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A qualitative investigation of psychological need-satisfying experiences of a mobile learning application: A Self-Determination Theory approach

Lucas M. Jeno [a,*,#], Kjetil Egelandsdal [b,#], John-Arvid Grytnes [c,$]

[a] Department of Education, University of Bergen, Norway
[b] The Centre for the Science of Learning and Technology (SLATE), University of Bergen, Norway
[c] Department of Biological Sciences, University of Bergen, Norway

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ABSTRACT

Much research on mobile learning is cross-sectional or lacks a theoretical basis for investigating the mechanisms of mobile learning and achievement. This may be a concern as well-formulated theoretical frameworks allow results to be interpreted and contextualized in a coherent and integrated fashion that could then be valuable when interpreting findings in educational contexts. The main aim of this study was to investigate biology students' experiences of using a mobile application for learning about species identification. We use Self-Determination Theory as a guiding framework to investigate students' experiences of need-satisfaction of autonomy, competence, and relatedness within a mobile application, and whether this influences students' learning processes. We conducted four focus groups with 26 biology students in higher education. Based on our thematic analysis, we find that students experienced the satisfaction of all three psychological needs while using the mobile application. Specifically, students' needs were satisfied by experiencing choice, feedback, mastery, cooperation, and discussion. These elements in turn were related to the process of identifying species. Contradictory to what we expected, students reported more learning from a traditional textbook, compared to the mobile application. Our results provide useful information for learning designers, which suggests that it is important to take need-satisfaction into consideration when designing technology. Our study offers new insight into the underlying need-satisfying experiences of mobile learning, and it provides an understanding of how the different elements of need-satisfaction contribute to different species identification processes.

1. Introduction

Mobile learning, "learning across multiple contexts, through social and content interactions, using personal electronic devices" ([1], p. 4), has been shown to be beneficial for student learning (e.g., [2]). There are several suggested reasons why mobile learning has positive impacts on students' learning. For instance, mobile learning: is not restricted to a formal location and can be accessed in multiple contexts [3,4], provides opportunities for collaboration and scaffolding [5], provides a form of learning that can be formal, self-directed, or spontaneous [1], complements and adds value to traditional teaching [6], increases motivation [7], and supports learning with technological tools that may enhance learning outcomes [8]. Many studies have been conducted to investigate the effectiveness of mobile learning on students' learning. For instance, in a recent systematic review on mobile learning in higher education, Crompton and Burke [9] and Sophonhiranrak [10] found that most studies on mobile learning report positive student outcomes. These findings seem to corroborate previous meta-analysis showing that mobile learning tools developed for learning have a positive effect on learning [2,11]. In contrast to these studies, however, Kates et al. [12] found in a meta-analysis that mobile phone usage had, on average, a negative effect on educational achievement, and this effect was more prevalent among higher education students than K-12 students. Despite this, Amez and Baert [13] argues that much of the research on achievement within mobile learning is based on cross-sectional data, which limits the possibility to infer causality or determine effects across time. Furthermore, they suggest that much of the research lacks theoretical frameworks explaining the underpinnings and mechanisms of

* Corresponding author.
E-mail address: Lucas.Jeno@uib.no (L.M. Jeno).
Postal address: Postbox 7807, 5020 Bergen, Norway.
$ Postal address: Postbox 7803, 5020 Bergen, Norway.

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mobile learning and achievement [13]. This may be a concern as well-formulated theoretical frameworks allow results to be interpreted and contextualized in a coherent and integrated fashion that could then be valuable when interpreting findings in educational contexts.

One theoretical perspective with a well-formulated framework and empirical support is self-determination theory (SDT; [14,15]). Central to SDT is the assumption that humans need certain psychological nutriments in order to function optimally. Optimal functioning is dependent upon the satisfaction of three basic psychological needs for autonomy, competence, and relatedness. Autonomy is defined as the willingness and volition in relation to one's behavior. Competence is defined as feeling effective in one's interaction with the environment. Relatedness is defined as feeling cared for and having a sense of belonging. These basic psychological needs are assumed to be universal, and thus invariant across gender, culture, and contexts [16]. However, despite these universal assumptions, SDT also stresses the importance of interpreting the phenomenological reality of psychological need-satisfaction as mediators of the environmental impact on outcomes [17]. In other words, the extent to which the environment impacts optimal functioning and wellness, is determined by the ways in which autonomy, competence, and relatedness are experienced in a given situation. Recently, work has been conducted to investigate the manifestation of the psychological needs within the technology and mobile learning domain [18,19]. Although this area of research is admittedly still in its infancy, it is nonetheless an interesting and important testing ground for SDT.

When reviewing the mobile learning literature related to motivation, we find that there are two central limitations. First, although research on mobile learning has increased in recent year, there has been a lack of theoretically driven studies that account for these findings [5,20]. This is a central limitation given that many of the technologies employed for motivation and learning are characterized by a behavioristic approach, such as the use of reward systems [21], which has been shown to have an undermining effect on motivation [22]. Second, most of the research carried out to date on motivation and mobile learning has employed a quantitative approach [7,23]. Indeed, only a small number of studies within the technology and education domain have included qualitative interviews [24,25]. Furthermore, there have been few studies that have used the SDT framework that are qualitative and aim to understand students' experiences [15]. Thus, investigating motivational research using qualitative methodology provides an important contribution to the field [26,27]. This will allow us to understand more deeply the individuals' experiences of technologies that may be more difficult to extract through quantitative methods.

Our objective is to help close this gap in the literature. Thus, the main aim of this study is to investigate the psychological need-satisfying experiences of a mobile learning application, through qualitative focus group interviews. The application we chose for the study is designed to assist with learning plant species identification, and it was created for higher education biology students. We employ the theoretical framework of Self-Determination Theory [14] to investigate the psychological underpinnings of learning using mobile learning. SDT is a macro-theory (i.e., a broad theory based on philosophical and empirical theory and research) of human motivation and personality and provides clear formulation and hypotheses of what constitutes an optimal functioning student. Moreover, SDT provides theoretical accounts of antecedents and consequences of a thriving student. Thus, SDT seems an appropriate theoretical framework to use in order to understand the underlying motivational principles of mobile learning and its impact on students' learning.

