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Testing the novelty effect of an m-learning tool on internalization and achievement: A Self-Determination Theory approach

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ABSTRACT

Perceived novelty in mobile applications is an inevitable aspect of today's technologies. Studies suggest that this perceived novelty effect increases motivation but wanes once the user becomes accustomed to the product. Using a Self-Determination Theory approach, the present study investigates how different tools relate to students' motivation, basic psychological needs, and achievement, over and above the effect of perceived novelty. The results from a randomized controlled experiment show that a mobile-learning tool and a digital version of a textbook are perceived as more novel than a traditional textbook. However, only the mobile-learning tool enhances the students' basic psychological needs. Additionally, using path-analysis, we find that the mobile-learning tool, need-satisfaction within the mobile-learning tool, and autonomous motivation account for achievement and internalization, over and above the effect of novelty. We argue that this finding is due to the inherent need-supportive elements within the mobile-learning tool that satisfy the basic psychological needs.

1. Introduction

Smartphones and tablets have become a ubiquitous and central aspect of today's society. Among adolescents and young adults in Norway, 97 percent report having access to a smartphone and 72 percent report having access to a tablet (Slettemeås & Kjørstad, 2016). In terms of usage, 98 percent and 39 percent report that they use smartphones and tablets, respectively, several times during the day (Slettemeås & Kjørstad, 2016). The widespread accessibility and usage of such tools extend the opportunities for using mobile-learning (m-learning) when teaching. M-learning, which may be defined as “learning across multiple contexts, through social and content interactions, using personal electronic devices” (Crompton, 2013, p. 4), allows students to access information quickly through the internet and to communicate and collaborate with peers across the world. As they are portable and easy to bring along, students can readily access, edit, and modify learning content (Derounian, 2017; Hashemi, Azizinezhad, Najafi, & Nesari, 2011). There are potentially several positive learning gains (i.e., achievements) to be found in m-learning tools, and technology may also help increase learners' motivation (Hartnett, 2016; Hashemi et al., 2011). For instance, Lepper (1985) and Lepper and Gurtner (1989) argue that technologies may provide students not only with educational advantages such as more active learning, sustained attention, and individualized instructions, but also motivational advantages such as optimal challenges, immediate feedback, curiosity, imagination, and enjoyment due to its game-like functions.

Although recent systematic reviews and meta-analyses find positive effects on learning outcomes from using m-learning tools in education (Cárdenas-Robledo & Peña-Ayala, 2018; Schmid et al., 2014; Wu et al., 2012), some argue that technology in itself does not

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enhance learning (Clark (1983, 1994a, 1994b). According to this view, what enhances student learning is the cognitive processes (i.e., instructional methods) stimulated by specific applications of the technologies and the novelty effect of new media (Clark, 1983). For instance, Burke and James (2008) found that students who perceived PowerPoint as highly novel, as opposed to those who perceived PowerPoint as low in novelty, reported a higher degree of learning and positive classroom behaviors. The increased attention and recall of novel stimuli is known as the "von Restorff effect" and has been shown to increase memory for several different tasks and topics (see Lynch & Srull, 1982). Furthermore, Keller and Suzuki (2004) highlight that this novelty effect of technology wanes with accustomization, which in turn decreases the user's motivation. For instance, technology might undermine intrinsic motivation due to constant distraction and impulses, create social isolation, and stifle creativity (Lepper, 1985).

The goal of education is for students to understand the importance and value of the learning task in order to facilitate lifelong learning and create change for the betterment of society (Ministry of Education and Research, 2011). There are several routes to enhance students' sustained learning and value, technology might be one way. However, not all technologies are designed equally, and some may impact students' motivational resources in different ways. Due to the large impact that technology has on today's students, and the increasing usage of technology in education (Felt & Robb, 2016; Male & Burden, 2014; Tømte & Olsen, 2013; Wilhelmsen, Ørnes, Kristiansen, & Breivik, 2009), the main purpose of the present study is to investigate how different technological tools impact motivation, value and importance, and achievement. We address this through the lens of Self-Determination Theory (SDT; Deci & Ryan, 2000; Ryan & Deci, 2017). SDT is especially useful for investigating these motivational dynamics given its specific hypotheses about how social factors enhance motivation. Further, SDT has specific predictions of the consequences of motivation for learning (i.e., achievement) and sustained learning and value (i.e., internalization).

1.1. Self-Determination Theory

Self-Determination Theory is a broad theoretical framework concerning human motivation and personality (Deci & Ryan, 2000; Ryan & Deci, 2017). A central assumption is that humans have an inbuilt propensity for wellness, internalization, and learning (Ryan & Deci, 2000b). Although humans have this potential for thriving and integration, SDT recognizes that the social context can either support or thwart this growth tendency. According to Basic Needs Theory (BNT), a sub-theory within SDT, humans have three basic psychological needs. When the needs for autonomy, competence, and relatedness are satisfied and supported, positive outcomes such as optimal motivation, internalization, and learning will follow (Baumeister & Leary, 1995; DeCharms, 1968; Ryan & Deci, 2017; White, 1959). *Autonomy* refers to experiencing choice, freedom, and volition with respect to one's behavior. Autonomy concerns feeling self-endorsement and voluntariness, that is, being true to one's inner interests and values. *Competence* refers to feeling effective in one's interactions with the social environment. Competence is satisfied under conditions that provide optimal challenges, effectance-relevant feedback, positive feedback, and feelings of mastery. Finally, *relatedness* refers to being and feeling connected and cared for by significant others, and having a sense of belongingness. The need for relatedness is supported when a person feels cared for and trusted, and when that person gives and contributes to the social environment. Need-supportive environments, in other words, are environments that satisfy the basic needs for autonomy, competence, and relatedness, tend to facilitate perceived choice and self-initiation, perceived competence, and trust (Deci & Ryan, 1985). When such need-supportive features are provided, and the basic psychological needs are supported and satisfied as opposed to frustrated and thwarted, students experience optimal motivation and learning (Deci & Ryan, 2000).

Organismic Integration Theory (OIT), a sub-theory of SDT, proposes that motivation differs in quality depending on relative autonomy (Deci & Ryan, 1985). That is, for situational learning activities (e.g., learning in the classroom), students may have different reasons for conducting their behavior (Vallerand, 1997). OIT differentiates between amotivation (lacking purpose and meaning for the behavior), external regulation (doing the activity out of an external contingency), identified regulation (doing the activity because it is valuable and important), and intrinsic motivation (doing the activity out of interest and enjoyment). Accordingly, OIT differentiates between two classes of motivation that differ in behavioral and cognitive functioning (Fig. 1). Autonomous motivation (i.e., identified regulation and intrinsic motivation) are behaviors that are initiated and governed by the self, whereas

