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Teaching Science Outdoors: Supporting Pre-Service Teachers' Skill Development with the Help of Available Mobile Applications

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Abstract: Outdoor environments provide excellent teaching and learning experiences in science education. However, many teachers find outdoor teaching challenging. In this study, we investigated factors supporting skill development and learning among pre-service teacher during a blended science didactics course that includes mobile interaction in outdoor environments. Available WhatsApp mobile application was used as an interaction platform between the pre-service teachers' and the teacher educator. Based on the findings, the pre-service teachers learned easy ways of using outdoor environments with pupils. They also identified challenges that may arise in outdoor teaching and upskilled on how to overcome them. From the perspective of interaction, submitting learning tasks, especially visual observations, through mobile messaging and reviewing tasks of other students in the application were perceived as important. However, the most crucial benefit of mobile interaction was considered to be the teacher's real-time feedback.

Keywords: teaching outdoors; science education; pre-service teacher; mobile application; blended learning

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1. Introduction

This paper contributes to the development of blended teacher education practices by exploring an outdoor education model that combines face-to-face and online interaction with existing mobile communication modes during outdoor education. Outdoor teaching is considered to be an important opportunity for teaching different science topics in authentic environments. Whereas learning outdoors has different cognitive and affective benefits for students—e.g., [1,2], science teachers often find teaching in outdoor environments challenging and tend to avoid it [3,4]. In science teacher education, improving pre-service teachers' skills for outdoor teaching and fostering their relationship with nature are essential for developing their future competences and motivation for outdoor teaching [5].

The recent increase in distant and blended learning has further challenged the practice of outdoor teaching not only in science subjects. One reason for that might be because the physical presence of the teacher is often considered to be an essential in organizing and supervising learning activities outdoors [6,7]. However, some practices of distant learning and communication may also work well and take on a role in organizing outdoor learning activities—e.g., [8,9]. In teacher education, where blended teaching has remained particularly popular even after the COVID-19 pandemic [10], exploring the approaches to organizing outdoor learning through different distant and hybrid learning formats may provide valuable insights. Learning about outdoor teaching through hybrid models may not only increase pre-service teachers' general competences for teaching outdoors but also give them ideas for organizing outdoor teaching in diverse pedagogical ways. Yet, few

studies exist on how distant and blended learning practices and outdoor teaching could be combined in science teacher education.

In this study, we investigated how a blended teacher education model, which combines face-to-face and online teaching with mobile interaction, facilitates the development of competencies for outdoor teaching. An important aspect of the model is the use of existing mobile messaging applications during simultaneous or asynchronous field tasks for communicating instructions and sharing observations, answers and questions. Whereas similar messaging applications have been used and studied in different learning environments [9], there is limited research on how such practices can benefit outdoor teacher education. Such knowledge is crucial for developing teacher education practices that address both the unique challenges of outdoor teaching and the increasingly popular hybrid approaches in teacher education.

The two research questions of this study were as follows: (a) How do pre-service teachers perceive the significance of outdoor science teaching, and what challenges and benefits do they see in it for their future teaching careers? and (b) How do pre-service teachers perceive mobile communication during outdoor tasks as part of their learning experience within a blended teacher education model?

2. Outdoor Science Education

Outdoor education is an experiential learning process that takes place in the built and natural environments—e.g., [5,11,12]. This form of education extends beyond the traditional classroom setting, incorporating direct engagement with nature, which has been found to provide multiple benefits to human well-being—e.g., [1,2,13–17]—and learning—e.g., [18].

The theoretical foundations of outdoor education are rooted in several key educational theories and philosophies. John Dewey's experiential learning theory is central, emphasizing the importance of learning through experience and reflection [19]. Dewey argued that education should not be confined to abstract, theoretical instruction but should engage learners in practical, real-world situations that encourage active participation and critical thinking. This cyclical model of experiential learning was further developed in particular by David Kolb [20]. According to Kolb, in the cycle of experiential learning, experience and the subject to be studied progress in the following order: personal experience—reflective observation—abstract conceptualization—experimental active learning—experimental activity. This model illustrates how experience alone does not guarantee learning; instead, learning requires conscious processing, or reflection, and articulation, or conceptualization. This is also the case in outdoor education, where experiences and observations alternate with reflections and conceptualization, for example, in classroom teaching. Similarly, largely models developed for science instructions or inquiry-based learning can be adapted to suit outdoor settings—e.g., [21].

Blenkinsop et al. [22,23] further expand on these ideas, emphasizing the importance of integrating ecological thinking into educational practices. They argue that outdoor education can serve as a powerful tool for cultivating an ecological consciousness, fostering a deeper understanding of human–nature relationships, and promoting sustainable living. This ecological approach encourages learners to develop a meaningful connection to the environment, which is essential for addressing contemporary environmental challenges [22,24,25]. Consequently, a common view in academic discussion is that without a relationship with nature, it is challenging to understand how nature works, what role humans play in it, how to prevent environmental problems, and how to care for nature—e.g., [26]. These kinds of transversal competencies also support learning in science.