1.1. Psychological need-satisfaction, technology, and learning

There are several aspects of technology that facilitates psychological need-satisfaction. For instance, Ryan and Deci [14] suggest that during gaming, need-satisfaction for *autonomy* is facilitated by making choices to enact agency. *Competence* is facilitated through clarity of goals, leveling (a clear signal of obtaining mastery), and informative feedback. Finally, *relatedness* is facilitated through cooperation and affiliation with others. This was corroborated in a study by Villalobos-Zúñiga and Cherubini [28] in the mobile learning domain. They conducted a functional decomposition study of mobile applications and found that features such as reminders, motivational messages, and goal setting were autonomy-satisfying features. Activity feedback, user history, self-monitoring, and rewards were important features for competence satisfaction. Whereas performance sharing, peer comparison, challenging peers, and messaging peers were all relatedness-satisfying features [28].

Few studies have directly investigated how the satisfaction of these basic psychological needs are experienced using mobile learning to increase students' learning [15]. In one of the first studies on this topic, Jeno et al [29] found that a mobile learning application with need-supportive features enhanced competence satisfaction and intrinsic motivation. Intrinsic motivation, in turn, positively predicted achievement. This finding was later replicated and extended by Jeno, Adachi, et al. [30], who found that need-satisfaction for autonomy and competence, while using a mobile learning application, positively predicted intrinsic motivation and achievement. Intrinsic motivation, in turn, enhanced students' positive affect. In a quasi-experimental study, Alamer and Khateeb [31] found that students using WhatsApp for learning a foreign language had higher motivation compared to a control group using a traditional method. This increase in motivation was accounted for by the satisfaction of autonomy and competence. Using a qualitative design, Peters et al. [32] investigated the perception of an asthma self-management mobile application in adolescent users. Using a deductive thematic analysis approach, these researchers found that, in line with SDT, subthemes that arose from the data were consistent with the conceptualization of SDT's psychological needs. These features and characteristics within the mobile application were in turn an important source for a higher quality of life with respect to managing their asthma problems. Similar results have been found in other contexts. Specifically, a study of high-school students has shown that psychological need-satisfaction from a mobile-based assessment application positively predicts behavioral intention to use the mobile application [33]. Among higher education students, Yang et al. [34] found that psychological need-satisfaction positively predicted an affective and cognitive learning involvement. Relatedly, Hsu et al. [35] found, in an online learning context, that a need-supportive learning climate was associated with psychological need-satisfaction for autonomy and competence; competence in turn was associated with learning gains and perceived knowledge transfers. Similar results were found in studies about course approval and course satisfaction [36] and passion and adaptive screen-based activities (Tóth-Király et al., 2019). Finally, in a study among MOOC participants, Martin et al. [37] found that integrating psychological needs into the course design was significantly related to less-than average dropout rates among course participants.

1.2. The present study

As above reviewed, research indicates that mobile learning tools may enhance students' learning to the extent to which they satisfy the psychological needs for autonomy, competence, and relatedness. Psychological need-satisfaction in turn seems to enhance psychological well-being, school adjustment, and learning. Finally, these findings seem to be replicated across methodological designs such as randomized experiments, longitudinal and cross-sectional design, and qualitative interviews.

Hence, there is clearly a motivational and learning benefit of using mobile learning in higher education [38]. However, in order for mobile learning to provide enduring, well-internalized motivation and deep learning, the technology should be designed to support and satisfy the psychological needs for autonomy, competence, and relatedness [39]. As aforementioned, the goal of this study is to investigate the

psychological need-satisfying experiences of a mobile learning application for species identification. Based on our review of the research and the theoretical propositions of SDT, our research question (RQ) is two-fold: "How do students experience elements of need-satisfaction when using a mobile application designed for species identification? How do they perceive that the mobile application influences their learning?".

Our contribution is important because it helps close a gap in the literature, and advance the motivation and mobile learning field. First, our qualitative results can be used convergently to supplement the quantitative studies [40], and to extend quantitative studies by providing in-depth insight into a phenomenon [41]. The inclusion of qualitative research to this field is important as qualitative research has the advantage of allowing us to explore and collect ample narratives of students' understanding, meaning, and experience of mobile learning, and the related underlying learning process in naturally occurring contexts [41]. Finally, our study will provide theoretical advancement in terms of the nuances of understanding students' learning experiences when using a mobile learning application. This is important because there are only a few studies investigating the underlying psychological processes in technology from a motivational perspective [42].

2. Methods

2.1. Participants

Participants ($N = 26$) consisted of Bachelor's ($n = 20$) and Master's ($n = 6$) students studying Biology at one of the larger universities in Norway. Selection criteria for recruitment was based on previous experience with species identification, and the participants must reflect the same ratio between Bachelor's and Master's students studying Biology. Within the beginning of the second year, biology students receive teaching in plant ecology, enactment of species identification, and field experience. All students in our study had prior experience with plant ecology, traditional (textbook: Lids Flora)- and alternative (mobile application: ArtsApp) identification tools, and field experience. We aimed to recruit a range of participants with respect to study stage and course affiliation that would allow us to answer our research questions. However, we ended data collection when the data became saturated [43].

2.2. Procedure

We conducted four separate focus group interviews. We ensured that each focus group was as similar as possible in terms of grade level (Bachelor's vs Master's students) and number of students in each group (6–8 students). All students signed an informed consent form upon arrival.

The procedure was as follows: First, the participants were provided with a tablet with the ArtsApp [29] (see below) application installed upon arrival. ArtsApp is a species identification tool designed to identify a range of species. Second, each participant was provided with ten different sedge species (Latin: *Carex*) and was asked to use the tablet and spend approximately 30 min identifying the varying sedges. This task allowed us to facilitate group discussion [44] so the students would have a recent experience with both the identification process and the mobile learning application. The same sedges were employed across all four focus groups. No information was provided to the participants regarding whether they should work independently, discuss, or work in groups. The participants were left in the research lab alone. Finally, after 30 min, the two first authors came back into the research lab and started the focus group interviews. Each focus group interview lasted approximately 45 min. The participants were given a gift certificate of 150 NOK (~18 USD) after participation.

