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The effect of a mobile-application tool on biology students' motivation and achievement in species identification: A Self-Determination Theory perspective



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ABSTRACT

Biology students traditionally use a textbook in the field and on courses to identify species, but now a new mobile-application tool has been developed as an alternative. Guided by Self-Determination Theory (SDT) we conducted an experimental study to test the effect of the mobile-application, relative to the traditional textbook, on students' intrinsic motivation, perceived competence, and achievement. Seventy-one students were randomly assigned to either an experimental condition (mobile application - ArtsApp) or control condition (textbook - Lids flora). As hypothesised, the students using ArtsApp had higher intrinsic motivation, perceived competence, and achievement, compared to the textbook control group, with medium to large effect sizes. Furthermore, using the mobile application, relative to the textbook, predicted intrinsic motivation, which in turn, predicted higher achievement scores in a path analysis. Lastly in a hierarchical regression analysis, intrinsic motivation and autonomous motivation accounted over and above in students' interest for species identification, and importance of knowing species. These results are in line with SDT's theorising: emphasising that when students act out of interest, choice, and have an internal locus of causality, they achieve better outcomes, presumably because these satisfy students' psychological needs for autonomy, competence, and relatedness. Factors facilitating this are interest, choice, and feedback, which we argue are in-built functions in the mobile application as opposed to the textbook, and which might account for the positive results. Further studies with several student-groups and complex designs are needed before inferring causality across educational levels. Based on the present study, we recommend that biology teachers in higher education employ mobile application tools in species identification due to increases in motivation and a higher degree of accurate identification of sedges.

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1. Introduction

The ability to correctly identify a particular plant or animal to species is the foundation of biodiversity science. Biodiversity research is increasingly critical in a world subject to unprecedented rates of climate change, habitat loss, and other

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environmental pressures (Rockström et al., 2009), as we urgently need to understand the impact of these drivers on our biodiversity and ecosystems. Providing the future workforce with the skills and competences necessary to meet society's needs in this area is a key deliverable of the educational system, and it is therefore a paradox that there is now a decreasing focus on learning plant and animal taxonomy at all educational levels (Lawler, 2016; Parkin, 2016). This declining interest in species knowledge and its underlying skills is, in part, a result from a shift towards an increased focus on what is seen as 'higher-order cognition' throughout the educational system (Bloom, 1956), reflecting the view that biodiversity knowledge and especially species identification skills are based on rote learning and rather simple cognitive processes. Investigating factors that increase species identification knowledge in general, the motivation for identifying plant and animal species, and the importance of knowing species is thus necessary. The main goal of the present study is to test the effect of a mobile application tool for the identification of species amongst biology students by assessing how the use of the mobile application affects the students' achievement, their motivational predictors for achievement, and their perceived value of species identification. Several reports state that STEM (Science, Technology, Engineering and Mathematics) education and research areas are highly important domains to invest in for the future, both across the world and in Norway in particular (Maltese & Tai, 2011; Ministry of Education and Research, 2015a, 2015b). However, amongst the OECD countries, Norway scores the lowest in student motivation and perception of usefulness in their education (OECD, 2014). With an increasing amount of electronic possibilities as teaching methods, textbooks may be seen as old-fashioned, and using mobile applications could be a way to increase students' motivation and achievement.