The development of a relationship with nature and observation in nature are traditionally seen as the tasks of biology teaching [27]. However, to motivate students to investigate phenomena and concepts that are meaningful to them, more physics and chemistry should also be taught outdoors [28,29]. In these subjects, learning through inquiry is particularly emphasized, while learning and practicing crucial observation skills are often neglected [30]. In outdoor environments, observation skills can be practiced in a student-centred and self-

directed manner, unlike in the classroom, which is typically teacher-led [31]. Making concrete and multisensory observations of the environment, such as the weather, potential hazards, sounds, smells, terrain, etc., can lead to a natural improvement of the observation skills—e.g., [32,33]. For all of the reasons mentioned above, we propose that outdoor education should form a crucial part of science teacher education—e.g., [34].

3. Mobile Communication and Outdoor Teaching

In the past years, a growing number of studies have investigated the transformation of teacher education practices into distance teaching and remote communication between teacher educators and pre-service teachers. Several digital pedagogy innovations have been made, and teachers' and students' digital competences have been shown to have developed throughout all levels of education [35]. However, signs of decreased engagement when studying and teaching as well as increased levels of stress have also been observed [35,36]. As the future teaching and teacher educational practices may well evolve towards hybrid models that include more remote teaching practices than before, research on engaging remote teaching and learning approaches as well as functional digital communication is all the more important.

Approaches to incorporate digital tools and digital communication in outdoor education range from using platforms to collect and share information [37] to placed-based outdoor mobile applications [38] and complete learning modules in online environments [39]. Studies have shown that using simple communication platforms as part of the learning setting can have benefits for the social atmosphere and learning outcomes by encouraging dialogue and sharing of knowledge [9,39–41]. Also, in teacher education, there is evidence of the potential benefits of various forms of mobile interaction for collaborative work between students and educators as well as facilitating the learning process—e.g., [42].

While mobile messaging between peers and with teachers can serve as an opportunity for argumentation [43] and the use of a WhatsApp group during field trips can increase learning outcomes [9], studies have shown that mobile messaging may also lead to a superficial epistemological quality of arguments and exhibitions of knowledge [44]. Few studies exist on the opportunities of mobile communication during field trips to increase pre-service teachers' competence in teaching and learning outdoors.

In particular, existing mobile interaction in outdoor learning settings might have potential in supporting pre-service teachers' development of competences in utilizing outdoor teaching settings. Teachers tend to consider outdoor learning activities to require the teacher to be present and to involve the use natural environments in ways that are primarily structured and teacher-led [7,45]. This may partly result from teachers' tendencies to fear losing control of students and to seek to avoid student risk during field activities [6,46]. Because of such norms, outdoor education may not transfer easily into remote teaching. Nonetheless, using the available modes of mobile interaction to communicate between teachers and students and among students offers a potential way of managing some of the challenges related to having a limited teacher presence in outdoor environments [8,9]. Whether such an approach could be used in teacher education to increase pre-service teachers' competence and readiness to use outdoor environments for teaching has been the topic of limited studies.

4. Blended Teacher Education and Teachers' Professional Development

Blended teacher training in the context of this article means adult education where pre-service teachers study alternately through face-to-face sessions on campus and independently online or otherwise [10]. The blended model in teacher education is continuously developing, but still one of its greatest challenges is facilitating the learning process [47], as well as supporting the professional development of pre-service teachers. In the case of outdoor education, the situation is even more challenging, as both the learning process and the learning environment might be unfamiliar for pre-service teachers while participating in a blended teacher education model.

The teaching profession is an interactional profession. Thus, in teacher education, particular consideration should be given to how teachers develop their interaction and methodological skills, even in distance learning. Clarke and Hollingsworth [48] developed a model of teacher professional development based on extensive empirical data. The model describes four interconnected components of professional development: (1) external factors, such as information sources and motivators, (2) experiences, such as professional experimentation and peer support, (3) significance, such as observable learning outcomes, and (4) personal influences, such as beliefs and attitudes or prior knowledge. These components are interconnected either through teacher reflection or the provided training content. Therefore, when an aspect of teacher education influences one component, changes also occur in the other components. In blended learning, especially in distance parts of learning, where pre-service teachers can easily fall into a passive recipient role, students find it challenging to understand how training content relates to their classroom practice [49].

Among the components of the professional development quadrant, the external factor component can most easily be influenced in teacher education. A teacher educator selects the sources of information that justify pedagogical choices. For example, instructions provided to pre-service teachers by teacher trainers can model science teaching both in face-to-face and distance learning. When students are guided to complete tasks outdoors, they can personally observe the related challenges and benefits [50]. At the same time, they gain experience of what kinds of tasks work and how they should be carried out outdoors versus in the classroom [4,51].

