two students to obtain more information about their perception during the time they were wearing the glasses.

Figure 1. Gaze-tracking gear.

4.2 Procedure

The structure of our teaching activity is partly motivated by Pugh and Girod (2007) and is designed to let the students observe mathematics out-of-school-in a deep way with the goal of increased passion, interest, and understanding for their subject. We wished to give them the opportunity to make their own transformative, aesthetical experience.

We ran the same five-hour teaching activity in two different classrooms, with different teachers. The first author was teaching the elementary teacher group with the second author also present. Both groups answered the pre- and post-survey. The results from the first lesson of course design had indicated that the elementary teacher group had found the activity more inspiring. Therefore, we chose this group for deeper research.

After they finished the pre-survey, they were given the task to go out, “find mathematics” and take ten pictures with their mobile phone. To find objects of mathematical interest they had to observe in a deeper way than in everyday live (Barnbaum, 2010, Munakata, 2012).

After 15 minutes, when they were back, they were divided into randomly assigned groups of four. Firstly, they did some individual reflections on their 10 pictures, and chose one for further work. They were asked to write down the reason for taking this picture and to analyse the mathematics they connect to it. They continued with group discussions, where they shared their chosen picture, described it and reflected about the related mathematical ideas. They were also asked to discuss the possible use and value of this photography activity for mathematics education. Each group chose a picture to present to the whole class. In the group presentation the students were again asked to tell about the reason and the mathematics. After a short presentation, the whole class discussed and added further thoughts and ideas.

The post survey for the whole group had the same questions as the pre-survey and in addition some qualitative questions to extract deeper elaborations about the photography activity and work with the images.

4.3 Research Design

4.3.1 Survey (quantitative and qualitative)

Both groups did a quantitative survey before and after the activity. Moreover, the post-survey included two open questions. With the survey, we wanted to examine participants' thoughts about mathematics teaching and mathematics as a subject, especially their thoughts about outdoor/ practical mathematics, creativity and the role of perception in mathematics teaching. The survey items were selected from View of Mathematics –questionnaire (Roesken, Hannula, & Pehkonen, 2011) and some new items were designed to capture the specific features of the activity. The survey was designed with five Likert type items. It was anonymous, except for the two voluntary students who wore the gaze-tracking glasses.

4.3.2 Gaze-tracking, audio, video and interview

Gaze-tracking technology allows us to assess the visual attention of the participants. So far, the majority of gaze-tracking studies have been performed in laboratories. The MathTrack -project (Hannula, 2016, Hannula & Williams, 2016) is one of the first full scale research projects to use several mobile gaze-trackers in a classrooms.

The mobile gaze-tracking glasses and algorithms used in this study were developed at the Finnish Institute of Occupational Health and released as open source (Toivanen, Lukander, & Puolamäki, 2017). The device has been used in Hannula's studies, proving the promise of the technology in giving a deeper insight into students' visual attention as compared to the conventional video recordings (Hannula, 2016; Hannula & Williams, 2016).

The most typical eye movements are fixations and saccades (Land, 2011). We are interested in conscious and unconscious saccades. In a natural scene exploration, these can occur up to five times per second. When changing the attentional point, the eyes (and head) are moving towards it, not only in one but several saccades, many of them being unconscious.

Two voluntary students wore the gaze- tracking glasses (Figure 2), connected to a laptop carried in a backpack. The glasses contain three cameras; two pointing towards the eyes and the third one recording users scene. The software computes the gaze point (Figure 3) in the scene camera, using the eye camera data. In order to obtain good quality eye data, the students should have normal vision (no glasses/contact lenses or strabismus). Moreover, they could not use mascara.

Figure 2. The gaze tracking glasses used in the study

Figure 3. Estimated gaze point

Outdoor lighting conditions, especially direct sunlight, poses some challenges in the gaze tracking; pupil size decreases, extra reflections occur, the eye camera image may totally saturate, and the participants squint the eyes, all of which contribute to a deterioration the eye data. Hence, to avoid direct sunlight, we chose a shady path and the participants wore caps.

As the gaze-device does not record audio, the students wore microphones during the gaze-tracking. On the walk during the photography activity the two students were instructed to go together and talk to each other. We wished to obtain some data of their communication.