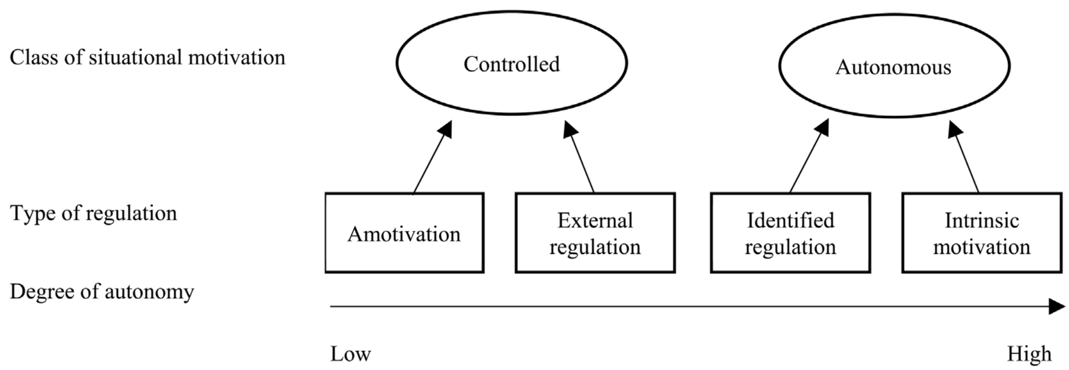

Fig. 1. The figure depicts the internalization process as specified within Self-Determination Theory. The figure is adapted from Ryan and Deci (2000a) and Jeno (2015).

controlled motivation (i.e., amotivation and external regulation) are behaviors initiated and governed by external forces. Generally, research shows that autonomously motivated students, as opposed to controlled motivated students, are associated with higher achievement (Black & Deci, 2000; Guay & Vallerand, 1997; Jeno & Diseth, 2014; Ratelle, Guay, Vallerand, Larose, & Senécal, 2007) and psychological well-being (Niemiec et al., 2006; Ryan & Connell, 1989).

Need-satisfaction and situational autonomous motivation (relative to controlled motivation) allow students to integrate and fully internalize regulations. Internalization, which refers to transforming external values, beliefs, and behavioral regulations into inner regulations (Deci, Ryan, & Williams, 1996; Schafer, 1968), is a natural intrinsic process and it is thus asserted by OIT that support for autonomous motivation should facilitate the internalization process (Deci, Eghrari, Patrick, & Leone, 1994). According to Vallerand (1997), situational factors can impact contextual internalization. That is, situational motivation for a learning activity may have a recursive bottom-up effect on the contextual internalization for the educational domain (Vallerand & Ratelle, 2002). A college student may have a controlled motivation for biology education (i.e., not internalized). However, a new teacher may introduce new learning tasks that support the need for autonomy, competence, and relatedness. The student starts to enjoy biology and thus start to internalize the behaviors of other biology learning tasks. The impact of the situational factors in a particular class or learning task facilitates a sustained autonomous motivation for biology education in general. Two previous studies have found support for this bottom-up effect (Blanchard, Mask, Vallerand, Sablonnière, & Provencher, 2007; Guay, Mageau, & Vallerand, 2003). Hence, more research is needed to address whether situational factors within technological tools can facilitate contextual internalization.

1.2. The present study

In general, studies in educational research within SDT have found support for its basic tenets (see for overviews; Deci, Koestner, & Ryan, 1999; Ryan & Deci, 2017). However, there is a gap in the literature on how different technological tools differ in their impact on motivation and achievement, with respect to the underlying need-support they provide. Moreover, there are few studies that directly test the impact m-learning has on internalization and achievement (Peters, Calvo, & Ryan, 2018). Hence, the present study helps to close this gap in the literature.

Use of technology is mainly a self-chosen activity, thus by definition, an intrinsically motivating activity (Rigby & Ryan, 2017). When employing m-learning tools for a specific learning task, the reason for doing the activity shifts from being intrinsic, towards extrinsic motivation. Hence, the design of an m-learning tool or product can greatly impact the user's motivation (Calvo & Peters, 2017). M-learning tools may enhance student motivation and achievement because they support pedagogical problems, have motivational pulls such as volition, mastery, or social support, but could also be due to the fact that they are appealing, aesthetically pleasing, or novel (Khaddage, Mü;ller, & Flintoff, 2016; Shroff & Keyes, 2017). In the present study we investigate the novelty effect on motivation and learning in an experimental setting. The research question we address is:

> *"do differences in need-support offered in different learning tools account for need-satisfaction, autonomous motivation, internalization, and achievement, over and above the effect of perceived novelty?".*

The context for this experiment was biology education and species identification. Biology education was chosen because of the increased emphasis on educating more skilled biologists, and the fact that biology students report low autonomous motivation and high controlled motivation compared to other majors (Ministry of Education and Research, 2015; Singer, Nielsen, & Schweingruber, 2013; Yu & Levesque-Bristol, 2018). Moreover, biology students must learn different skills that might not be intrinsically motivating, but nevertheless are important skills to master for their educational and practical work life as biologists.

1.2.1. Novelty

One skill that is commonly not perceived as interesting or important is taxonomic identification of organisms, especially of species groups that many students find difficult and uncharismatic, such as sedges (e.g., Jeno, Grytnes, & Vandvik, 2017). This might be due to the sedges' small morphological variations in color, traits, and appearance, in contrast to other species groups. Students have traditionally employed a textbook format for taxonomic identification, which might be perceived as less novel and engaging than technological tools. When introduced to an m-learning tool, the perceived novelty effect of any smartphones and tablets might contribute to an increased engagement and persistence in usage. That is, the motivational pull of m-learning tools may have in-built features that are perceived as appealing and that contribute to increased interest, motivation, and actual usage. Previous research suggests that appraisal of novelty predicts higher interest (e.g., Adachi, Ryan, Frye, McClurg, & Rigby, 2017; Silvia, 2005). Hence the first hypothesis we investigate is:

H1. A digital textbook and an m-learning tool will enhance perceived novelty, relative to the traditional textbook.

1.2.2. Need-support, motivation, and achievement

Once mastered, identification of species is a transferable skill that is important for many subfields within biology, hence valuing and integrating the importance of species identification is essential for biology students. Thus, we investigate whether need-satisfaction —afforded by different species identification tools—and situational motivation predict contextual internalization with respect to species identification.

In one of few studies, Jeno et al. (2017) found that need-supportive features within a mobile application tool enhanced students' intrinsic motivation and perceived competence. In turn, intrinsic motivation positively enhanced achievement. Results further suggested that the mobile application indirectly predicted achievement through intrinsic motivation. Similarly, a study by Jeno, Adachi, Grytnes, Vandvik, and Deci (2018) found that a mobile application positively predicted the need for autonomy and competence, and intrinsic motivation. Intrinsic motivation positively predicted positive affect (change scores), whereas competence predicted achievement. Indirect effect analyses showed that the mobile application tool predicted achievement and positive affect through intrinsic motivation and competence. In a study on homework, Nikou and Economides (2018) randomly assigned high-school students to a traditional homework condition or a mobile-learning condition. Their results showed that the mobile-learning condition increased autonomy, competence, relatedness, and learning, compared with the traditional condition. Similar results have been found in online usage (Shen, Liu, & Wang, 2013; Wang, Tao, Fan, & Gao, 2015) and in intentions to use a technology tool (Fathali & Okada, 2017; Nikou & Economides, 2017; Shroff & Keyes, 2017).

Research in adjacent topics further provides support for our line of reasoning. For instance, in the gaming domain, Ryan, Rigby, and Przybylski (2006) conducted a range of studies and found that satisfaction of the basic needs for autonomy, competence, and relatedness fully accounted for the perceived enjoyment of the game and changed scores in psychological well-being. Similar results have also been corroborated in passive media such as television shows (Adachi et al., 2017). In a study of integration of ICT in PE-lessons, researchers found that ICT predicted post-test measures of need-satisfaction (Legrain, Gillet, Gernigon, & Lafreniere, 2015). Need-satisfaction in turn positively predicted autonomous motivation, which in turn predicted cognitive skills and motor performance. Hence, the second hypothesis we test is:

H2. The m-learning tool will enhance the basic psychological needs, autonomous motivation, and achievement relative to the traditional textbook and digital textbook.