1.1. Mobile-learning, motivation and achievement

Electronic-learning (e-learning) and mobile-learning (m-learning) has transformed the traditional learning context from classroom to a virtual space (Gikas & Grant, 2013; Hashemi, Azizinezhad, Najafi, & Nesari, 2011; Tham & Werner, 2005). A survey conducted by the National Institute for Consumer Research (SIFO) shows that 74 percent of the Norwegian population has access to a smartphone and 46 percent have access to a tablet (Slette-meås, 2014), and this number is only expected to increase. Moreover, across the OECD countries, 96 percent of 15-year-old students have a computer, smartphone or tablet at home (OECD, 2015). The increased use of smartphones and tablets in the population in general raises the possibilities for supporting learning and motivation in the educational domain. There have been several studies on the effectiveness of mobile learning, relative to traditional learning methods. For instance, in a quasi-experimental study on plants among elementary-school students, Huang, Lin, and Cheng (2010) found support for a mobile learning system (MLS). One group of students was introduced to a mobile learning system (experimental condition), while a control group was introduced to a guidebook. Both groups were asked to observe and find plant characteristics and morphology. The study showed that the MLS had a statistically significant effect on students' attitudes towards outdoor plant learning and pre-test/post-test achievement scores compared to the guidebook. Noguera, Jiménez, and Osuna-Pérez (2013) did a similar study with physiotherapy students learning manual therapy. Students were randomly assigned to two conditions, either an experimental condition (mobile application) or a control condition (traditional teaching session). Using a comparative crossover design, it resulted in students in the experimental condition scoring higher in general on a post-experimental test. The effects of m-learning have also been found in studies where students learn about culture (Hwang & Chang, 2011), bird observation (Y. S. Chen, Kao, & Sheu, 2003), statistical concepts (Ling, Harnish, & Shehab, 2014), and dementia (Pitts et al., 2015). A meta-analysis by Wu et al. (2012) found that studies on mobile learning primarily focus on evaluating the effectiveness of mobile learning and that these studies employed mobile phones as a learning system. Importantly, the results show that 86 percent of the studies report positive results of the research outcomes, as opposed to one percent who reported negative outcomes. A recent meta-analysis by Schmid et al. (2014) investigating the effect of technology among higher education students, finds support for the effectiveness of technology in education.

Several reports within the educational domain argue that an integration of digital competence in education is highly important for future employability and knowledge acquisition (Erstad, Amdam, Arnseth, & Silseth, 2014; Ministry of Education and Research, 2015b). Tømte and Olsen (2013), in a report on how technology contributes to increased learning outcomes in higher education, find that students perceive that technology contributes to flexibility in their studies. In light of this, it might be argued that mobile-devices could have several motivational benefits for the student, for example, freedom, ownership, communication, enjoyment, and accessibility (Jones & Issroff, 2007). Studies investigating the effect of technology have previously found support for this reasoning (Law, Lee, & Yu, 2010; Martens, Gulikers, & Bastiaens, 2004; Pitts et al., 2015; Sha, Looi, Chen, & Zhang, 2012). Hence, the benefits of mobile learning are that students are given more volition and are more active in their learning. One theory that has proved especially useful in analysing motivational factors, student motivation, and achievement in education is the Self-Determination Theory (SDT: Deci & Ryan, 1985).

According to SDT, students have three inherent basic psychological needs for autonomy, competence, and relatedness (Deci & Ryan, 1985; Ryan & Deci, 2000b). Satisfaction of the basic needs is theorised to be positively associated with psychological well-being, whereas thwarting of the needs is detrimental to well-being, and associated with psychological ill-being. A basic tenet of SDT is that the satisfaction of the basic psychological needs is necessary for intrinsic motivation, i.e. those behaviours that are performed for the inherent satisfaction of the activity, as opposed to extrinsic motivation which is carried out for some instrumental reason (Ryan & Deci, 2002). SDT differentiates between two classes of motivation: autonomous and controlled. Autonomous motivation is a behaviour that is performed out of volition and self-endorsement. Controlled motivation, on the other hand, is regulated by rewards and punishment, or by introjection (ego-involved or

avoidance of self-derogation) (Niemiec & Ryan, 2009). In general, research finds that intrinsic motivation and autonomous motivation are positively related to beneficial outcomes, whereas controlled motivation is not (Deci & Ryan, 2008; Fortier, Vallerand, & Guay, 1995; Koestner, Ryan, Bernieri, & Holt, 1984; Ryan & Deci, 2009). Lastly, SDT has a dialectic approach and assumes environmental support (psychological need support) for autonomous motivation, while environmental control (psychological need thwarting) of students' behaviour is predicted to frustrate the basic psychological needs that lead to controlled motivation. The notion of support has been found meta-analytically and is necessary across all educational levels (Deci, Koestner, & Ryan, 1999).