2.2.1. Mobile learning application

The mobile learning application used in this study is "ArtsApp", which functions as a key for species identification and is freely available in Norwegian and English [45]. Classical keys are general identification tools consisting of dichotomous statements associated with characteristics needed to identify a species, and each statement leads to a new statement until enough characteristics are described to identify a species. The mobile learning application was developed as an interactive tool that students can use to identify several different species in the Norwegian flora, as an alternative to the traditional textbook employed by biologists.

The mobile learning application has the advantage over traditional textbooks with identification keys in that it allows students to identify species in a more dynamic fashion. Students can start identifying a species by selecting the characteristics freely as opposed to the textbook where the identification goes through a set order of characteristics. The mobile learning application provides students with pictures and drawings of species and species characteristics that facilitate the identification process. Furthermore, the mobile application provides information on which characteristics you have identified, which ones you have left, and how many species are left after each level. Lastly, the mobile application provides GEO data and a species distribution map that allows students to assess the likelihood of finding the species in the region and also removes species that are less likely to be found in a certain geographic area. The mobile application was not originally developed based on the satisfaction of the psychological needs. However, features within the application align with the conceptualization of basic need satisfaction within SDT (e.g., meaningful choices, optimal challenges, clear and dense feedback) [46], and previous studies on mobile learning support this (e.g., [28,29,32]). Investigating these issues is potentially important for technology development and educational purposes. See Fig. 1 for two pictures of the user interface for the mobile application.

2.3. Methodological design

We conducted a qualitative study to explore the students' psychological need-satisfying experiences when using ArtsApp to identify species. We followed the guidelines provided by Twining et al. [47] for conducting qualitative studies in technology and learning. Specifically, we aimed for alignment and internal consistency and coherence between five different levels: theoretical stance (i.e., ontology and epistemology), methodology approach, design, data methods and instruments, and analysis. See Table 1 for an overview of the consistency and alignment between these different levels in relation to our research design.

Focus group interviews were chosen as a data collection method as focus group interviews allow the participants in the group to share similar and in-depth experiences, opinions, wishes and reflections [44,48]. Furthermore, focus groups enhance group interaction that might not be possible in individual interviews, and thus generate rich and dynamic data for analysis [44]. We employed a semi-structured interview in all of our focus groups. We used the same interview guide across all four interviews (see Appendix). The interview guide was developed by the first author and revised and modified by the other authors. The questions were based on SDTs conceptualization of the psychological needs and a literature review on the research of SDT within technology.

We used thematic analysis [49] and NVivo 12 software to code and analyze our data. NVivo 12 was chosen because of its strength in data management, data coding, and the ability to achieve depth and span in data analysis [50]. Following Braun and Clarke [49] suggestions for thematic analysis, we conducted our analysis following these steps: 1) familiarizing ourselves with the data, 2) generating initial codes, 3) searching for themes, 4) reviewing themes, 5) defining and naming themes, and 6) producing the report. We followed these steps as suggested and were also used in alignment with our deductive approach, however, these steps can blend together and become recursive ([51], p.