1.2.3. Internalization

Lastly, we investigate whether it is the inherent motivational principles embedded within different m-learning tools that explain autonomous motivation, internalization, and achievement: specifically, whether the underlying elements of need-satisfaction (i.e., perceived autonomy, competence, and relatedness) explain these motivational processes and outcomes. Research within the gaming context support our reasoning (Lomas et al., 2017). Moreover, in a study that directly investigated the facilitation of internalization, Deci et al. (1994) found that students spent significantly longer time on a computer during a free-time period when they were in need-supportive study conditions relative to less need-supportive study conditions. This suggests that students that were in the need-supportive study conditions internalized the reason for doing a behavior and integrated the behavior into the self. Internalization in turn was positively associated with intrinsic motivation and perceived choice (i.e., autonomy). The last hypothesis we investigate is:

H3. The m-learning tool will predict need-satisfaction, autonomous motivation, internalization, and achievement, even when controlling for perceived novelty.

The present study contributes theoretically and to the literature in a number of important ways. First, we test how the perceived novelty of different tools used for species identification contributes to need-satisfaction, motivation, and achievement. That is, we test whether need-satisfaction afforded within the different tools enhances autonomous motivation, internalization, and achievement. This has, to our knowledge, not been investigated, thus providing further advancement of the field. Second, we measure autonomous motivation and controlled motivation, as opposed to only measuring intrinsic motivation, which has been done by others (Jeno et al., 2017, 2018; Martens, Gulikers, & Bastiaens, 2004). This helps to close the gap in the literature on how different classes of motivation relate to m-learning, and removes the confounding effect that novelty has on intrinsic motivation in an m-learning context (e.g., Lepper, 1985). Lastly, we investigate how situational motivation impacts students' contextual internalization for species identification, which has both empirical and practical relevance.

1.3. On the different meanings of novelty

It is important to note that there are conceptual differences between types and functionality of novelty. That is, novelty may be operationalized as both interest (i.e., intrinsic motivation) and as an innovation (i.e., product). According to Rogers (1983), an innovation is an idea, practice, or object that is perceived as new, which in turn determines the reaction. Previous research has shown that perceived product novelty is positively related to positive attitude and perceived rewards, and negatively related to perceived product risk (Wells, Campbell, Valacich, & Featherman, 2010). Moreover, Park and Chen (2007) found that perceived usefulness and ease of use positively predicted attitude toward using smartphone. Thus, to the extent that a product is perceived as novel, the reaction toward the product is positive.

In contrast, novelty, incongruity, and curiosity are central motivational characteristics of intrinsic motivation (Berlyne, 1954, 1963). For SDT, intrinsic motivation is the inherent tendency to seek novelty and challenges, to explore, and to learn (Ryan & Deci, 2000b). A recent study by Adachi et al. (2017) found that perceived novelty of a TV-show positively predicted intrinsic motivation to view the show and willingness to recommend the show to others. Moreover, some researchers even suggest that novelty is a basic psychological need (e.g., Gonzá;lez-Cutre, Sicilia, Sierra, Ferriz, & Hagger, 2016). Additionally, within gaming, novelty is only engaging to the extent that it provides competence satisfaction, as opposed to new rewards or new level designs (Lomas et al., 2017; Peters et al., 2018).

To summarize, despite novelty being central to intrinsic motivation, we operationalize motivational novelty as something different from product novelty. Hence, in line with the theoretical underpinnings of SDT, we reason that only technology that supports the basic psychological needs will facilitate the internalization process, motivation, and learning, over and above the contribution of the novelty (i.e., product novelty) effect of technology.

2. Methods

2.1. Participants

The participants were sixty-nine (47.8% females; M_{age} = 21.8 years) undergraduate students in Biology. The students were recruited from a mandatory field-course in Organismal Biology. During this week long field-course, the students are taught about different species, how to identify species, and the environmental impact on these species. The participants were asked to participate in the study on the second day of the course. The experimental period lasted for three days.

2.2. Procedure

A research assistant unaware of the study hypotheses randomly assigned the participants to one of three conditions: a traditional textbook-condition (n = 23), a digital textbook-condition (n = 23), and an m-learning tool-condition (n = 23). The students were brought to a classroom and presented with an envelope. The envelope contained three parts: some general information, an experimental task, and a post-experimental questionnaire. All students were provided with the following information: "In front of you there are two documents. The first contains species identification questions. The second document is a questionnaire. Please start with the first document, the species identification questions". Then, the participants were given different information depending on which condition they were assigned to.

Participants in the m-learning tool-condition were given the following information; *"please answer all the species identification questions by using the mobile application ArtsApp"*.

Participants in the traditional textbook-condition were given the following information; *"please answer all the species identification questions by using the textbook Lids Flora"*.

Finally, participants in the digital textbook-condition were given the following information; *"please answer all the species identification questions by using the digital version of Lids Flora"*.

All the students were given the final information: "You may use as long time as you need. If you are not able to answer a question, simply move on to the next. When you are done with the species identification questions, you may start with the second document, the questionnaire. Please answer all questions and be as sincere as possible".

Several ethical considerations were taken to ensure the participants safety. First, we received permission to conduct the study by the Norwegian Centre for Research Data (NSD).

Second, all students were told that participation was voluntary, that participation was anonymous, and that the information provided would be treated confidentially. Third, all students were given the opportunity to withdraw from the study at any time. Last, participants were provided with the opportunity to debrief by talking to the research assistant or contact the first author. None of the participants withdrew, needed debriefing, or reported any inconvenience as a result of participating in the experiment.

2.3. Materials

2.3.1. Traditional textbook

In the traditional textbook tool, Lids Flora (Lid & Lid, 2005), the species identification process is dichotomous. That is, each question has only two possible answers and a student must choose an appropriate answer before moving on to the next question. A student starts with a broad taxonomic level (e.g., structure of the spikelets) answering a succession of questions about morphological characteristics. Depending on the taxon, by answering 8–10 questions the students will usually end up with a species identification. This process is hierarchical, meaning that in order to correctly identify a species, a student must correctly answer each question of the identification process. Such hierarchical dichotomous identification tools require solid biological content knowledge. The textbook includes drawn illustrations of the more common sedge species a few pages away from the key itself, as well as definitions and corresponding drawings of the main characteristics and a user guide for the main identification keys in the introduction of the textbook. The traditional textbook has been the standard tool for biologists and may not be perceived as novel. It is also voluminous and may be less practical to bring along to the field (see Fig. 2).

2.3.2. Digital textbook

The digital textbook tool was developed for the purpose of this experiment. In this identification tool, the identification process is done on a smart phone or on a tablet, but the questions are identical to the textbook. That is, in the digital textbook tool, the students move through 8–10 dichotomous questions in a given order. The digital version of the textbook includes pictures and a description of the main characteristics relevant for the identification key for the sedges, which are identical to the textbook. In contrast to the traditional textbook, the digital textbook identification process is done through smartphones or tablets, and thus may be perceived as more novel and innovative. Moreover, the digital textbook may be perceived as easier to bring along and thus more suitable for fieldwork.