Some studies have tested the effect of mobile-learning on motivation directly. Koh et al. (2010) find that students who were in the experimental-condition relative to students in the control-condition, scored higher on an achievement test, had higher autonomous motivation and meta-cognition, and experienced higher psychological need satisfaction. Roca and Gagne (2008) conducted a study investigating the antecedents of acceptance and intentions of use of e-learning. Results indicated that perceived competence and autonomy predicted the participants' perceived usefulness, playfulness and ease of use, which in turn predicted intentionality. A similar study found support for these relationships among teachers (Sørebø, Hallgeir Halvari, Gulli, & Kristiansen, 2009). Ryan, Rigby, and Przybylski (2006) performed a range of studies, both experimental and cross-sectional, investigating need satisfaction and its contribution to gaming experiences. Results indicated that across all studies, the participants' need satisfaction of autonomy and competence predicted a unique proportion of their enjoyment and preference for future play. Tamborini, Bowman, Eden, Grizzard, and Organ (2010) replicated the results in a similar experiment showing that all three needs mediated perceived game skills, co-playing, natural mapping, and enjoyment.

1.2. Overview of study

Results generally show that technology supports learning, over and above traditional methods. Further, students may be interested in, and motivated for, technology (Jeno, 2015; Jones & Issroff, 2007), thus m-learning and intrinsic motivation for learning a task may have a synergetic effect resulting in enhanced learning. The present study aims to investigate how a mobile application tool vs. a traditional identification tool relates to and affects students' achievement scores, intrinsic motivation, and perceived competence. The mobile application is a newly developed identification tool named "ArtsApp". The structure of ArtsApp generates more choices and also more volition than the traditional textbook. In line with SDT, choice and volition promotes a perception of satisfaction of the need for autonomy. Furthermore, the information provided during the identification process is, to a larger extent in the application than the textbook, competence-supportive due to feedback and a game-like experience during the identification process. In light of this, the following hypotheses are put forth: 1) ArtsApp contributes to higher achievement scores, perceived competence and intrinsic motivation compared to the traditional identification tool; 2) intrinsic motivation and perceived competence have an indirect effect between the identification tool used (ArtsApp, textbook) and achievement; and 3) intrinsic motivation, autonomous motivation, and autonomy support explain a unique proportion of interest in species identification and the importance of knowing species.

Within a Norwegian context, research guided by SDT has found support for SDT's basic assumption in elementary school (Olaussen, 2009), secondary education (Diseth, Danielsen, & Samdal, 2012), and upper secondary education (Jeno & Diseth, 2014). However, few studies have thus far employed a SDT perspective in higher education in Norway. As the reviews above show, generally few studies have tested how m-learning affects learning using SDT as a theoretical framework, although there have been some studies in other domains such as ICT (Legrain, Gillet, Gernigon, & Lafreniere, 2015), health studies with virtual clinicians (Williams et al., 2014), online gaming (Wang, Tao, Fan, & Gao, 2015), and online learning (K.-C. Chen & Jang, 2010; Hartnett, George, & Dron, 2011). Our study is important in further understanding how m-learning can affect student achievement, and why some mobile applications could contribute to learning gains and others might not.

1.3. Materials

The Norwegian flora is well-known and relatively species poor, but with some notable exceptions, such as the sedges (Latin: *Carex*). There are over 2000 different species of sedge across the world: 97 of them are found in mainland Norway. For new undergraduate biology students, sedges may look like grasses and other graminoids but once learned it is easy to distinguish them. Many students struggle to identify the sedges to species, and lack motivation to even try to identify this group. Traditionally, teaching and identification of sedges has been carried out using classical identification keys in the Norwegian standard plant identification book "Lids Flora" (Lid & Lid, 2005). The identification process in Lids Flora is hierarchical and makes use of dichotomous "keys". These require the students to first identify which family the plant belongs to, then, based on characteristics of the individual, students have to choose between two possibilities before moving to the next identification question. To find the right species among the 104 Norwegian species, a student usually has to go through 8–10 questions, often involving microscopic and hard-to-distinguish characteristics before ultimately finding the right species. These keys are often comprehensive and require solid knowledge of technical terms and morphology. In addition to being comprehensive and complex, the students do not see the flora as well suited to fieldwork or other practical work.