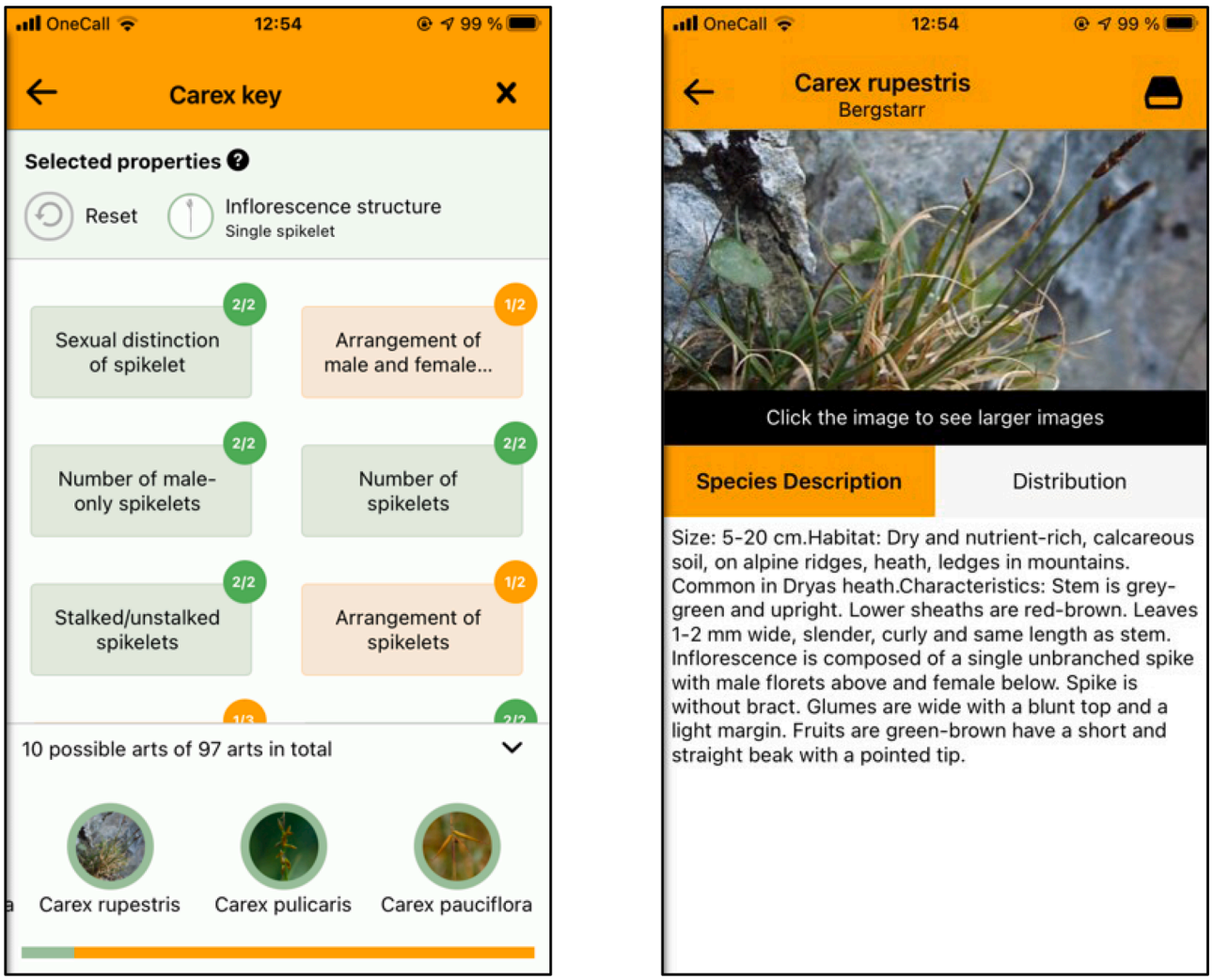

Fig. 1. Overview of the mobile learning application.

4).

Our research design has addressed potential ethical concerns that might be problematic. All names and sensitive information, if any, are anonymized in the results. The focus group interviews were audio-recorded and transcribed verbatim. Furthermore, all audio tapes were deleted after transcription, coding, and data analysis. Each interview was transcribed by a research assistant with formal training in transcribing qualitative research.

2.4. Data analysis

Trustworthiness of our study was addressed through several different means such as ensuring credibility, transferability, dependability and confirmability, and reflexivity [52]. For *credibility*, we employed triangulation as a central strategy. First, we used data triangulation in which we collected data from multiple samples (i.e., focus group interviews). Second, we used investigator triangulation in which we had two researchers interview the participants, code the data, and interpret the results. In regard to the initial coding, this was conducted by the two first authors. Given our deductive approach, we identified patterns and themes and subthemes using the constructs of psychological needs for autonomy, competence, and relatedness as theorized within SDT. Furthermore, we identified themes and subthemes at the semantic level in which themes are identified within the semantic meaning of the data [49] to explore the explicit and in-depth experience of students' psychological need-satisfaction when identifying species. Both coders read and re-read the data and provided an initial coding in NVivo. Reliability of data coding was managed through data moderation in which the first two authors compared and agreed upon their coding of the data. Finally, we triangulated the data analysis by supplementing the thematic analysis with thematic map analysis. We analyzed how each theme and subtheme related to one another and provided an overview of how close the relation is by specifying the associations between the themes and subthemes. The subthemes are based on theoretical concepts and constructs, and aggregates of the thematic analysis described above.

To ensure *transferability*, we have provided a thorough description of the research process such as the full interview guide, our research design, and citation examples from each theme and subtheme to allow other researchers to make a transferability judgement as to whether our results are transferable to their context. In terms of *dependability* and *confirmability*, we have provided information for each step of the research design and process, and full descriptions of the decision made at each step, so that others can evaluate the research process. Finally, in terms of *reflexivity*, we have followed a deductive approach in our development of the interview guide, coding, and analyses, as outlined by SDT. Additionally, we have triangulated at multiple steps to reduce preconceived assumptions from the researchers.

3. Results

Below we present the results from our analysis. Our representation of data analysis is based on all four focus group interviews. Furthermore,

Table 1
Overview of research design.

Level	Research design
Theoretical stance: Ontology	Self-Determination Theory: universal assumption about humans' basic psychological needs, and its antecedents and manifestations.
Theoretical stance: Epistemology	Self-Determination Theory hypothesis driven and testable, and phenomenologically informed.
Methodological approach	Qualitative design with a research question (RQ) based on the conceptualization of SDTs theoretical propositions, in relation to a research gap in the literature and research objectives
	RQs: "How do students experience elements of need-satisfaction when using a mobile application designed for species identification? How do they perceive that the mobile application influences their learning?".
Design	Top-down (deducting) approach to data collection given SDTs theoretical framework and universal claims of what constitutes a thriving human.
Data methods and instruments	Semi-structured focus group interviews in which we had developed guiding questions based on the theoretical framework of SDT and literature review on psychological need-satisfaction, mobile learning, and learning. Interview guide was based on SDTs conceptualization of the psychological needs and a literature review on the research of SDT within technology.
Data analysis	Thematic analysis with a deductive approach using NVivo 12 software to code and analyze our data. Thematic mapping of the theme and subthemes and how they relate to each other.

the results are organized around our deductive approach based on the psychological needs, but also around new themes that emerged.

3.1. Students' experience of need-satisfaction

Results from the analysis of the students' experiences of need-satisfaction from the focus group interviews are presented in Table 2 along with citation examples for each theme and subtheme.

3.1.1. Autonomy

The students' experienced two main aspects with the mobile application that satisfied their psychological need for autonomy; 1) the opportunity to *choose a preferred language*, and 2) the opportunity to *choose the order of key characteristics* when working with identifying species.

The first aspect is the opportunity to choose whether the language of the app should be in Norwegian or English. However, some students said that they did not notice this opportunity, and thus, used the default language (i.e., Norwegian) of the app. The second aspect is the freedom to choose the order of key characteristics when identifying species. This was highlighted by the students as a positive feature, especially when comparing that with the process of identifying species through textbooks. When working with textbooks the students experienced that they had to follow a predetermined order of characteristics when trying to identify a species. When working with the app, the students experienced that they had the freedom to choose which characteristics they wanted to look at first.

3.1.2. Competence

The students experienced that the mobile application supported their competence for several reasons: 1) the *language was easy to understand*, 2) the mobile application was *easy to navigate*, 3) the mobile application was *easy to bring along to fieldwork*, 4) the *sketches/pictures made the identification easier*, 5) the *choice of key characteristics made the identification easier* and 6) the *availability of information to carry out the identification process*.