Enabling peer support and peer learning is also an important component of professional development and perhaps the most challenging to organize in a blended model of learning. Pre-service teachers must find discussion and communication sufficiently easy to experience the benefits thereof [50]. Such peer support, along with feedback from the teacher, may strengthen the pre-service teachers' ability to learn and teach outdoors [33]. Thus, personal experiences, the opportunity to examine one's attitudes, and the emergence of significance through long-term activity should be integrated into a teacher's professional development [48].

5. Materials and Methods

In the Finnish teacher education system, future elementary school teachers take courses that should provide them the skills to teach science topics for grades 1–6 [29]. In the University of Jyväskylä adult education program for elementary teachers, the environmental studies didactics course is worth 6 ECTS credits. The adult education program utilizes a blended learning approach, which includes distance learning via Zoom, face-to-face meetings on campus, and independent work. The Moodle platform is used and students are provided with iPads. Generally, the rhythm of distance and face-to-face sessions is 2–3 weeks of distance learning followed by 1 week of face-to-face meetings. During the face-to-face period, all scheduled teaching is conducted in person, with no distance learning taking place. In the academic year 2023–2024, when students participated in the blended learning environmental studies didactics course, it comprised 40 h of distance learning via Zoom, 8 h of face-to-face lessons, and 115 h of independent work. According to the Finnish core curriculum, the content of the environmental studies subject draws from five scientific disciplines: biology, geography, health education, physics, and chemistry [29]. Throughout the course, students delve deeper into the didactics of these disciplines and the teaching content for elementary school.

During the environmental studies course, students were given among others six weekly assignments that they completed outdoors in their local environment or practicum schools. These assignments were related to the different scientific disciplines. The students joined a WhatsApp group where they submitted their outdoor assignments. WhatsApp was chosen as the application is available for all, typically used for informal communication, and familiar to everyone. Similarly to other courses, students also used the Moodle platform, where all the assignments were additionally described. For example, students received the following task: "Take a picture of a phenomenon observed outdoors, give it a name,

explain how the phenomenon occurs, describe the interacting objects in the phenomenon, and identify the quantities that can be associated with the phenomenon" (Appendix A). Participation in the WhatsApp group, sharing assignments with others, and participating in the research were voluntary for the students. For instance, it was possible to submit assignments to a Moodle folder, where only the teacher educator could view and comment on them. However, all students wanted to participate in the WhatsApp group and openly submitted their assignments for everyone to see and comment on. Additionally, outdoor assignments were supported with theoretical background for outdoor education, as well with group discussions during Zoom sessions.

In total, 40 students participated in the teaching, and 39 participated in the research. At the final class session, students answered a survey containing four open-ended questions (1–4 thoughts on outdoor teaching as part of their own teaching, benefits of outdoor teaching, challenges of outdoor teaching, and the use of WhatsApp during the course) and 28 statements (5–6 relationship with nature and skills in outdoor teaching, 7–10 development of outdoor teaching skills during the course, 11–17 feedback and peer support/peer learning during the course, 18–32 attitudes and motivation during outdoor learning), which were answered on a 7-point Likert scale (where 1 represented the lowest possible rating and 7 the highest) (Appendix B). The items were based on the Intrinsic Motivation Inventory questionnaire [52,53]. The dimensions of interest, perceived competence, effort/importance, value/usefulness, and relatedness were chosen from the inventory, and 2 to 4 items of each dimension were used in the survey. The translation of the items to Finnish was conducted by two researchers, and the survey had been used and checked by a native English speaker earlier [54]. Although the purpose was not to study the students' motivation, the chosen statements allowed students to reflect on their actions and learning during the teaching program. The survey was piloted first in another study and further developed in the current study [55].

From an ethical perspective, the research can be classified as low risk because no personal or background information was collected from the participants. Thus, the purpose of the research was to gain new knowledge generally at the phenomenon level.

A mixed-methods approach [56] was used to study students' perceptions of their learning and the use of mobile interaction. All meaningful expressions (n = 325) from the students' open-ended responses were extracted and categorized using data-driven classification (n = 43, from 30 classes connected with outdoor teaching and 13 with WhatsApp). The categorized data were next converted into a numerical form to enable visualization using network analysis tools. The network analysis was conducted using Gephi (Version 0.10.1) software [57]. In addition to graphical representation, Gephi allows for the examination of co-occurrences of information units. Co-occurrence can be observed through the links between nodes, including their length and strength. The shorter and stronger the links between two nodes, the more frequently the information contained within those nodes appeared in the students' responses. The visualization employed the ForceAtlas2 algorithm [58]. ForceAtlas2 is a practical, continuous linear algorithm with clear visuality and readability, and it is also suitable for small networks (starting from as few as five nodes). In the projection generated by the algorithm, each node (information unit) is positioned relative to others based on the forces of attraction and repulsion between nodes, forming links (edges). In this study each node represents a specific category formed from data and with number value from 1 to 43 (see categories in Appendix C). The links between nodes (sources and targets) are formed based on the meaningful expressions found in individuals' responses within each class. A meaningful expression is assigned a numerical value according to the category to which it belongs. In the algorithm's projection, nodes appear as spheres and the links between them as lines. In the analysis, meaningful expressions served as edges, and classes categorized as nodes.