An alternative to this traditional textbook method is "ArtsApp", which was developed jointly by bioCEED—Centre of Excellence in Biology Education, the Norwegian Biodiversity Information Centre, and the Centre for Science Education. ArtsApp is available for Android smartphones and can be freely downloaded at Google play (bioCEED, 2015). ArtsApp is a mobile application that allows students to identify sedge species more dynamically with the ability to choose which of all the

characteristics of the species to determine first, and can thus start with the easier characteristics instead of having to move down in a given order. ArtsApp contains pictures of the characteristics in question, in addition to the textual descriptions (Fig. 1a and b). ArtsApp also keeps track of your progress in terms of how many species you have excluded and how many you have left to choose between before ending up with an identification. ArtsApp can also be geographically 'smart' in that it can exclude species that are not found, and therefore not relevant, in your study area.

2. Method

2.1. Participants and procedure

The participants were 71 Second-year bachelor students at a large university in Norway, 35 percent males and 65 percent females, with a mean age-class of 21–22 years ($SD = 0.97$). The students were recruited during a field course as part of a mandatory biology course. Ninety-four students were asked to participate, with the possibility to win cinema tickets for participating. Written information about the purpose of the study was given to the students before starting the experiment. All the students were assured that their answers would be treated confidentially and they were informed that the study had obtained approval by the Norwegian Social Science Data Services for research (NSD). Finally, students were told that they could withdraw from the study at any time without consequences. Students who wanted debriefing had the opportunity to talk to a trained research assistant, or contact the first author for more information. Using these methods, we obtained a response rate of 75 percent. All the participants were given the correct answers to the identification questions in plenum at the end of the field course. The experiment was conducted over three days due to time constraints of the field course.

The experimental procedure was as follows: participants were introduced to general species identification processes on the first day of the course. This general introduction included both the traditional "Lids Flora" (Lid & Lid, 2005) textbook method and the new "ArtsApp" digital method on smartphones or tablets. After this general introduction we conducted the experiment. A trained research assistant, unaware of the study hypotheses, randomly assigned the participants to one of the two conditions – the experimental condition (ArtsApp – mobile application) or the control condition (Lids Flora – textbook). The participants were then given an envelope containing information about the study, the test, and the post-experimental questionnaire. All the participants were given the following information: "In front of you there are two pieces of paper. Part 1 is the identification questions. Below that, is part 2, a questionnaire. Please start with part 1, the identification questions". The participants who were assigned to the control condition were then given the following instructions: "Kindly answer all the questions by using the textbook Lids Flora. You can use as long time as you want. If you are not able to answer a question, simply move to the next. When you are done with the questions you can start with part 2, the questionnaire. Please respond to all the questions and be as sincere as possible". Participants who were assigned to the experimental condition were given the following instructions: "Kindly answer all the questions by using your smartphone or tablet and the