2.3.3. M-learning tool ArtsApp

In contrast to the above species identification tools, the m-learning tool ArtsApp offers a dynamic and non-hierarchical identification process. A student may start the identification process at any question. ArtsApp further provides a student with informational feedback in terms of digital pictures and explanations of species' traits, feedback on eliminated species, and the opportunity to consult

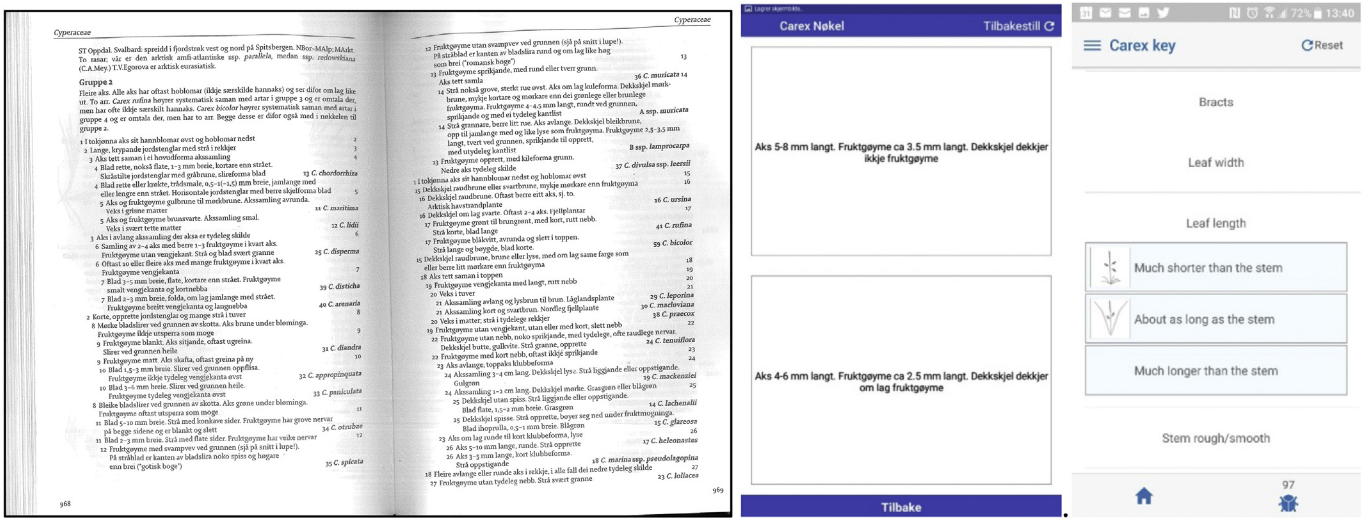

Fig. 2. Images of the three species identification tools employed in the three different conditions: a) a scanned picture of a dichotomous identification key in the traditional textbook; b) a dichotomous identification key from the digital textbook; and c) the dynamic identification key in the m-learning tool.

pictures of the remaining species at any point in the identification process. ArtsApp allows a student to save observations for future reference or comparison, excludes species that are geographically remote and therefore probably irrelevant, and consults species distribution maps. ArtsApp is freely available in English and Norwegian at Google Play (bioCEED, 2018) and at App Store (University of Bergen, 2017), which allows for continued updates, unlimited stage abilities, and easy accessibility for fieldwork.

2.4. Measures

Need-satisfaction. A nine-item need-satisfaction scale was used to measure the participants' experience of within-condition autonomy, competence, and relatedness. The Player Experience of Need Satisfaction scale (PENS; Ryan et al., 2006) consists of three subscales, of which three items measures autonomy ("I experienced a lot of freedom with this identification tool"), three items measure competence ("I feel competent at identifying species"), and three items measure relatedness ("I feel close and safe with this identification tool"). Participants answered on a seven-point Likert-scale ranging from 1 (not at all true) to 7 (very true). The following Cronbach's alpha was found for autonomy ($\alpha = 0.89$), competence ($\alpha = 0.83$), and relatedness ($\alpha = 0.84$).

Situational motivation. To measure the participants situational motivation for using an identification tool, we employed the 16-item Situational Motivation Scale (SIMS; Guay, Vallerand, & Blanchard, 2000). The SIMS measures different motivational regulations for doing a particular task. The participants were given a general statement asking "why are you currently identifying species". The participants were given different situational reasons; intrinsic motivation ("Because it is interesting"), identified regulation ("Because I am doing it for my own good"), external regulation ("Because I am supposed to do it"), and amotivation ("There may be good reasons, but I personally don't see any"). The participants rated the items on a seven-point Likert-scale ranging from 1 (corresponds not at all) to 7 (corresponds exactly). The following Cronbach's alpha was found for each subscale; intrinsic motivation ($\alpha = 0.93$), identified regulation ($\alpha = 0.82$), external regulation ($\alpha = 0.66$), and amotivation ($\alpha = 0.76$). One item (item 4) was deleted from external regulation due to low inter-item correlation. Previous studies have used the subscales separately or combined them into an autonomous (i.e., intrinsic motivation and identified regulation) and a controlled (i.e., external regulation or amotivation) subscale. In the present study, we collapsed the different regulations into autonomous and controlled subscales.

Novelty. A six-item scale was developed to measure the perceived novelty of each identification tool. The development of the scale was based on theories of innovation (i.e., Technology Acceptance Model, Innovation Diffusion Theory), and research literature on innovation and technology adoption (Davis, 1989; Rogers, 1983; Straub, 2009; Tatikonda & Rosenthal, 2000). The scale consists of items encompassing the technology's perceived usefulness, perceived ease of use, perceived complexity, and relative advantage over similar technologies. An item example is "This identification tool is a new and modern way to identify species with". The students were asked to respond on a Likert-scale ranging from 1 (not at all true) to 7 (very true). The Cronbach's alpha for this scale was $\alpha = 0.87$. Given the development of this new scale, we conducted a factor analysis to investigate the scales factor structure. A direct oblimin rotation was employed and found a clear one-factor solution with an eigenvalue explaining 63.5% of the variance. All factor loadings were over 0.30. See the Appendix for overview of the items.

Internalization. In order to measure the participants contextual internalization towards species identification, we employed the value/usefulness subscale within the Intrinsic Motivation Inventory (IMI; Ryan, 1982). The value/usefulness scale (e.g., "I believe this activity could be of some value to me") consists of seven items and participants answered on a seven-point Likert-scale ranging from 1 (not at all true) to 7 (very true). The following Cronbach's alpha was found for this scale ($\alpha = 0.92$).

Achievement. A nine-item knowledge test was given to the students as a measure of achievement. The achievement test comprised six questions that consisted of factual questions (e.g., "what characterizes a sedge?"), and three questions that asked students to identify three different sedges (e.g., "which sedge is in plastic bag number 1?"). The achievement test was developed by a botanical expert. The three sedges were picked by a research assistant unaware of the study hypotheses. The achievement test ranged from 0 to 26 points. Previous studies have employed the same procedure to measure the effect of m-learning on achievement among biology students (Jeno et al., 2017, 2018).

Technology competence. The students' self-perceived technology competence was measured on a one-item question. The participants were asked to indicate how true the statement "I am competent with technology" was for them on a Likert-scale ranging from 1 (not at all true) to 7 (very true). The item served as a manipulation check.