To make appropriate comparisons, statistical tests suitable for small datasets were adapted (e.g., independent samples Mann-Whitney U-Test and χ^2 Test, more specifically described in results). The Jamovi (Version 2.5.6) [59] program was used for the statistical analysis of numerical data obtained from the survey. Particular attention was paid to

analyzing how students assessed their own relationship with nature and their outdoor teaching skills after the course.

6. Results

6.1. Teaching Outdoors: Benefits and Challenges (Q1)

In this section, we examine the open-ended questions (items 1–3) and some statements from the Likert-scale items (statements 5–6 and 18–32). The average scores were 5.82 for nature relation (statement 5) (SD 0.970) and 4.95 for outdoor learning skills (statement 6) (SD 0.887), respectively. Based on this, it can be concluded that the current group of pre-service teachers enjoy to at least some extent spending time in nature and they may be willing to take their students outdoors during lessons. Next, the association between the relationship with nature and outdoor teaching skills was examined through Spearman's correlation coefficient. This revealed a fairly strong positive correlation ($r = 0.613$, $p < 0.001$), indicating that the higher the students rated their relationship with nature, the higher they also rated their outdoor teaching skills.

A mean variable was formed from statements 18–32, which addressed attitudes and motivation during outdoor learning and had a strong internal reliability (McDonald's $\omega = 0.883$). This variable was named "nature experience". The Shapiro–Wilk test showed that nature experience was not normally distributed ($p < 0.001$), indicating that nonparametric analyses were suitable. Nature experience was examined in relation to the assessment of one's relationship with nature and one's outdoor teaching skills applying Spearman correlation. This revealed that nature experience had a moderate positive correlation with both the nature relationship ($r = 0.572$, $p < 0.001$) and outdoor learning skills ($r = 0.552$, $p < 0.001$). In other words, students who enjoy teaching outside also have a better relationship with nature and possess better outdoor teaching skills.

In the open-ended responses, students were asked to briefly write about their thoughts on outdoor teaching as part of their own teaching, the benefits of outdoor teaching, and the challenges of outdoor teaching. The results of these responses are visualized through network analysis in Figure 1, and the data from the figure are further explained in Appendix C, Table A1.

In summary, it can be said that students mentioned more benefits than challenges related to outdoor teaching. Many planned to use outdoor teaching as part of their own teaching.

> *I aim to teach outdoors as much as possible*. (Student 6)
>
> *In my opinion, outdoor teaching is an important part of modern education. It is a meaningful way to teach and learn*. (Student 10)
>
> *I hope that outdoor teaching will be a central part of my teaching. It brings phenomena to a concrete level and allows for environmental observation*. (Student 15)

They felt that they received tips during the course for planning their own lessons and understood the importance of persistence and practice. They found teaching outdoors easy because nature is close in Finland, being outdoors is motivating, teaching is student-centred, and it is tangible. Many students emphasized the importance of outdoor teaching and noted that the core curriculum requires teaching outdoors.

> *When nature is all around, you can concretely demonstrate natural phenomena*. (Student 1)
>
> *In nature, genuine wonder, observation, and natural inquiry are emphasized*. (Student 7)
>
> *When teaching outdoors, all the senses work to benefit learning*. (Student 12)
>
> *I think outdoor teaching is a key part of teaching environmental studies and also in developing a connection to nature*. (Student 31)

The most significant challenge mentioned was managing the pupil group outdoors. Planning was also seen as challenging, and some doubted their subject content knowledge.

> *Group management skills are emphasized because students' attention can be drawn to things outside the subject*. (Student 10)

The task instructions must be clear and specific when going outdoors. Otherwise, managing the student group can be difficult. (Student 16)

Probably, how to regularly take a large group outdoors, for example. (Student 38)

Species identification is a challenge. (Student 1)

Figure 1 can be further used to examine the co-occurrence of different nodes, i.e., which aspects students associated in their responses. Figure 2 shows a cluster of co-occurrences where the node "going to use" is linked to other nodes.