We did video recordings of the group activity where the two voluntary students joined. The communication about their pictures could give interesting additional data. For the same reason we did a video recording of the whole class activity. There are many disturbing acoustical elements in a classroom during a group activity with several groups. Therefore, we decided to combine the video with audio recordings.

Pilot studies (Hannula, 2016) showed that an interview, together with the gaze tracking video as stimulus, is needed to do adequate analyses. After the third walk, we did a recall interview in two parts with each of the two students. In the first part, they did not see the gaze video. We wanted to know which kind of objects they remembered and whether they saw different objects after the photography activity and why they thought they saw something different. Secondly, we did a stimulated recall interview, showing the video from the gaze-tracking and asking the same questions. We did the interview in two parts to find out whether a visual stimulus will help them to remember what they saw. We took notes of the interview. After the analysis of the gaze-tracking videos, the teacher had follow-up interviews with the students.

4.3.3 Notes and photographs from all students

All students sent electronically the one photograph they had chosen for discussion to the teacher (the first author). They also wrote notes about the reason for taking their picture and the mathematics behind it. These responses varied in length from two sentences to half a page.

4.4 Methods for data-analysis

4.4.1 Quantitative analyse of the survey with SPSS

We formed theoretically based sum variables of survey items, but the reliability of the scales proved to be unsatisfactory, especially for the pre-survey. We assume that the low reliabilities for the pre-survey might be partly due to the students not perceiving the meaning of some of the items before the photography activity. After the activity, however, they seemed to have changed their perspective on teaching with photography. Because of the low reliabilities of the planned sum variables, we decided to analyse the data item by item.

We used reliability analysis to examine whether we can construct sum variables based on theoretical ideas regarding, for example, outdoor learning and aesthetics. When comparing the changes between pre- and post-survey, we used paired samples t-tests.

4.4.2 Qualitative analysis of the survey, together with notes and pictures

The analysis of the open-ended questions in the survey started by making categories, related to our research focus: Outdoor/practical/everyday live, creative/ new ideas, visual attention, use of photography and mathematical concept, increased interest for mathematics. We then connected appropriate answers to every question of the quantitative analysis. To get more information about the possibilities for usage of this activity in mathematics classroom we also sorted the answers by items that appear in the Norwegian curriculum, for example algebra, geometry, statistics etc.

4.4.3 Analysis of gaze-tracking video with the program ELAN

Because of technical problems, we only had the video from Kari from the first and second walk and the video from Ola from the third walk. We looked through both videos several times and then decided to analyse Ola's video in detail. We named the objects and the duration of each gaze. In addition, we marked whether the objects were photographed by him or his partner, or discussed in the classroom work. We did not mark objects like the path he walked on. When he came to the stairs we could not be sure what kind of object it was for him. Asking him after the analysis, he said that the stairs he walked on were not an object of mathematical interest. We excluded the gazes on stairs for the time he was walking on them.

4.4.4 Ethical reflections

At the start of this project, we informed the students about the project and every student in the elementary teacher group signed an informed consent form for the use of data that might identify a person. Students had the option to change groups. Students who did not want to appear in a video were identified so that we could place them away from cameras and remove them in case they accidentally appear on video. The middle school teacher group was informed about the study, but no informed consent forms were used, as they only filled in the survey.

The first author was also a teacher. To avoid coercion the survey was returned anonymously.

5 Findings

5.1 Effects of the activity on student views

A paired-samples t-test was conducted to compare items focusing specifically on outdoor learning (1), creativity (2), visual experiences (3), and photography (4 and 5) in the pre- and post-survey. In the scores for items on outdoor learning, creativity, or visual experiences, there was no significant difference. However, there was a significant difference in the scores for two items on photography indicating a more positive attitude towards using photography in mathematics teaching (Table 1).

Table 1. Paired-samples t-test.

		pre		**post**		**Both**		
Item	N	Mean	SD	Mean	SD	Pairwise t-test	df	sig
1. As often as possible, the teacher should deal with tasks in which pupils make their own practical experience outside the classroom.	47	3.96	.75	4.09	0.88	-1.182	46	.243
2. In mathematics, one has to be creative to come up with new ideas.	47	3.81	0.92	4.04	0.88	-1.756	46	0.086
3. Teachers should frequently use didactical methods that include visual experiences.	49	4.29	0.65	4.27	0.73	0.227	48	0.821
4. Students' perception of mathematics in everyday contexts will increase through doing photography.	47	3.43	0.80	4.02	0.87	-4.027	46	0.000
5. Students can learn mathematical concepts by analysing pictures with mathematical objects.	49	3.82	0.73	4.45	0.71	-5.310	48	0.000

Based on Table 1 we will present the results of item 4 and 5 in detail.