The first three aspects relate to the user experience of the mobile application. In all three cases, the students compared the experience of working with the app to the experience of working with their main textbook when identifying plants. Regarding the first aspect, they considered the language of the textbook as old fashioned and difficult to understand. Even though the main terms were the same, they felt that the mobile application used a simpler and more understandable language, thus making the key concepts more comprehensible. Regarding the second aspect, the students experienced that the mobile application was faster, more flexible, and easier to navigate, compared to the textbook. The students stated that they valued not having to search through several pages when identifying species, and they appreciated that the pictures and information about the different species were gathered in

Table 2
Students' experience of need-satisfaction.

Theme and subthemes	Frequency	Citation examples
Theme 1: Autonomy		
Choice of language	3	"I used English at first, but then John said that there was a Norwegian one there too…"
Choosing order of key characteristics	35	"…in the book, there is a certain path you must follow. … here you can choose which characteristic you want to start with."
Theme 2: Competence		
The language was easy to understand	8	"It [the language] was quite simple. It was very good that it was so short and to the point."
The app was easy to navigate	7	"It's easier to find out if you have made a mistake. … In books I feel that I often have to, just, start from the beginning, because I do not know where I have made a mistake, and it is no use sitting and flipping. But here it is like, I can only go into it: "could it be what I have answered here? Oh, that might not be right. That one!"
The app was easy to bring along to the field	2	"The app is very good when you want to look up something quickly, when you are out in the field and "okay, this what we're identifying, here and now". While the book is a bit more of a study."
Sketches/pictures made the identification easier	10	"The pictures, it's easier when they ask about glume. Then they sort of show what the three different alternatives look like."
Choice of key characteristics made identification easier	35	"I think the app made it very easy for us, really. At least with the fact that we could choose the order. Because when you sit with that book, it's easy to think like "oh, I cannot do this! I couldn't even identify a dandelion", sort of. You have to know all the features in the book. Here you don't need to know everything."
Availability of information to carry out the identification process	20	"I also liked that you could see how many [options there were]… So now you have these fourteen species, and you can go and check, "Am I completely on track, or not". It was very good to see what was left there."
Theme 3: Relatedness		
Cooperation during the identification process	5	"It is easier for everyone involved to have an overview of how far they have come as well [when working with the app], than if they are working with a book"
Discuss different key characteristics	2	"…one can discuss, "is this bract longer or shorter?" Then you can look at the examples [in the app], and discuss and try to find the answer"

Note: Frequency denotes the total number of codes found in the data for each subtheme.

one place, which is not the case in the textbook. Regarding the third aspect, some students experienced that the mobile application was easier to bring along when conducting field work because mobile devices (phones and tablets) are smaller and more portable than textbooks.

The fourth aspect, the use of pictures, was described by the students as useful because they could look at and consider different kinds features and species characteristics (i.e., stems, leaves etc.,), and compare with the species they were trying to identify. Some students also stated that the explanatory drawings made it easier to understand the concepts and different characteristics of the species.

The fifth aspect, the opportunity to select the order of key characteristics when identifying species, allowed them to select the parts they mastered first. This made the students more confident in their ability to identify the species, compared to the textbook where they had to follow a predesignated order. It also helped the students get further ahead in the identification process. The students explained that when they used the book for identifying species it was easy to get stuck if they were unable to identify a particular characteristic, while the mobile application enabled them to proceed with the identification process even if there were some characteristics they could not identify.

The sixth aspect, information provided for the identification process, helped the students reduce the number of possible outcomes. This was experienced by the students as useful because it enabled them to look at, and compare, the remaining alternatives with the specimen they were trying to identify. For instance, the determination of four different key characteristics might lead to only five species remaining as possible outcomes, instead of the initial 97. This made the process of identifying species more manageable and enabled the students to look at and compare pictures of the remaining species. However, some students also mentioned that the freedom to choose the order of key characteristics and the elimination process could also lead one astray if the wrong choices were made.

3.1.3. Relatedness

The mobile application was perceived by the students as enabling collaboration with peers to a greater extent than a textbook could when working with identifying species. The students explained that the mobile application enabled them to 1) *cooperate during the identification process* and 2) *discuss key characteristics*.

In the first case, the students experienced that the mobile application helped them keep track of their progress when trying to identify a species, and that this enabled them to show each other and compare both the characteristics they had selected and the remaining species. If they were stuck, they could also show what they had done to the teacher and ask for advice. Furthermore, one student explained that when they arrived at a final solution, they compared their result with their peers to see if they had arrived at the same species. The possibility of visualizing both the outcome and the characteristics selected to get there was perceived as easier compared to working with a textbook and taking notes.

Secondly, the students experienced that the mobile application helped them compare and discuss the characteristics they were struggling with during the process of identification. Sometimes the students experienced that they were struggling with a particular characteristic and collaborated to find a solution.

3.2. Students' experience of learning

Results from the students' experience of learning are presented in Table 3. We provide citation examples for each subtheme. Although the students did find the app more motivating and easier to use than the traditional textbook, many of them believed that the textbook was better for their learning. They supported this claim by arguing 1) that the book is more thorough and provides more extensive information than the app; 2) the app does not make all the connections that the book provides, such as how the different species are related phylogenetically; 3) that the need to follow a specific path when identifying species forced the students to use more time on characteristics they did not understand while the app allowed them skip these; and 4) that working with the book made them go through the process of note-taking on the side when identifying species, while the app does not require this.

Some students, however, claimed that they learned less from the book because they became so tired and demotivated when working with it. They argued that even though they used more time and effort on identifying the species when working with the book, they did not experience that they learned more, just that more time was wasted. One student said that even when she succeeded, she did not feel any sense of achievement, just relief that she was finished. Several of the students also stated that the combination of the app and textbooks was useful for their learning when working with species identification. They argued

Table 3
Students' experience of learning.