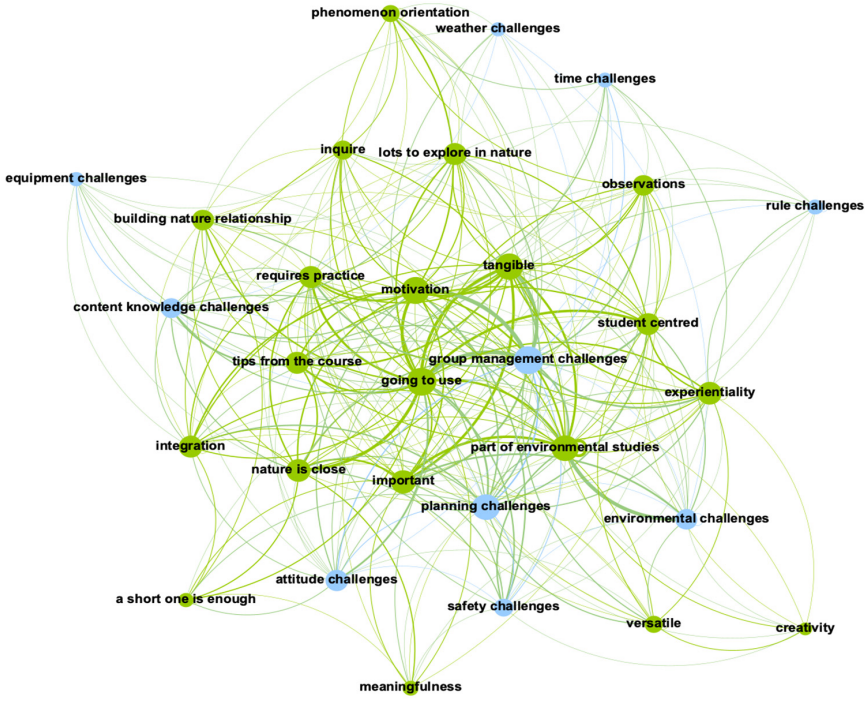

Figure 1. Network projection of the descriptions of the benefits (green nodes) and challenges (blue nodes) of outdoor teaching mentioned in the students' open-ended responses. The positioning of nodes in the center of the projection indicates their centrality in the data (i.e., mentioned by multiple students).

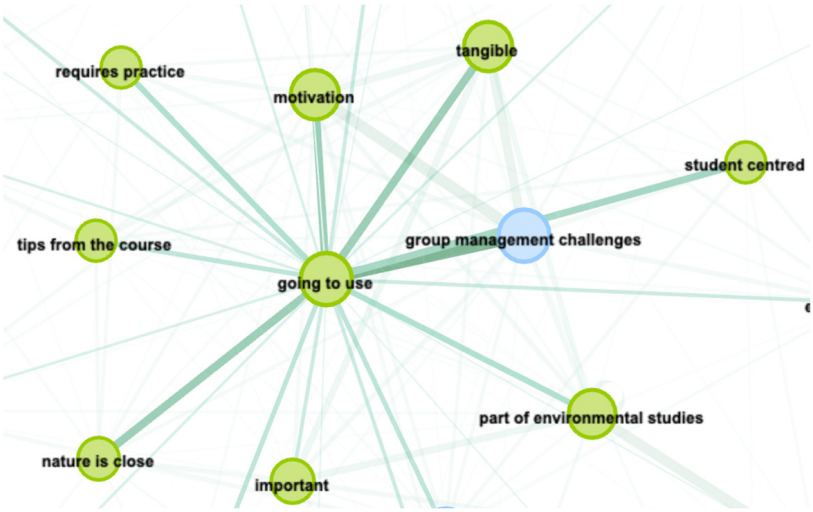

Figure 2. The connection of the node "going to use" to other nodes. The length (the shorter the line, the stronger the connection) and strength of the edge between two nodes indicate how frequently the information contained in the nodes co-occurs in students' responses.

Figure 3 examines the co-occurrence of the node "motivation" with other nodes. Here, a so-called negative connection can be observed, meaning that challenges related to group management may strongly affect the motivation to teach outdoors.

Figure 3. The co-occurrence of the node "motivation" to other nodes.

6.2. Using WhatsApp During the Outdoor Tasks (Q2)

In this section, we examine the analysis results of one open-ended question (item 4) and several Likert-scale statements (items 11–17; however, items 11–12 were summed during the analysis as well as items 14–15, in order to distinguish between verbal and visual communication more clearly). In the Likert-scale statements, students were asked to assess the usefulness of various WhatsApp functions during the course. The results of these responses are compiled in Figure 4.

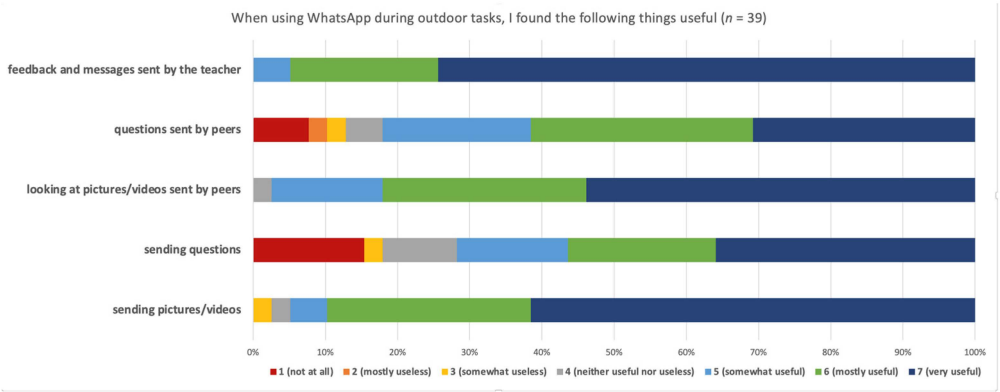

Figure 4. Summary of students' responses regarding the usefulness of WhatsApp functions.