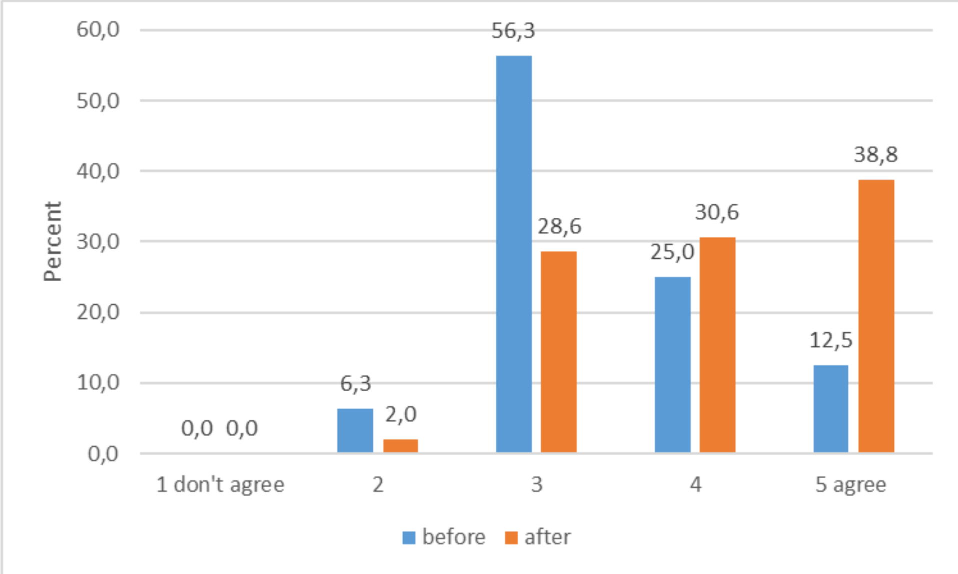

Figure 4. Responses to Item 4: Students' perception of mathematics in everyday contexts will increase through doing photography

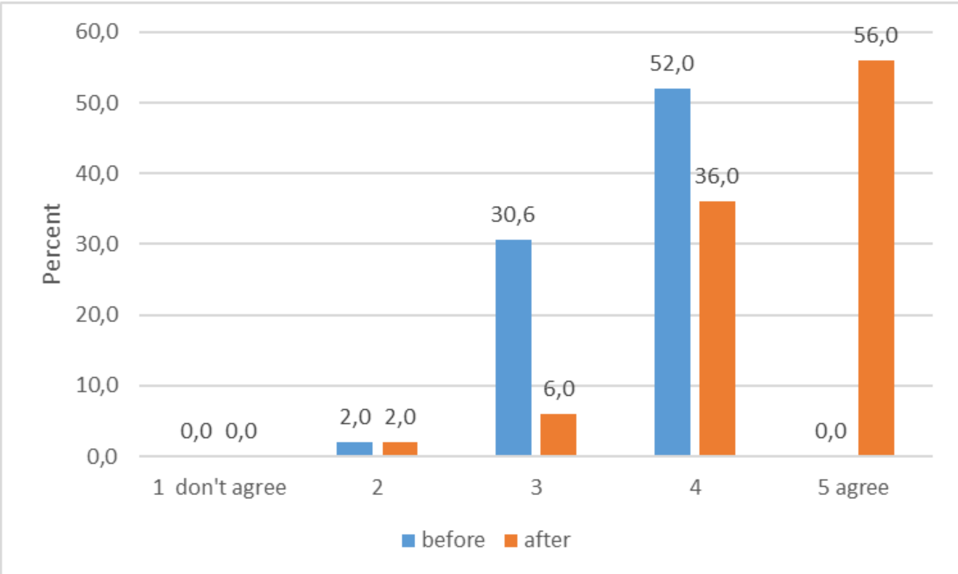

Figure 5. Responses to Item 5: Students can learn mathematical concepts by analysing pictures with mathematical objects.