Theme and subthemes	Frequency	Citation examples
Theme 4: Learning		
The textbook is better than the mobile application for learning	18	"I think maybe I learned the most from the book. Just because, as I said, in the app you can go into what you know already, but there [in the book] you had to sort of flip a little forward and flip a little back, and read up on."
The mobile application provides less information than the textbook	14	"Of course you learn a little [from the app]. But as mentioned, the book is so much more thorough, if it is learning you're after, then I think that is where one should focus."
The mobile application does not show all the connections that the textbook provides	2	"I worked with insects [with the textbook], I got a kind of connection between all the families. About how close they are. The app does not provide this."
The mobile application allows the student to skip concepts they do not understand	9	"…you come across far more concepts in the book than you do in the app, because you cannot choose only the ones you know and you are forced through those you do not know."
Using the mobile application does not require note-taking	1	"I feel that you benefit more from the book than the app. Because then you have to sit and take notes and read. And then you also go much more in depth … I take notes of the type of key characteristics that one has used to arrive at a species"
Learned less from the textbook than the mobile application because of demotivation	2	"When I first found out what species it was, I didn't care about the characteristics. "Is it that species? Done." I think I was so demotivated by the book that I just stopped caring at the end, and just "I don't give a shit about those species", and finished."
Believes the combination of the mobile application and textbooks are useful for learning	5	"The purpose of the app is to make species identification more attractive. That it does not seem like an ancient tradition that all students have to go through because it is still in the syllabus but shows that it is an important skill. But I think, you cannot come up with a better solution than a textbook, and if you study biology then you just have to go through that to."

Note: Frequency denotes the total number of codes found in the data for each subtheme.

that the app made species identification easier, more attractive, and motivating, while the use of books contributed with additional knowledge that the app did not provide.

3.3. Areas of improvement for the mobile application

The results of the students' suggestions for improvement of the mobile application are presented in Table 4 along with citation examples for each subtheme. The students commented and highlighted several aspects and areas that they believed could be improved in the mobile application. Some of these were related to the existing purpose of the mobile application, while others were related to an expansion of the mobile application's purpose.

In regard to the mobile application's current purpose, many of the students wished the mobile application would include more species and more information, pictures, and videos. Some students also mentioned that the identification process should start at a higher level than "family" to separate different families of species from each other. Others said that it would be helpful if the mobile application showed contrasting examples, such as the difference between a short leaf and a long leaf within a certain family of plants.

When it comes to expanding the purpose of the mobile application, some students suggested that the mobile application could include a forum where they could ask experts and fellow users about the identification of a species. Another aspect mentioned was the possibility to register their findings and report them to the national databank for species registration.

Table 4
Students' opinion on how the mobile application could be improved.

Theme and subthemes	Frequency	Citation examples
Theme 5: Areas of improvement		
Include more species	2	"Are you planning [on including] insects and these sorts of things also? … With insects it would have been damn cool if you could get an answer without a magnifying glass. Like if you were on a trip, and just "I do not have a magnifying glass, but I can do it anyway!""
Include more information, pictures, and videos.	24	"I think more pictures, more text, or more explanations along the way would help a lot. Like "Okay, this is that", and "This [is] that kind of concept", and possibly some additional information."
The identification process should start at a higher level than "family"	4	"[When starting the identification process at a higher level] Then you have the opportunity to actually – if you do not know if it is grass or sedges – identify what it is. Then you can start on the category itself."
Show contrasting examples	5	"I think if you pressed here you can find out if it is male-axis or female-axis, or something. When you press that button, then, it might have been okay with a little information about male and female-spikelets. Such things you tend to forget"
Include a discussion forum with experts	3	"You found this species here, and so you do not know. And then there is some expert biologist in that field who says "yes, this is a …""
Register findings in the national species database	2	"…there is quite a lot of potential, in terms of the [national] species database, for example, which has such a registration system, and would very much like more people to have it as a hobby to register species. And if it could somehow have been connected, and that you can identify species in such an app and then get up, like, "Register in the species database", then there is obviously a big potential there."

Note: Frequency denotes the total number of codes found in the data for each subtheme.

3.4. Thematic mapping

Results of the final thematic mapping of the associated processes between each theme and subtheme are presented in Fig. 2. Specifically, results show some reduction of subthemes after refinement of the initial coding. For autonomy, we identified only one subtheme that fulfilled the requirements for the concept of autonomy satisfaction. Furthermore, the results show that choice was also associated with feelings of mastery. For competence, we found two major subthemes representing need-satisfaction of competence, mastery and feedback. We also found that more information within the mobile application would in turn increase students' competence satisfaction via feedback. For relatedness we found two subthemes, cooperation and discussion, which reflect the experience of need-satisfaction in terms of the need for relatedness. The need-satisfaction of relatedness was found to facilitate the identification process. For the learning process, we identified three: value, learning, and the identification process. Finally, for areas of improvement, four subthemes were identified: information, species, database and discussion.

4. Discussion

The main aim of this study was to investigate the psychological need-satisfying experiences of a mobile learning application for species identification among higher education biology students. The results of our qualitative analysis found elements of psychological need-satisfying experiences when students were using the mobile application for species identification. Students reported that the experience of choice was central for the experience of the psychological need for autonomy. Specifically, the ability to choose the order in which the students could identify seems to be the central driver for the satisfaction of this need. Less prominent, but still relevant for the need for autonomy, was the ability to choose language. These findings are in line with the theoretical propositions of SDT which suggest that volition and meaningful choices are important for the satisfaction of autonomy [14].

For the need for competence, the students reported that mastery over the mobile learning application (i.e., navigation), portability (i.e., easy to bring along), comprehensible language, and informative feedback, were all relevant elements for satisfaction for the need for competence. Based on the students' experiences, clarity was important for their experience of the satisfaction of the need for competence, specifically in terms of language, pictures, navigation, and information. This is in accordance with SDT and previous research. Specifically, representational feedback (i.e., display, pictures, color schemes highlighting progress) is a proxy of the need for competence [46], and a source for psychological need satisfaction [14]. Furthermore, based on our thematic mapping, the students' satisfaction of autonomy was a necessary condition in order for the students to feel effective and competent. Results showed, for instance, that the ability to choose the order of characteristics in the mobile application enhanced their feelings of mastery and confidence, compared to the textbook. This may suggest that elements of competence satisfaction alone may not be sufficient for motivation and learning, and that the satisfaction of autonomy is also a prerequisite [53].