This figure highlights that almost all functions were perceived as useful. Interaction with the teacher was rated highly useful by all the students. The exchange of visual information was also emphasized, with both sending and viewing images/videos from peers being considered mostly useful, while students rated their own activity as slightly more useful. In contrast, verbal communication, including sending and reading questions, received the lowest ratings.

The analysis of the open-ended responses, where students were asked to briefly evaluate the use of WhatsApp during the course, is presented in Figure 5 and Appendix C, Table A2.

Based on Figure 5, it can be said that WhatsApp was definitely perceived as easy to use. Although this study cannot compare this result with another group, the students compared their own experiences with other courses running at the same time, where mobile interaction was not utilized.

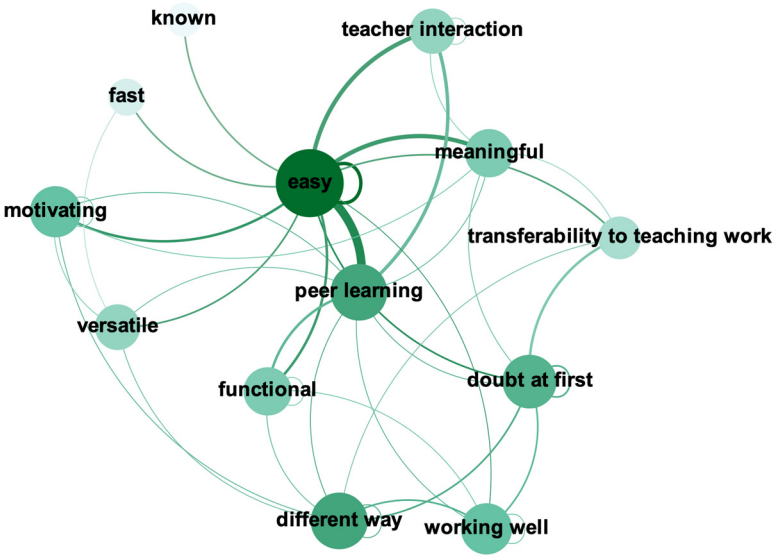

Figure 5. Projection of students' thoughts on the use of WhatsApp in open-ended responses, where the central positioning, size, and strength of the nodes indicate their centrality in the data (mentioned by multiple students).

Peer learning was also mentioned in almost every student's response. Although WhatsApp was chosen as the application to be used in the course, many students expressed skepticism about the app's functionality in their open-ended responses. After the course, they recognized that they were wrong, as the app worked well, was easy to use, and offered a different way of completing tasks.

> *At first, I was skeptical. After the experience, I really liked it. I plan to use it with my students*. (Student 35)
>
> *Initially, the idea of using WhatsApp seemed difficult, but after the first task, my opinion changed*. (Student 12)
>
> *It was surprisingly enjoyable! At first, I was doubtful, but I found it to be incredibly useful and learned a lot from it*. (Student 17)
>
> *At first, the working method felt strange and overwhelming because everyone's responses were visible. But in the end, the tasks were such that reviewing the answers was quick, and it was interesting to see how others interpreted the instructions. If tasks are to be shared among students, this method works much better than the Moodle discussion board, where tasks are linked because in Moodle, you have to open each link separately, which takes a lot of time*. (Student 24)

In addition to the ease of use, communication with the teacher was also found to be easy, and the teacher's interaction supported peer learning (Figure 6).

Figure 6. The co-occurrence of the node "teacher interaction" with nodes "easy" and "peer learning".

It was also interesting and educational to look at others' feedback (pictures). The teacher's feedback gave me even more ideas. (Student 11)

Much more enjoyable than if the pictures had been sent through the computer. It was really nice to complete the tasks and follow the pictures others had produced. Additionally, it was helpful to read the feedback given on them. I learned a lot through this! (Student 22)

7. Discussion and Conclusions

In our research, we aimed to answer the following research questions: (a) How do pre-service teachers perceive the significance of outdoor science teaching, and what challenges and benefits do they see in it for their future teaching careers? and (b) How do pre-service teachers perceive mobile communication during outdoor tasks as part of their learning experience within a blended teacher education model?