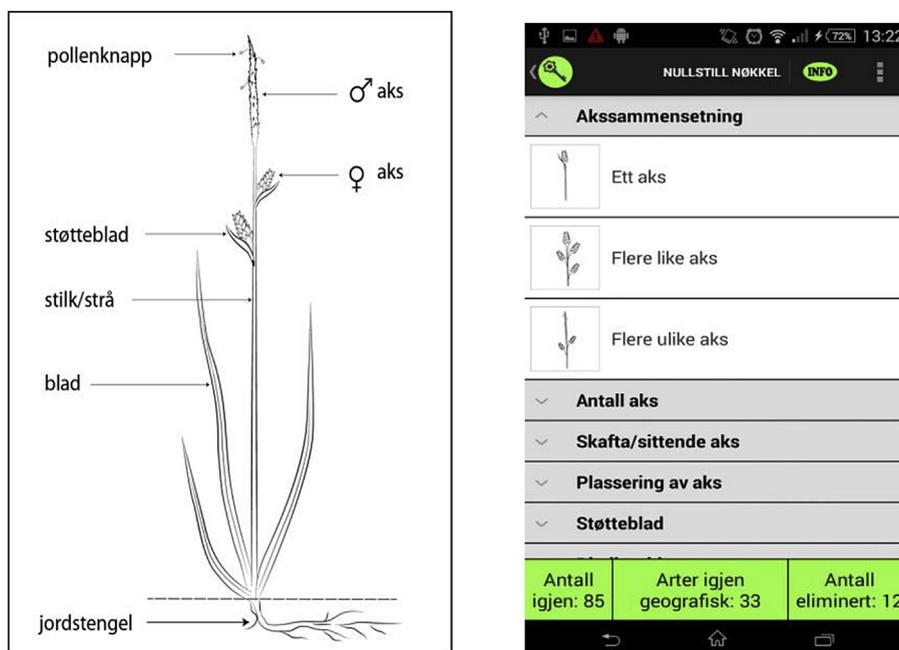


Fig. 1. Screenshots of ArtsApp: a) structure of the sedge, b) different ways to identify a species and showing at the bottom how many species are left, how many are left according to geographical location, and how many species have been eliminated.

application ArtsApp. You can use as long time as you want. If you are not able to answer a question, simply move to the next. When you are done with the questions you can start with part 2, the questionnaire. Please respond to all the questions and be as sincere as possible". All the participants in the control condition were provided with a textbook; participants in the experimental condition who did not have their own smartphone or tablet were given a tablet they could use during the experiment.

2.2. Measures

2.2.1. Intrinsic motivation

In order to measure a participant's intrinsic motivation for species identification when using the textbook or mobile application, the interest/enjoyment subscale within the Intrinsic Motivation Inventory (IMI) was employed. The IMI subscale consists of 7 items (e.g. "I enjoyed identifying species using ArtsApp/Lids Flora"), and has previously been used when assessing participants' intrinsic motivation after experiments. Previous studies have found reliable and valid psychometrics for this subscale (Deci, Eghrari, Patrick, & Leone, 1994; McAurley, Duncan, & Tammen, 1989; Ryan, Connell, & Plant, 1990). The composite variable showed high reliability ($\alpha = 0.95$, $M = 4.36$, $SD = 1.69$). A principal component analysis was performed to investigate the underlying factorial structure of the scale. The results revealed a one-factor solution with eigenvalues exceeding 1, explaining 75.7 percent of the variance, with factor loadings above 0.6.

2.2.2. Perceived competence

To assess students' perceived competence for identifying species, the subscale of perceived competence within IMI was employed. This subscale measures how efficacious participants perceive themselves and has been shown to be a good measure for perceived competence (Plant & Ryan, 1985; Ryan, Mims, & Koestner, 1983), consistent with SDT (Deci & Ryan, 1985). The scale consists of 5 items (e.g. "I think I am pretty good at identifying species"). The subscale showed good reliability ($\alpha = 0.84$, $M = 2.98$, $SD = 1.14$). Factor analysis (PCA) produced a one-factor solution with eigenvalues above 1 explaining 64.77 percent of the variance.

2.2.3. Autonomy support

To measure students' perception of autonomy support from their course teacher, the Learning Climate Questionnaire (LCQ) was chosen (e.g. "I feel that my instructor provides me [with] choices and options"). The LCQ indicates the student's perception of how much autonomy has been provided by the teachers. The scale has 6 items ($\alpha = 0.83$, $M = 4.85$, $SD = 0.99$). Factor analysis (PCA) revealed a one-factor structure for 5 items with eigenvalues above 1, explaining 60 percent of the variance. One item was omitted due to low factor loadings.