2.5. Statistical analyses

A power analysis was conducted in order to determine the number of participants needed for the current experiment. The R package "pwr" (Champely, 2018) was used to calculate the number of participants needed for each condition. The calculations were based on effect sizes, standard deviations, and mean averages drawn from previous similar studies (Jeno et al., 2017, 2018). Specifically, we took the lowest reported effect size of $d = 0.40$, along with the desired power of .80, alpha level of 0.05, and number of conditions ($k = 3$), and calculated the minimum number of participants needed. Based on our power analyses, we needed a minimum of 23 participants per condition to reach the desired power.

One-way analysis of variance (ANOVA) with a Tukey post-hoc test was used to test for mean differences between conditions in the study variables (Hypotheses 1 and 2). The strength of the difference between the means (i.e., effect size) was calculated using Cohens *d*. The calculation is the difference between the means divided by the standard deviation. Finally, path-analysis was employed to investigate two multivariate path-analysis models (Hypothesis 3). Conventional goodness-of-fit criteria such as chi-square (χ^2) test, Comparative Fit Index (CFI), and Root Mean Square Error of Approximation (RMSEA) were employed to evaluate the fit of the models (Byrne, 2016; Hu & Bentler, 1999; Kline, 2011). In our models, we specified that the condition (i.e., traditional textbook, digital

Table 1
Descriptive statistics of all study variables.

Measures	Mean	SD	Range	Min.	Max.	Skewness	Kurtosis
Competence	3.20	1.18	1–7	1	6	0.29	−0.35
Autonomy	4.04	1.55	1–7	1	7	−0.36	−0.48
Relatedness	4.43	1.52	1–7	1	7	−0.44	−0.08
Autonomous motivation	4.43	1.31	1–7	1.25	7	−0.11	−0.31
Controlled motivation	3.48	1.03	1–7	1	6.13	0.21	−0.16
Novelty	4.92	1.64	1–7	1.67	7	−0.40	−1.13
Internalization	5.30	1.28	1–7	1.57	7	−0.58	0.10
Achievement	7.42	5.33	0–26	0	20	0.79	−0.37

textbook, ArtsApp) would predict need-satisfaction, autonomous motivation, and novelty. The two models differ in their dependent variable, with model 1 predicting internalization and model 2 predicting achievement.

3. Results

3.1. Manipulation check

To ensure that individual differences among the students' technology competence were equally distributed across the three study conditions, we compared the means between the three conditions. A one-way ANOVA revealed no significant differences between the conditions for technology competence, $F(2, 68) = 0.69$, $p = .51$. The results indicate that the students' individual differences in technology competence are randomly distributed across the conditions and do not contribute to any systematic bias that might affect the mean differences of our results on novelty.

3.2. Descriptive statistics

Descriptive statistics are presented in Table 1. The results show that the study variables follow a normal distribution. The large standard deviation in achievement reflects the large range of the variable differentiating the students' species identification skills. Bivariate correlations are presented in Table 2. The results are all in the expected direction.

3.3. Primary analysis

Mean differences. To test hypothesis 1—whether the digital textbook and the m-learning tool enhanced perceived novelty relative to the traditional textbook—we conducted a one-way ANOVA (Table 3). The results show that there is a significant between-group difference for perceived novelty. The m-learning tool and the digital textbook both have higher perceived novelty than the traditional textbook, confirming hypothesis 1 (Fig. 3). The m-learning tool has the highest perceived novelty, and is significantly higher than the digital textbook. The effect sizes are all strong in magnitude.

A one-way multivariate analysis of variance was used as an omnibus test (Tabachnick & Fidell, 2007) to investigate our second hypothesis that the m-learning tool would enhance basic psychological needs, autonomous motivation, and achievement relative to the traditional textbook and digital textbook. Results are significant as assessed by a multivariate test ($V = 1.22$, $F(16, 108) = 10.48$, $p < .001$, $\eta^2 = 0.61$; see Table 3). Follow-up analyses (one-way ANOVAs) show that there is a significant between-group difference for competence, autonomy, and relatedness. As expected, post-hoc analyses reveal that the m-learning tool enhanced autonomy, competence, and relatedness significantly, relative to both the traditional and the digital textbook with strong effect sizes, lending support to our hypothesis; see Fig. 4. Further, there is no significant difference between the digital textbook and the traditional textbook across competence, autonomy, or relatedness ($p > .05$). Contrary to our hypothesis, we find no significant between-group difference on autonomous motivation between the study conditions ($p = .98$). For achievement, we find a significant between-group

Table 2
Correlation of all the study variables.

Measures	1	2	3	4	5	6	7	8
1. Competence	–							
2. Autonomy	.38**	–						
3. Relatedness	.40**	.79**	–					
4. Autonomous motivation	.33**	.22†	.13	–				
5. Controlled motivation	-.27*	-.14	-.12	-.67**	–			
6. Novelty	.40**	.69**	.66**	.05	-.03	–		
7. Internalization	.35**	.16	.08	.85**	-.64**	.10	–	
8. Achievement	.47**	.36**	.29*	.37**	-.22†	.27*	.24*	–

Note: ** sig at $p < .01$, * sig at $p < .05$, † sig at $p < .10$.

Table 3
ANOVA results between the study conditions and the study measures.

Measures	Traditional textbook Mean (SD)		Digital textbook Mean (SD)		M-learning tool Mean (SD)		F(df)
Competence	2.83	(1.09)	2.85	(1.18)	3.88	(.97)	7.02(2, 65)*
Autonomy	3.26	(1.33)	3.67	(1.55)	5.16	(1.07)	12.89(2, 66)**
Relatedness	4.02	(1.39)	3.85	(1.64)	5.39	(1.02)	8.66(2, 66)**
Autonomous motivation	4.39	(1.56)	4.43	(1.26)	4.48	(1.12)	.03(2, 67)
Controlled motivation	3.45	(1.26)	3.48	(1.01)	3.50	(.84)	.01(2, 68)
Novelty	3.32	(1.19)	5.10	(1.24)	6.35	(.72)	46.21(2, 68)**
Internalization	5.15	(1.52)	5.40	(1.33)	5.37	(.99)	.25(2, 67)
Achievement	6.43	(4.38)	3.74	(2.32)	12.09	(5.01)	25.29(2, 68)**

Note: *$p < .01$, **$p < .001$.

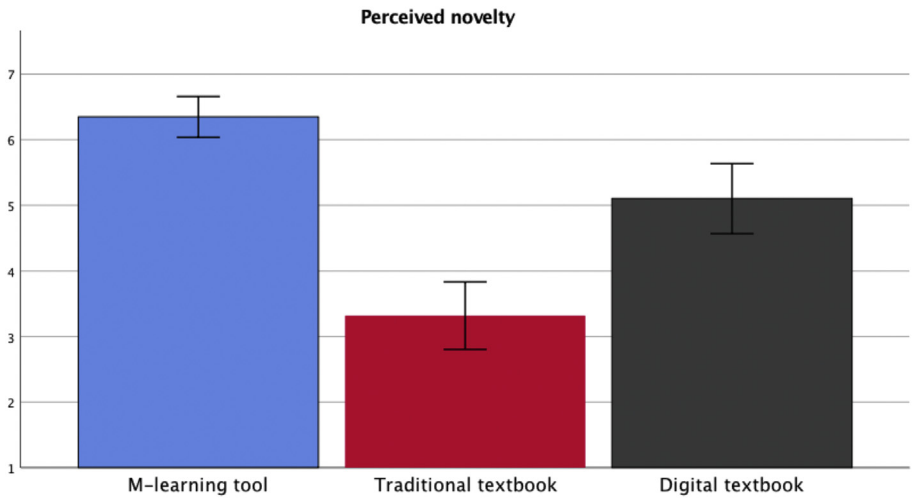

Fig. 3. Mean difference with confidence intervals between the three study conditions on perceived novelty.
Effect size (Cohen's d): M-learning tool vs Traditional textbook ($d = 3.08$), M-learning tool vs Digital textbook ($d = 1.23$), Digital textbook vs Traditional textbook ($d = 1.46$).