For relatedness, the students reported that the mobile learning application facilitated discussion with peers and cooperation during the identification process. The students' experience of the satisfaction of the need for relatedness was less prevalent compared to the other two needs. However, the students highlighted that cooperation during the identification process was facilitated to a greater extent with the mobile

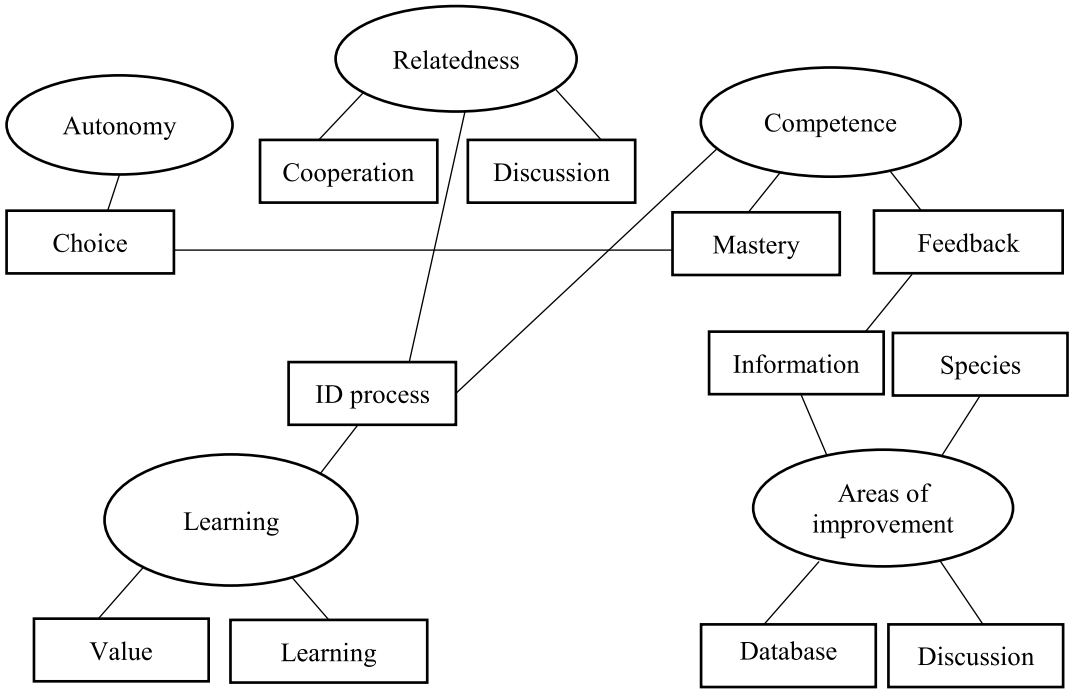

Fig. 2. Final thematic map showing main themes and subthemes, and their proposed relation to each other
Note: ID process= Identification process.

application compared to the textbook. In addition, the students report that the mobile application provides opportunities for discussing species characteristics, which is less prominent in the textbook. These findings are in line with SDT which suggests that belonging to a group, collaborating, helping others benevolently, are proxies for the satisfaction for the need for relatedness [54]. Similar results have been found by Jeno, Vandvik, et al. [30]. Interestingly, however, the facilitation of the need for relatedness is less obvious when performing individual activities such as species identification [29], hence, the students have perceived that the mobile application, or the technology itself, has provided the opportunities for discussion and cooperation, even though the relatedness satisfaction occurred in a face-to-face context, and not through the mobile application.

In line with previous studies (e.g., [29,30,42]), we found that students' experiences of psychological need-satisfying elements within the mobile learning application are underlying mechanisms that facilitate the identification process. That is, students reported that experiences of autonomy (i.e., choice) and competence (i.e., feedback, mastery, and information) were underlying psychological processes that aided the students' identification process. In contrast to what we expected, students reported that they learned more from the traditional textbook, compared to the mobile application. This is in sharp contrast to previous work (e.g., [29,30]), which has found that students, on average, perform better on objective achievement tests using mobile applications, compared to traditional tools. One explanation for this finding could be that students' experiential feeling of learning is not in line with how they actually learn (e.g., [55]). That is, the students may *feel* like they are learning more from textbooks given that this classification is the common approach within biology [56], when in fact they are *actually* learning more from the mobile application due to need-satisfying elements in the application that supports their needs for autonomy and competence. Yet, another explanation could be that the amount of effort is lower when using the mobile application, which might lead to the perception that they are learning less [57]. Finally, students may feel like they are learning less because of the positive emotions accompanying intrinsic motivation such as interest, excitement, and enjoyment [58]. However, students may actually learn more when using the mobile application because intrinsic motivation manifests through deeper and more meaningful learning [59].

Interestingly, although the traditional textbook may be used in multiple contexts and be used to interact with content (partly defined as mobile learning), previous research based on SDT seems to suggest that it's the underlying need-satisfying elements that accounts for the positive elements, and not devices or applications per se (e.g., [30,60]). However, more research is necessary to understand why students report that they believe they learn more from traditional textbooks compared to mobile applications, as this may have methodological implications for how learning is assessed (self-report vs. objective measures).

Finally, a theme arose that was related to usability and improvement of the mobile application. Students reported that there were several aspects within the mobile application that could be improved. These aspects included adding more information, pictures and videos to the mobile application. They also suggested adding more species to the mobile application and providing contrasting examples of species characteristics which would be useful for the identification process. The students additionally suggested that having a discussion forum linked to the mobile application where the students could consult with biology experts would be very useful. Interestingly, the results of the thematic mapping showed that students' suggestions for improvement within the mobile application was closely related to the satisfaction of the psychological need for competence and optimal principles of human-technology interaction [61]. For instance, providing more information, contrasting examples, and a discussion forum would allow students to receive more dense and granular feedback that would then allow them to master the identification process and feel efficacious in their identifying. These factors are important for satisfying the need for competence and relatedness [14]. Although less prevalent in our data, the students' suggestions that the mobile application should start the identification process at a higher level seems to be rooted in the need for autonomy. That is, the ability to choose which level to start with provides students with ownership which then also provides opportunities to match the level with ability (i.e., competence). This has previously been supported in other domains suggesting that competence satisfaction alone is not sufficient for high-quality motivation, autonomy satisfaction

is also a prerequisite [53].