Regarding the first question, it can be noted that there is little previous research on how systematic and continuous engagement in outdoor tasks affects students' teaching skills. According to our findings, the students reflected in many ways on the benefits and challenges of outdoor teaching, as well as on their own learning, and specifically related these reflections to their future teaching. This is particularly evident in their descriptions of challenges, which are placed within the context of the school environment, such as safety concerns or group management issues. Outdoor teaching is seen as a natural part of their future science teaching. The students in this study had the opportunity to engage in outdoor tasks systematically, allowing more time for the development of their outdoor teaching skills. Arikan [4] also emphasizes the importance of reflection in his research when teachers compare outdoor and indoor teaching tasks.

Traditionally, one of the challenges has been that outdoor teaching is time-consuming and requires extensive preparation [4]. However, based on our findings, it can be said that personal experiences with short outdoor tasks across different science topics broaden pre-service teachers' perspectives on student-centred activities. This, in turn, leads pre-service teachers' to highlight the motivational factor of outdoor learning. In this respect, our research findings are consistent with previous studies [30].

Although, in our study, the pre-service teachers utilized an existing application for mobile interaction, the application itself likely did not hold significant importance. It can be assumed that any familiar and easily accessible application could provide a meaningful learning experience just as well. In the context of elementary school, if similar mobile interaction is to be utilized with pupils, the availability of tools and age restrictions must be considered. Nonetheless, our study provides a wealth of useful new information regarding what factors can be seen as challenges and benefits outdoor learning offers.

Through the second research question, we aimed to further investigate the structures of blended education, particularly how mobile interaction supports the development of pre-service teachers' skills. Based on the results of this study, it is possible to enrich the blended teacher education model with structures that support the development of outdoor teaching skills. In addition, students' relationship with nature also seems to play an important role: the perception of their own connection with nature positively correlates with their perception of their outdoor teaching skills. This finding is supported by previous research, which suggests that pre-service teachers who consider the natural environment important are also more likely to engage in outdoor learning and teaching [33]. Thus, if teacher education supports either the development of students' relationship with nature or the enhancement of their outdoor teaching skills, it may potentially foster both areas.

The customization of tasks to the outdoor environment also plays an important role—see [4,33,50]. For example, tasks that highlight observations with the help of multiple senses provide pre-service teachers' with a proof of the value of taking their pupils outdoors. The significance lies not merely in replicating indoor tasks outdoors but in utilizing the outdoor environment itself. For instance, in our findings related to the usefulness of WhatsApp activities, sending and viewing photos and videos was found to be beneficial. In contrast, verbal communication, particularly related to conceptual learning, was not perceived as

equally important. When personal observations are shared and different ways of making observations are recognized, learning and understanding are deepened, which can also lead to more meaningful concept formation [30]. Thus, students realize that traditional outdoor learning, such as identifying plant and animal species, can be extended to the exploration of much more diverse scientific phenomena.

Another important aspect of this study is the facilitation of the pre-service teachers' learning process within the blended model. On the one hand, providing support to students' wellbeing is crucial, but on the other hand, supporting the development of teaching skills, such as digital skills, during their studies is also significant—see [35]. In other words, the teaching must be sufficiently comprehensive to support the professional development of teachers. With the students in this study, the WhatsApp application provided an external structure for social interaction—see [48]. In the WhatsApp group, assignments were submitted, and discussions related to the tasks took place. The teacher trainer was part of the group and provided feedback on all assignments. Communication with the teacher was perceived as highly important—cf., [60]; the teacher confirmed the accuracy of observations, corrected misunderstandings, offered additional ideas, or provided other elements to support students' learning. The most significant finding was that this interaction was perceived as easy. The value placed on ease of communication within the blended model has also been highlighted in other studies—e.g., [50].

In addition to reflecting on their own attitudes and learning, and receiving external support, peer learning also emerged as equally important in this study. In a blended model where students learn relatively independently and may even experience loneliness, enabling peer learning and social interaction is crucial—see [48]. In this regard, the WhatsApp application worked excellently. Still, it is important to note that students also participated in discussions in other environments, such as during Zoom sessions. Previous research related to the professional development of teachers also supports our findings on the importance of facilitating the learning process [48]. Mobile communication in our blended model proved to be effective, especially from the perspective of outdoor learning, as it effectively connected students to their own local environment, observations were made within it, and interactions were supported with the rest of the group.

Although the results of this study provide new perspectives on the development of the blended model in science teacher education, it is important to note that the sample size of this study was small. Furthermore, when using informal tools in a formal context, the personal nature of the tools must always be considered. Likewise, reliance on internet connectivity can pose a significant challenge in some situations. Functional solutions to these challenges have been identified in previous research [61], and these will be taken into account in our potential future research.

Additionally, the measures used in this study are based on students' opinions. This means that we cannot be certain about which practices will influence teachers' outdoor teaching in reality. This study also failed to investigate whether the students' outdoor teaching skills were already at a high level before the course. Nevertheless, based on the results, it can be assumed that if their skills were already strong, their understanding of the importance of outdoor teaching was further supported. According to the model of teachers' professional development [48], the quality of teaching is influenced not only by concrete didactic skills related to outdoor education but also by an understanding of how to support pupils' relationship with nature and their well-being.