The results of both specific photography questions (Figure 4 and 5) show an increase in positive answers after the activity. In Figure 4, they answered mostly in mid-scale before the activity. The reason can be that some students were not used to photographing and analysing pictures. They had no concrete idea before they had this experience. Afterwards, more students "fully agreed" that doing photography will increase students' perception of mathematics in everyday contexts, while even more students agreed that analysing pictures helps students to learn mathematical concepts.

The question is which mathematical concepts students can learn. Our participants gave possible applications to mathematics education (see the examples in Table 2) and emphasised that they could design tasks at all different levels.

Table 2. Examples - Photographs and mathematical concepts

	• Symmetry • Geometry • Perspective • Arithmetic • Interdisciplinary options with physics: Speed/ acceleration/ time
	• Symmetry/ reflection • Geometry: Perceiving the shape of the leaf, construction • Number-theory • Arithmetic – designing wordtasks • Fibonacci number/ golden ratio • Interdisciplinary options with science/ art and craft.
	• Pattern • Symmetry • Counting and arithmetics • Geometric shapes and calculation of areal and volume • Measurement • Economy • Designing wordtasks

Figure 6. Ola presented his picture to the whole class and sketched the lines of a football pitch.

Ola	We chose my picture of a dirt pitch … this could be a nice task, if one could get a spraybox from the caretaker and paint the lines of the pitch. We had to paint a rectangle … many terms … and then you have to halve it [drawing], a new term. Then you have to make a circle [drawing] with a certain radius and diameter. You have to draw another rectangle [drawing on the left-hand side] and here too [drawing on the right-hand side]. We will measure that in metres, maybe in centimetres. And here are these half moons. This could be an extra challenge, however, I am not quite sure about how to do this. [pause: 5 seconds] And we have this one here, five metres ... [drawing two small rectangles in the goals]. And maybe these small penalty spots there, which are eleven metres from the goal. You can calculate the area, the circumference and teach about angles… yes. … these are some terms…
Teacher	Yes, that is right. The image can be a starting-point to learn …
Ola	Yes, it is a very good practical task, I think, to involve the students in.
Teacher	Because they are interested in football.
Ola	Yes, absolutely.
Teacher	Are there some more ideas from the group?
Birte	… volume … how much gravel do we need … just bought gravel that was expensive … how much we have to buy. This could be suitable in the elementary school.
Helga	Do you think of calculating the price?
Birte	Yes
Teacher	Is it possible to adjust it for a higher level?
Birte	Yes, for the students who need an extra challenge.
Solveig	Another task could be how many footballers are in a team. How many are they together at the field.

Ola	Yes
Solveig	Two are sick [everybody is laughing]
Trude	… multiplication as well …
Ola	yes
Trude	See, here is a line … and here is a piece of a line … the golden ratio.
Teacher	Can you find the golden ratio here?
Trude	I don't know.
Teacher	We have to find out.
Trude	We can calculate that … and this is a mathematical task as well.
Teacher	yes
…	[omitted a few minutes of irrelevant discussion]
Sonja	There are so many lines which we can draw. And we can work with that and explore … yes…
Ola	And there is a lot, for those who are interested in statistics. How far do they run during a match, inside this rectangle there … And one can look at averages, kilometres, miles, for example.
Karl	Calculation of percentages … the number of passes, analyse matches and so on.
Trine	Statistics … goals scored. Who has the ball most.

In the beginning Ola focuses mostly on geometry (2 – 14) and measuring (7). Later other students had new ideas involving arithmetic (14, 28, 29, 31, 32), statistics (43 – 48), and economy (22-24). A picture from the outdoor world was the starting point for a rich discussion about applications in mathematical education.

In their written notes and during the presentations students mentioned several other topics that are important in the Norwegian mathematics curriculum, including algebra, probability, combinatorics, and functions.

5.2 Results from the gaze-tracking videos, supplemented with the recall interview

Because of the much stronger light in the outdoor conditions, the pupils of the students' eyes were small. The parametres had to be adjusted so that the eye pupils would be recognized.

In the video of Kari from the first walk, we observed that she mostly looked at the path and fixated on several objects, like houses, cars, people and so on, only for a very short time. In the recall interview, she said that she mostly paid attention to the path and the glasses, in addition to other people who could see her. She could not remember that she fixated on any special object. Nevertheless, we found that she had been looking at several objects that she photographed afterwards. It is interesting to notice that she did not remember these gazes in the interview.

We analysed Ola's video for the third walk (from exiting the building until reentering the building) in detail with ELAN and found some interesting results.