4.1. Limitations and future directions

There are several limitations concerning this study. First, the interview setting in our study was not in a natural context for the students. This might have limited the students' ability to provide more naturalistic experiences during the identification of species [62,63]. We recommend that future studies conduct interviews with students during a field excursion to collect more realistic experiences from the students. Furthermore, all students had previous experience with both identification tools (i.e., mobile learning application and traditional textbook), so it would be interesting to conduct interviews with novice students without identification experience. This would help us disentangle whether past experience and preferences carry-over students' answers and lived experiences. Future studies are recommended to address this limitation.

Second, the small sample size in our qualitative methodology does not allow for generalization. However, representativeness is not the aim of focus group interviews [44]. Furthermore, we achieved data saturation, and thus more data collection would be redundant. Future research should include a larger sample size in order to increase the external validity of our results. There might be differences across institutions, cultures and countries that could drive these results. Furthermore, conducting a quantitative study investigating the same themes and subthemes using a larger sample size with sufficient statistical power would allow for generalization to other similar populations. However, given the lack of qualitative research investigating motivation and mobile learning, our contribution is important as it adds to understanding the underlying experiences of students' psychological need-satisfaction. Third, our sample was homogenous in terms of subject matter (i.e., biology) and educational level (higher education). Inclusion of a more heterogeneous sample would increase the internal validity of our results. Lastly, our analytical plan was based on a top-down approach using the theoretical conceptualization of SDT. We acknowledge that we might have found different results if we would have used different data-analysis approaches (e.g., Grounded Theory, Phenomenology, Critical theory), design (i.e., inductive approach), or other motivational frameworks (e.g., Self-efficacy, Expectancy-value Theory, Flow Theory). An interesting avenue for future research would be to integrate other theoretical approaches with the principles of psychological need-satisfaction, to further understand how mobile learning can be used to support student learning and motivation.

4.2. Conclusions

Although many studies have investigated the role of mobile learning and learning in general, our study addressed the research gap on the lack of qualitative studies in Self-Determination Theory and the understanding of students' experiences of mobile learning (e.g., [15,25]). Our research questions, do students experience elements of need-satisfaction when using a mobile application designed for species identification and does it influences their learning, were mostly supported. The psychological needs for competence (i.e., mastery and feedback) was the most salient need underlying the identification process, however, the availability of choices (i.e., autonomy satisfaction), was also prominent in our findings. One aspect of our research question that was not fully supported was the extent to which the mobile application facilitated the students' learning. Future research is needed to further understand why this occurred.

The present study offers new insight into the underlying need-satisfying experiences of mobile learning, and it provides an understanding of how the different elements of need-satisfaction contribute to different species identification processes. We offer several practical and theoretical implications based on our results. First, our results provide theoretical advancement for which processes are relevant for psychological need-satisfaction within mobile learning. Specifically, the need for competence is a strong contributor of the students' experiences with the mobile learning application. However, it seems also that the experience of choice when satisfying the need for competence, is essential for the students' phenomenology. For instance, providing choice, with structure, might be need-satisfying elements underlying learning processes in mobile learning [64]. Although our study is specific to species identification and biology education, the benefits of employing a meta-theory of human motivation and functioning such as SDT [65], is that it allows us to employ the propositions within the theory to understand why and when mobile learning features and mechanisms should have an impact on motivation, learning, and wellness. Using this framework allows other researchers to transfer the implications of our results to other contexts (informal learning), subjects (physics, physiotherapy), and educational levels (e.g., elementary, secondary), based on the unifying perspective of need-satisfaction.

Second, the results of our study may provide useful information to educational-technology developers on which features, characteristics, or designs that could be included in the technologies to support basic psychological needs. For instance, providing meaningful choices and valuable information so that users may have a part in the decision-making process. This could be the ability to turn on/off features, the choice to take tutorials, or how to go about a learning process. Further, providing clear explanations for tasks, feedback on the learning progress, and allowing the user to decide or level up based on skills or appropriate challenges, are all important for enhancing mastery and competence. Finally, cooperating or interactions on learning tasks, and providing a joint and shared prosocial goal, are design features that could enable relatedness.

Finally, our study corroborates many of the previous findings within SDT. This is important given that qualitative findings may supplement and extend the quantitative results and provide useful insight into the phenomenology of students' experiences with mobile learning. These findings may in turn support the development of questionnaires, interventions, or factors to assess in cross-sectional or longitudinal research.

Declaration of Competing Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Appendix

Experiences with the identification of species

- Do you have experience with identifying species?
  - Which species?
  - What tools have you used?

Experiences with ArtsApp

- Have you used ArtsApp before?
  - What did you use it for?
- How/have you used Lids Flora (or other keys)?
  - What was different?

Autonomy

- How did you proceed in the identification process with ArtsApp?
  - Can you reflect on what you did?
  - Did you follow a specific method/structure? Or did you choose freely? (Compared to Lid's Flora?)
- What was it like to use the app?
  - Were there any features/functionalities that were good/bad, or that were missing?
- What was the language of the app like?
  - Was it understandable?
  - Did you choose any language? Why not?

Competence

- Can you identify/key? (skills)
  - Is there anything you didn't master?
  - Which skills are you missing?
- Were you able to key/identify? (Challenge)
  - What made it difficult, easy?
  - Can you explain how you went forward?
  - Were you able to navigate within the app?
- Did you experience that you received information/feedback when you were keying/identifying? (Feedback)
  - What kind of information (look at explanation, characteristic combinations => species, images/pictures of the species and characteristics) did you get, and was it helpful?
  - Did you experience sufficient information/feedback?

Relatedness

- Did the app help you in the keying/identification process?
- Did you have the opportunity to get some support in the app to, or look for help if you were wondering about something?
- Did you work alone, or did you collaborate during the identification/keying?
- Were there any opportunities for collaboration through the app?

Learning

- Did you experience any increase in knowledge on species identification as you were identifying species?
  - Understanding of the identification process?
- Did you get anything out of using the app?
  - Did you experience mastery?
- Different than previous identification of species (for instance Lid's Flora)

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