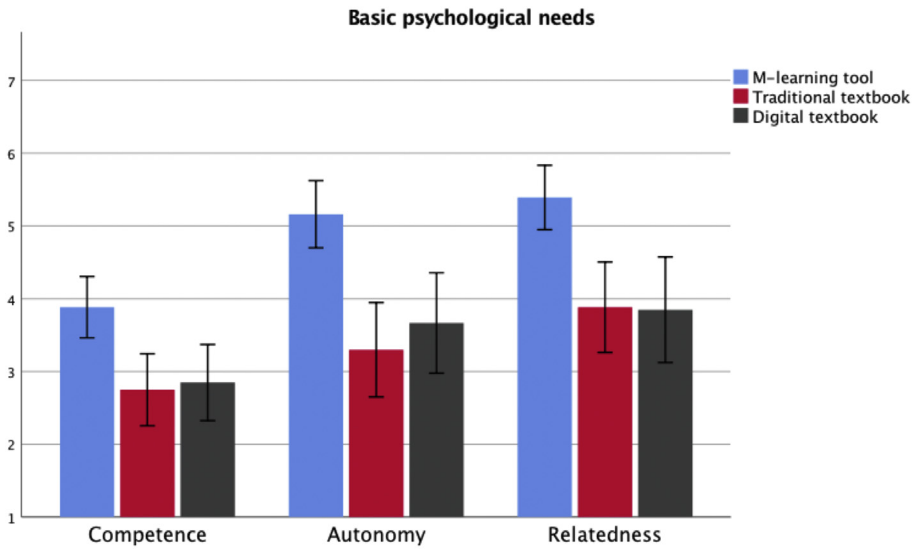

Fig. 4. Mean difference with confidence intervals comparing competence, autonomy, and relatedness across the three study conditions. Effect sizes (Cohen's d) for competence: M-learning tool vs Traditional textbook ($d = 1.02$), M-learning tool vs Digital textbook ($d = 0.96$). Effect sizes for autonomy: M-learning tool vs Traditional textbook ($d = 1.58$), M-learning tool vs Digital textbook ($d = 1.12$). Effect sizes for relatedness: M-learning tool vs Traditional textbook ($d = 1.18$), M-learning tool vs Digital textbook ($d = 1.13$).

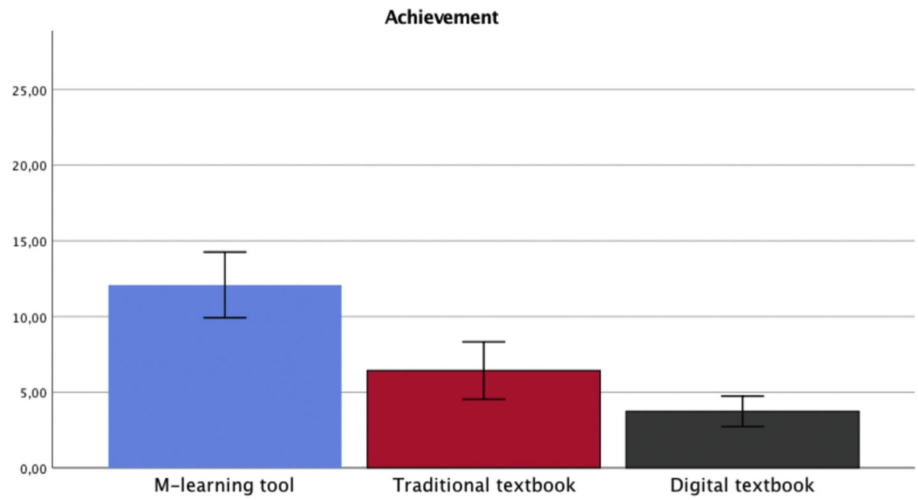

Fig. 5. Mean difference with confidence intervals between the study conditions on achievement. Effect sizes (Cohen's *d*): M-learning tool vs Traditional textbook ($d = 1.20$), M-learning tool vs Digital textbook ($d = 2.14$).

difference. Post-hoc analyses support our hypothesis that the m-learning tool is significantly different from both the traditional textbook and the digital textbook (Fig. 5). There is no significant difference between the traditional textbook and the digital textbook ($p > .05$).

Direct and indirect effects. To test our last hypothesis, we ran two separate path-analytical models. We expected that the m-learning tool would directly and indirectly predict need-satisfaction, autonomous motivation, internalization, and achievement, even when controlling for perceived novelty, traditional textbook, and digital textbook. The model fit for our first model (Fig. 6) is excellent: $\chi^2(2) = 0.20$, $p = .91$, CFI = 1.0, RMSEA = 0.00 (CI: 0.00, 0.09). The model as whole accounted for 73 percent of the variance in internalization. Specifically, the results show that the m-learning tool positively predicts need-satisfaction and novelty. Need-satisfaction positively predicts autonomous motivation, whereas novelty is a negative predictor of autonomous motivation. Autonomous motivation is a positive and significant predictor of internalization, whereas need-satisfaction and novelty are not. Indirect effects in the model were calculated by means of Sobel tests. Results show that condition indirectly and positively predicts autonomous motivation ($\beta = 0.29$, $z = 2.78$, $p < .01$). That is, the m-learning tool (relative to the digital and traditional textbook) positively predicts autonomous motivation, albeit indirectly through need-satisfaction. Need-satisfaction indirectly predicts internalization ($\beta = 0.47$, $z = 3.21$, $p < .01$). This suggests that need-satisfaction enhances autonomous motivation, which in turn enhances internalization. Further, condition is a significant indirect predictor of autonomous motivation ($\beta = -0.28$, $z = -2.44$, $p < .05$). That is, the m-learning tool (relative to the digital and traditional textbook) enhances novelty, which in turn negatively predicts autonomous motivation. Finally, novelty is a negative indirect predictor of internalization ($\beta = -0.32$, $z = -2.77$,

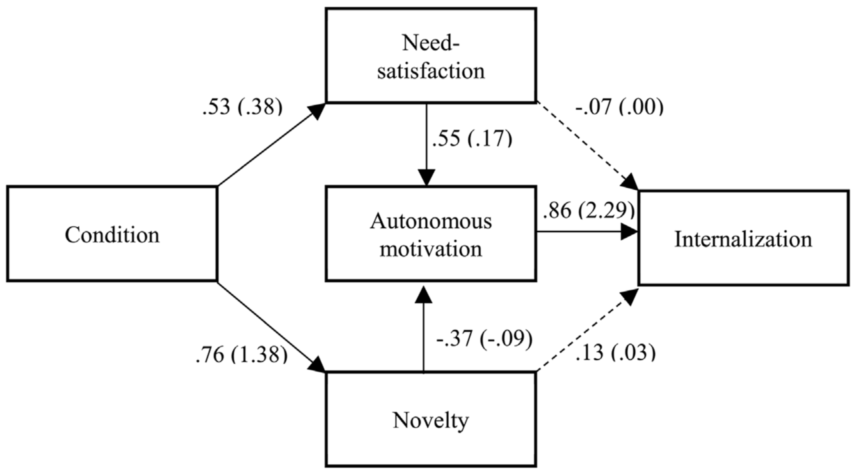

Fig. 6. Path-model 1 of the study variables predicting internalization. The results show standardized regression coefficients.
Condition coded as m-learning tool = 1, Digital textbook = 0, Traditional textbook = −1. A covariation between the residuals in need-satisfaction and novelty was estimated ($\beta = 0.59$) to improve model fit. All solid line paths are significant at $p < .05$. Non-significant paths are shown as stippled lines. Effect sizes (f^2) for each path is presented in parenthesis.