Table 3. Objects discussed/photographed or not

	Occurrences	**average duration (s)**
Discussed/photographed	197	0.63
Not discusssed/not photographed	33	0.41

He focused more than five times as much on objects which were discussed or photographed.

Table 4. Occurrences and average duration of discussed/photographed objects

Discussed/ taken picture of			**Not discussed/ taken picture of**		
Object	Occurrences	Average duration (s)	Object	Occurrences	Average duration (s)
Car	52	0.48	Fence	11	0.42
House	49	0.85	Stairs	3	0.63
Lamppost/ flagpole	24	0.29	Motorcycle	5	0.36
Tree	22	0.79	Barrier	3	0.47
Window	11	1.43	Cycle rack	3	0.30
Dirt pitch	10	0.51	Machine	2	0.98
Sign	10	0.35	Leaf	2	0.31
Container	7	0.32	Log	1	0.38
Cycle	5	0.73	Tube	1	0.37
Playground	4	0.60	Student	1	0.31
Gully cover	3	0.35	Kajack	1	0.23
Total	197	0.63		33	0.41

The occurrence of cars and houses is highest (Table 4). In the discussion in the classroom, they had discussed images of car numbers, car rims, cars as objects for counting and sorting. In addition, houses were discussed in different ways.

The rate for photographed or discussed objects was significantly higher than for the other objects (Table 3). However, there was one object, the fences, that attracted his attention quite often (Table 4). Asked about that, he said that he had not been aware of gazing at fences.

In the statistical analysis there was no significant difference in average gaze duration for the two groups of objects (Table 3). When we study details, he had longer attention on windows, a machine, houses and trees than for example on lampposts or flagstaff and cars (Table 4). He paid attention to cars and lampposts quite often, but not for a long time. The gaze on windows had a long average duration. He told us that they were quite interesting as mathematical objects.

This means that more often or longer visual fixation can be a sign of greater interest. However, the gaze-tracking video alone does not give explanations, so it was important to have the recall interview afterwards.

Additional observations: In the before-walk both did not notice much. Without seeing the gaze-video they could not remember a lot from the photography-walk. Seeing a stimulus video helped them to remember the objects that they had looked at and to explain their thoughts.

When they walked together, we expected them to talk about what they found and thought. Alas, they hardly ever did so. The two students worked in a quite different ways although both were very positive about the activity.

6 Discussion

The aim of our study was to explore the effect of photography-based teaching in outdoor conditions and our findings indicate that photography can be an appropriate tool in mathematics education. It seems that students' perception had shifted more towards mathematical objects after the intervention (Figure 4). Through their own experience they seem to have gained a renewed interest and excitement in mathematical concepts (Pugh and Girod, 2007). Everyday objects became mathematical objects through the experience of photography (Munakata and Vaidya, 2011). The students reflected upon the photographs and communicated new and creative teaching ideas. The results indicate that visualisation, or the art of re-seeing (Arcavi, 2003; Barnbaum, 2010; 2014), can be taught. Arcavi stated that visualisation could be a strong tool for learning mathematics. However, the mathematics content in our study was rather basic (Table 2). It seems that mathematizing was difficult for the students and they were not able to see more complex mathematics (e.g. fractals) in the surroundings. In a future study, we plan to have a warm-up activity for the students to attune them better for observing more advanced mathematics.

Barnbaum stated (2010, p. 58) that what we really see depends on our background. If we have more knowledge, training, and experience, we will see deeper. In our study, the students seemed to see and photograph objects which they were aware of from the beginning (for example cars and windows). On the other hand they photographed objects that they gazed at, but were not aware of (for example Kari saw houses and Ola fences). “Seeing without seeing” had an impact on their choices too. This finding might give an implication for education, both in general and mathematics: What children see and experience, also unconsciously (for example all kinds of media, toys, and environment), can become important for their future choices.

During the first walk with the gaze-tracking glasses, the students looked at objects only for a short time and in the later interview they did not remember what they had been looking at. The importance of visual information (video record) for the process of remembering was obvious. The data from the third walk, however, indicated a higher number of occurrences and longer gazes for objects previously photographed or discussed. To take pictures seemed to have an impact on the duration and occurrence of fixations of our gaze-tracking student. However, we do not know if he focused on mathematics, when he, for example, observed the cars 52 times.