In further research, a longitudinal study that follows students from teacher education into the first years of their teaching careers could provide more specific information about the solutions learned during teacher education.

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Appendix A

Weekly WhatsApp assignments to complete outdoors during the Environmental Studies course.

1. Please use the list and complete nine observation tasks (e.g., send a picture of something that smells good, is white-colored, or feels rough). Use all your senses while exploring nature.
2. Complete one sheet of the digital herbarium. Choose a plant you find in nearby nature.
3. Take a picture of a phenomenon observed outdoors, give it a name, explain how the phenomenon occurs, describe the interacting objects in the phenomenon, and identify the quantities associated with it.
4. Use the TrackIt observation tool to observe one environmental studies outdoor lesson during your internship. Pay special attention to student-centered and teacher-centered activities. Take a picture of the observation tool graph and send it with a brief discussion.
5. Take four pictures during your material walk (use the list of chemistry material walk tasks, e.g., find something painted, something made of wood, something rusty) and four pictures from the phenomenon walk (use the list of physics phenomenon walk tasks, e.g., take a picture where friction is useful, where movement is constant, or where movement is swinging).
6. Take a "placefie"—a picture of a place that is meaningful to you—and explain why you have chosen that place.

Appendix B

Outdoor education survey for elementary teacher students.
Open-ended questions:

1. What do you think about teaching outdoors as part of your future teaching?
2. What is the easiest part of teaching outdoors?
3. What is the most difficult part of teaching outdoors?
4. Please describe generally how you experienced using WhatsApp during the course.

Statements (seven-point Likert scale):

5. My relationship with nature. . .
6. My outdoor teaching skills. . .
7. During the course, I learned the justifications for outdoor teaching.
8. During the course, I learned to plan outdoor teaching.
9. During the course, I learned to implement outdoor teaching.
10. During the course, I gathered ideas about various interactive activities.
11. When using WhatsApp during outdoor tasks, I found sending pictures useful.
12. When using WhatsApp during outdoor tasks, I found sending videos useful.
13. When using WhatsApp during outdoor tasks, I found sending questions useful.
14. When using WhatsApp during outdoor tasks, I found pictures sent by others useful.
15. When using WhatsApp during outdoor tasks, I found videos sent by others useful.

16. When using WhatsApp during outdoor tasks, I found questions sent by others useful.
17. When using WhatsApp during outdoor tasks, I found feedback/messages sent by the teacher to others useful.
18. I often completed the outdoor tasks immediately.
19. I really enjoyed the outdoor activities.
20. I believe I was quite good at the outdoor activities.
21. I invested a lot of effort in outdoor activities.
22. I think the outdoor activities were beneficial to my teacher education.
23. I felt very distant from my group members during the outdoor learning.
24. I had fun outdoors.
25. It was important to me to do well in the outdoor activities.
26. After spending some time outdoors, I felt capable.
27. I think going outdoors was important because it helped me learn.
28. I was satisfied with the interaction with other course participants and the teacher.
29. I didn't focus on the outdoor tasks at all.
30. While outdoors, I thought about how much I enjoyed being outside.
31. I was quite skilled in outdoor activities.
32. I didn't try my best to succeed in the outdoor tasks.

Appendix C

Table A1. Characteristics of categories (nodes) formed from the students' expressions (benefits and challenges of outdoor teaching) in the projection.

Category (Node)	Betweenness Centrality [1]
going to use	22.723
group management challenges	16.452
planning challenges	14.203
motivation	11.422
environmental studies methodology	11.393
tangible	10.708
important	9.027
nature is close	7.240
experientiality	5.995
lots to explore in nature	5.978
requires practice	5.923
building nature relationship	4.810
environmental challenges	4.557
attitude challenges	4.538
student-centred	4.495
integration	4.398
inquire	4.168
observations	3.758
tips from the course	3.355
safety challenges	2.278
phenomenon orientation	1.975
content knowledge challenges	1.924
versatile	1.490
meaningfulness	0.948
time challenges	0.713
weather challenges	0.475
equipment challenges	0.382
a short one is enough	0.365
creativity	0.174
rule challenges	0.134

[1] The number is a ratio that expresses the number of shortest paths through the node to other nodes relative to the total number of connections in the entire network.

Table A2. Characteristics of categories (nodes) formed from the students' expressions (using WhatsApp) in the projection.

Category (Node)	Betweenness Centrality [1]
easy	25.917
peer learning	7.036
different way	4.083
teacher interaction	4.0
versatile	2.286
meaningful	2.0
doubt at first	1.452
motivating	0.869
transferability to teaching work	0.536
working well	0.536
functional	0.286
fast	0.1
known	0.1

[1] The number is a ratio that expresses the number of shortest paths through the node to other nodes relative to the total number of connections in the entire network.

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