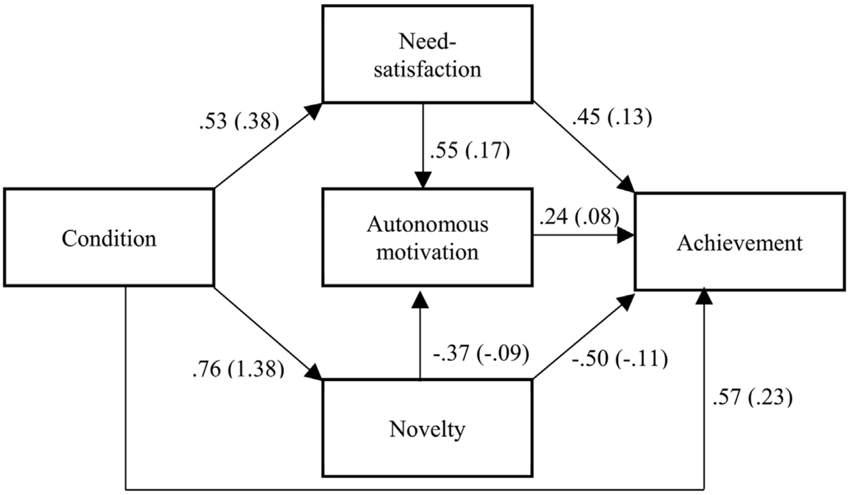

Fig. 7. Path-model 2 of the study variables predicting achievement. The results show standardized regression coefficients. Condition coded as m-learning tool = 1, Digital textbook = 0, Traditional textbook = −1. A covariation between the residuals in need-satisfaction and novelty was estimated (β = 0.59) to improve model fit. All paths are significant at $p < .05$. Effect sizes (f^2) for each path is presented in parenthesis.

$p < .01$). This suggests that novelty negatively predicts autonomous motivation, which in turn negatively predicts internalization. The effect sizes for each path ranges from very weak (i.e., need-satisfaction → internalization) to strong (i.e., autonomous motivation → internalization).

Results from our second model also show excellent model fit, $\chi^2(1) = 0.00$, $p = .99$, CFI = 1.0, RMSEA = 0.00 (CI: 0.00, 00); Fig. 7. The model as a whole predicts 41 percent of the variance in achievement. Specifically, condition positively and directly predicts need-satisfaction, novelty, and achievement. Need-satisfaction positively predicts autonomous motivation and achievement. Novelty negatively predicts autonomous motivation and achievement. Finally, autonomous motivation is a positive predictor of achievement. In terms of indirect effects, the results partly support our assumptions. Condition is a significant indirect predictor of autonomous motivation via need-satisfaction (β = 0.29, $z = 2.31$, $p < .05$). That is, the m-learning tool (relative to the digital and traditional textbook) positively predicts need-satisfaction, which in turn positively predicts autonomous motivation. Condition is negatively and indirectly related to autonomous motivation through novelty (β = −0.27, $z = -2.34$, $p < .05$). This suggests that the m-learning tool (relative to the digital and traditional textbook) positively predicts novelty, which in turn negatively predicts autonomous motivation. Condition is not an indirect predictor of achievement through need-satisfaction (β = 0.24, $z = 0.64$, $p = .52$). Need-satisfaction is not a significant indirect effect of achievement via autonomous motivation (β = 0.13, $z = 0.56$, $p = .57$). Moreover, condition is not a significant indirect predictor of achievement via novelty (β = −0.38, $z = -0.82$, $p = .41$). Lastly, novelty does not indirectly predict achievement through autonomous motivation (β = −0.08, $z = -0.56$, $p < .58$). The effect size from condition to achievement is moderately strong, whereas the effect size of need-satisfaction and autonomous motivation are both weak.

4. Discussion

The main goal of the present study was to investigate how different technological tools impact student motivation, internalization, and achievement. In particular, we tested whether the need-supportive features offered in a plant taxonomic identification tool impact students' autonomous motivation, internalization, and achievement over and above the effect of novelty. In general, the results support our hypotheses.

Consistent with our first hypothesis, we find that both the digital textbook and the m-learning tool are perceived as significantly more novel than the traditional textbook. This is in line with the assumptions that new, unfamiliar, complex, and modern products are perceived as more novel (Rogers, 1983; Silvia, 2005; Tatikonda & Rosenthal, 2000). An important finding is that the m-learning tool is perceived as significantly more novel than the digital textbook. This may be due to the m-learning tool having more functionalities and features, such as integration of Wi-Fi-connection and being geographically “smart” in that it can exclude options that are not relevant based on where the user is located, compared to the digital textbook (Rogers, 1983). Importantly, this finding is not due to confounding effects of the students' technology competence, which was controlled for and evenly distributed across the conditions.

For our second hypothesis, we predicted that the m-learning tool would enhance the basic psychological needs, autonomous motivation, and achievement relative to the traditional textbook and digital textbook. Results from the ANOVAs partly support this. The m-learning tool enhances the psychological needs for autonomy, competence, and relatedness, relative to both the digital and the traditional textbook. This may be linked to the underlying motivational elements of need-satisfaction such as providing students with choice and options that are built into the m-learning tool. Moreover, the dense feedback and possibility of matching the challenge (i.e., species characteristics) to the user's ability (i.e., knowledge of traits) provide support for competence. Finally, perceiving trust in the identification tool provides a feeling of relatedness. Our results are consistent with theorization of SDT. According to Deci and Ryan (2000), the motivational dynamics perceived in mobile applications, such as support of choice and volition, optimal challenges and effectance-relevant feedback, and the experience of reciprocal trust and care, will satisfy the users' basic psychological needs. These results are also consistent with previous studies (Jeno et al., 2017; Nikou & Economides, 2018).

In contrast to our hypothesis, we find no significant difference in autonomous motivation between the study conditions. The students may have found the situational learning activity of identifying species as equally self-determined. For achievement, we find that the m-learning tool contributes to significantly higher achievement scores than both the digital textbook and the traditional textbook, as expected. The m-learning tool is more intuitive and easier to use, with a modern design and user interface which may contribute to higher achievement scores. Such features within a mobile application are pedagogically significant and may enhance a student's learning (Shroff & Keyes, 2017), which may be especially important in disciplines such as biology that benefit from visualizations, graphics, and direct interaction with the learning content (Zydney & Warner, 2016).