In Barnbaums’s terms, the progress might be seen as a move from “seeing without seeing” to “re-seeing”. In Dewey’s terms, we can understand it as the start to make *an* experience. To make the experience more complete and fulfilling a further study has to cover the whole process, from re-seeing to mathematizing.

The results from the survey show that most students made vital experiences in the sense of Dewey (Pugh and Girod, 2007, p. 16), from the process (to see and photograph) to the product (the images, analysis, and discussions). Boaler (2016, p. 3) claims that visual, open, and creative mathematical approaches can be appropriate to suit most students and at any level. Our findings show that they can be suitable for teacher education as well. We agree with Arcavi (2003, p. 215) that visualisation should play an important role in learning and doing mathematics.

6.1 Reflections on the gaze-tracking methodology

In addition to evaluating the teaching unit, this study also explored the options and limitations of using mobile gaze-tracking in an outdoor-environment. Bright light and additional reflections were a potential problem. However, our data and analysis indicated that after adjusting computational parameters for smaller pupil size, gaze data in outdoor conditions is of good quality. We were unfortunate with technical problems unrelated to outdoor conditions and lost much of the data. In future studies it would be good to have more subjects to get data that are more complete. This will improve the options to compare the variations between the individuals in a controlled pre- and post-intervention comparison. However, the coding of the data is very time consuming and gives a limitation for the number of subjects. It will be important to find a more efficient and automatically coding system. That would help to analyse data from more individuals.

The gaze-tracking devices were influencing the student experience and behaviour to a minor extent. When outdoors, the students wearing the gaze trackers were aware of increased attention from other people. They also felt their visual field limited, for example when walking stairs. Taken together, it is seems plausible that wearing the gaze trackers influenced their visual attention to some extent. Moreover, as the teaching activity lasted for five hours, one student felt the goggles to be uncomfortable. Consequently, we allowed the students to take the device off after two hours and only wear it again for the third walk.

We are aware that gaze direction is not the same thing as target of attention. In addition to collecting gaze data, we asked the students to talk with each other (second walk), or to think aloud (third walk) when walking outdoors. Despite the instruction, they did not talk as much as we had expected. It is important in future studies to design better instructions for participants so that they would generate more verbal data. The interviews, both after the recording and after the analysis, were necessary to avoid wrong interpretation of the gaze data. For this reason, we were able to interpret, for example, the long fixation on the stairs as fixation on the path to walk on and not as an interesting mathematical object.

Despite the technical problems and methodological limitations described above, the gaze data provided us with a novel insight into students' visual attention in a natural outdoor setting. Firstly, we were able to get information about such attentional events that were either below the level of consciousness or forgotten immediately after the event. Kari fixated for example cars and the house, but could not remember this. Later she photographed these earlier seen objects. These events would not be accessible in a stimulated recall interview without gaze data. These findings about conscious and unconscious visual attention might be important for future educational research and development.

Moreover, even when students were aware of their gazing and recalled it afterwards, our quantitative data is more accurate.

We had gaze trackers for only two students and even their data were incomplete. We have no way to tell if these two case students were illustrative of other students' gazing behaviour. Hence, this study can be considered a methodological pilot, which was – despite technical problems – able to confirm the feasibility of mobile gaze tracking as a research methodology for outdoor mathematics.

6.2 Developing the photography-based teaching activity and research further

The activity was successful in helping the students re-see familiar objects (Barnbaum, 2010, p. 58) with mathematical vision. The notes, answers from the survey and the video from the presentation show that there were many ideas for applications, both in different themes of mathematics education and in an interdisciplinary context. As the mathematical content was rather simple, the two different student groups should get different tasks in a future study. The 5-10 group needs the challenge for more advanced mathematics, as for example functions.

In table 4, we see the difference between fixations at discussed/not discussed or photographed objects. Further variations to study could be whether they or others photographed objects of visual interest.

Our results show that this activity seems to help students to see with "fresh eyes" (Wong, 2001, p. 329) and have a satisfactory learning experience in the Deweyan sense. To make the work even more complete and fulfilling, the process could be extended in a way, Munakata and Vaidya (2011) described. Their students designed a problem-solving task and the solution, based on a photograph, and presented their work in an exhibition. In a future project, students ought to go the whole way from the process to the product, from re-seeing, photographing, analysing, and reflecting about the photograph and mathematical content to designing a task and presenting their work.

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