In terms of the direct and indirect effects of the m-learning tool on need-satisfaction, autonomous motivation, internalization, and achievement, the results from the two path-analytical models generally support our hypothesis. First, the m-learning condition (relative to the digital and the traditional textbook), positively predicts need-satisfaction and novelty. Only need-satisfaction in turn positively predicts autonomous motivation, whereas novelty negatively predicts autonomous motivation. This suggests that only within-condition need-satisfaction positively accounts for autonomous motivation, whereas the perceived product novelty is negatively associated with autonomous motivation. Moreover, the indirect effect analyses suggest that the m-learning tool positively predicts autonomous motivation, via the effect of need-satisfaction. This is consistent with previous research and SDT. For instance, Ryan et al. (2006) found that the effect of condition and enjoyment is fully accounted for by need-satisfaction. According to SDT, the effect of the social environment on growth, integrity, and wellness is fully mediated by the satisfaction of the basic psychological needs (Ryan & Deci, 2017).

For internalization, autonomous motivation is a positive predictor of internalization, whereas need-satisfaction and novelty are not significant predictors. Need-satisfaction predicts internalization through autonomous motivation. This is in line SDT. According to Vallerand (1997), the adjacent level of motivation may have a recursive bottom-up effect on that proximal level of motivation. That is, the situational motivation for a learning activity may impact the contextual internalization of the educational domain. This model has been previously validated in the context of education (Guay et al., 2003) and sports (Blanchard et al., 2007). For achievement, the m-learning condition, autonomous motivation, and need-satisfaction are direct predictors of achievement, whereas novelty is a negative predictor of achievement. This further suggests that it is not the perceived newness, usefulness, or efficiency of a product that predicts achievement, but the underlying motivational mechanisms afforded within them. This may have practical implications for how technologies are created for educational purposes and in general.

4.1. Limitations and future research

There are several limitations in our study that are worth discussing. First, the sample size employed in the present study was small. We conducted power analyses prior to the experimentation in order to recruit the necessary number of participants, and thus the sample size was appropriate for the purpose of the study. However, it is recommended that future studies use larger sample sizes when conducting experiments with three conditions. This is important for two reasons: i) to increase power in the process models (i.e., path-analytical models) and ii) to increase the ability to generalize to the larger population.

Second, the experimentation time was short, which may be problematic for the internalization process. A longer experimental time (i.e., longitudinal design) may increase the effect of need-satisfaction on internalization and the explained variation in internalization. Furthermore, the short experimental time may not capture long-term retention (i.e., deep learning), which is important for academic achievement. However, the achievement test provided to the participants during the experiment was developed to measure not only factual knowledge (i.e., the number of species in Norway) that students can find by searching, but also conceptual knowledge on what to look for when identifying species and how to use the identification tool to find the correct species. Nevertheless, future research needs to address the implication of surface vs deep learning in m-learning tools.

Third, the achievement scores were low across all conditions. The students in the present study were undergraduate students during the first week of a field-course about learning to identify species. Hence, the low achievement scores are mostly due to the students' low experience in identifying species. Others have reached similar conclusions (e.g., Jeno et al., 2018). Future studies should extend the experimental time and include more advanced student samples in order to address whether the low achievement is due to identification experience or other confounding factors such as motivation, prior knowledge, or floor-effect of the achievement measure.

Last, the present study is an investigation of biology students and identification of species. Future studies should investigate the underlying need-supportive features in other mobile applications to assess how these features impact students' situational motivation, contextual internalization, and achievement. This is important for generalizing the results beyond student populations and contexts.

4.2. Implications for theory and practice

Overall, the present study provides an important contribution to the m-learning field. The results provide an understanding of the motivational features embedded within different identification tools. Importantly, we provide an understanding of how the perception of novelty does not necessarily predict optimal motivation and achievement when accounting for need-supportive features. Moreover, the theoretical approach of SDT to understand the underlying motivational processes in m-learning tools is an important advancement towards designing high-quality m-learning tools. Through the lens of SDT, we argue that not all m-learning tools are designed equal, and that those tools that satisfy the basic psychological needs for autonomy, competence, and relatedness are the tools that contribute to autonomous motivation (optimal motivation), internalization (sustained learning and value), and achievement (learning). This helps close the gap in the literature in the SDT-field and m-learning, as we are, to our knowledge, the first to address this through the conceptual lens of SDT.

Based on our results, we offer some practical recommendations. First, educators and m-learning developers should evaluate and create m-learning tools in light of the need-satisfaction afforded within the m-learning tools. This is important for how we create technology, but also which technologies are employed in education. For instance, designing new m-learning tools that provide a sense of choice, volition, and agency is necessary to satisfy the need for autonomy, by providing support for behaviors that are pursued out of self-initiation. Satisfaction of competence is accomplished through provision of dense and informative feedback, positive feedback, and optimal challenges. Such competence-enhancing features within an m-learning tool are important for a user's sense of mastery and engagement. Additionally, truly immersive and engaging m-learning tools (Przybylski, Rigby, & Ryan, 2010; Ryan & Deci, 2017) include need-supportive features such as cooperation, reciprocal trust, and caring in the m-learning tool which satisfy the need for relatedness. By providing such features, the user is involved and feels connected with the identification experience when using the m-learning tool.

Second, m-learning tools may have different motivational pulls within them that make them more attractive to use than other m-learning tools and traditional learning tools. However, although students may be attracted to some tools due to their novel features, they are not necessarily contributing to internalization and achievement. Traditional tools may incorporate need-supportive features, but m-learning tools have more possibilities to facilitate such processes making them more perceived as both novel and engaging.

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Appendix

Achievement

- How many species of sedges (Carex) are there in Norway?
- In sedges with unequal spikelets, is the male spikelet on top or below?
- What do we find inside the perigynium?
- Where do we find the (inflorescence) bract in a sedge?
- Which of the following characteristics are important for identifying a sedge species? A) Number of stigmas, B) If the node is hairy or not hairy, C) Breadth of the petals, D) If the spikelets are stalked or not stalked
- Which sedge is in the plastic bag number 1?
- Which sedge is in the plastic bag number 2?
- Which sedge is in the plastic bag number 3?
- What characterizes a sedge?

Perceived competence

- My ability to identify species is well matched with the challenges of identifying species
- I feel competent at identifying species
- I feel capable and effective in identifying species

Perceived autonomy

- I experienced a lot of freedom with this identification tool
- I can find something interesting to do in this identification tool
- This identification tool provides me with interesting options and choices

Perceived relatedness

- I experienced support from this identification tool
- This identification tool provides me with meaningful information that I can rely on
- I feel close and safe with this identification tool

Autonomous motivation

- Because identifying species is interesting
- Because it is for my own good to identify species
- Because I think it is pleasant to identify species
- Because it is good for me to identify species
- Because it is fun to identify species
- I identify species by personal choice
- Because identifying species is enjoyable
- Because it is important for me to identify species

Controlled motivation

- Because it is expected to identify species
- There may be good reasons to identify species, but I don't see any
- Because it is something that I have to do
- I identify species, but I am not sure if it is worth it
- I identify species because I don't have any choice
- I don't know, I don't see what identifying species brings me
- Because I feel that I have to identify species
- I identify species, but I am not sure it is a good thing to pursue it

Perceived novelty

- The use of this identification tool was a new experience for me
- This identification tool is a new and modern way to identify species with
- This identification tool is an effective way to identify species with
- This identification tool is easy to use
- It is exciting to use this identification tool
- This identification tool is practical to bring along to the field

Internalization

- I believe species identification has some value to me
- I think species identification is useful for me and my subject
- Species identification is important for me because it can increase my understanding of species
- I would be willing to identify species more because it has some value to me
- Species identification can help understand more of biology
- Species identification could be beneficial to me
- I think species identification is an important activity

Technology competence

- I am competent with technology

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