2.2.4. Self-regulation

The Learning Self-Regulation Questionnaire (SRQ-L) was employed to measure students' autonomous and controlled motivation for learning biology. The scale was adapted for the purpose of this study and consists of two subscales, three items for autonomous motivation ("I participate in class because it's a good way to improve my understanding of biology") and three items for controlled motivation ("I participate in class because I want others to see I am intelligent"). The respondents were asked to answer on a 7-point Likert-scale ranging from not at all true to very true. Autonomous motivation produced adequate alpha levels $\alpha = 0.71$ ($M = 6.3$, $SD = 0.74$). Controlled motivation produced low alpha levels $\alpha = 0.55$ ($M = 2.6$, $SD = 1.06$) below the cut-off of 0.70, which might be a concern. However, according to Cronbach (1951) and Vallerand, Fortier, and Guay (1997), scales with few items underestimate the inter-correlations between the items. The same item average with more items would have yielded an adequate alpha-level in our study.

2.2.5. Species identification questions

5 items were included concerning species identification and preference when keying. Three were control items: previous experience with species identification, previous experience with identification of sedges, and preference of identification tool (ArtsApp vs. Lids Flora). Two questions were measures of interest for identifying species and importance of knowing species.

2.2.6. Achievement

A nine-question test was used to measure students' achievement levels. The questions were developed by a biologist specialised in identifying species. Six of the items were multiple-choice concerning characteristics of sedges and three questions were about three different sedges given to the students to identify. The sedges were picked by a biologist, and presented during the experiment to the students by a research assistant unaware of the research hypothesis. Two independent raters (biologists) scored the students' answers on a sheet. Different numbers of points were given depending on the difficulty of the question. For instance, a correct answer identifying the sedges gave more points than multiple-choice items. Furthermore, students could receive partial points for making an identification of a very similar sedge. The scores on the achievement test ranged from 0 to 26. An inter-rater reliability test was conducted and showed high agreement with $\alpha = 0.97$. The nine questions on the test were combined to an observed composite variable labelled "achievement" in order to assess an overall achievement level.

2.3. Analytical strategy

All data analyses were performed with IBM SPSS 23 and IBM AMOS 23. To test for indirect effects in our model, we employed structural equation modelling (SEM). Several goodness-of-fit indices can be used to evaluate acceptable model fit in SEM. The most recommended indices are CFI, NFI, TLI, RMSEA, and χ^2/df ratio. According to Byrne (2016), CFI (Comparative Fit Index), NFI (Normed Fitted Index), and TLI (Tucker-Lewis Index) measure how well the hypothesised model fits the independent model or sample data. RMSEA (Root Mean Square Estimate Approximation) is a measure of how well the model would fit if optimal parameters were available (Byrne, 2016), while the χ^2/df is a representation of the difference between the unrestricted and restricted covariance matrix. According to Hu and Bentler (1999), CFI, NFI, and TLI > 0.95 are viewed as indicators of good model fit, while RMSEA < 0.05 is recommended (Bentler, 1990; Browne & Cudeck, 1992). A $\chi^2/df < 2$ and $\chi^2/p > 0.05$ indicate excellent model fit. Recently, however, values for CFI, NFI, and TLI > 0.90, and RMSEA < 0.08 are considered as acceptable model fit (Byrne, 2016; Kline, 2011).

There was one missing value each for perceived competence, intrinsic motivation, achievement, importance of knowing species, and interest in identifying species. Multiple imputations were carried out to account for this in the primary analyses. A total of five imputations were conducted using the pooled mean for each value. Such procedures have been recommended when the missing data are at random and are few (Schafer & Graham, 2002; Schafer, 1999). The final sample size is thus 71 for all study-variables. All variables approximated a normal distribution as shown by acceptable skewness, kurtosis, and standard deviation (Table 1). Reliability analyses and factor analyses were conducted to investigate the study measures' internal consistency and showed satisfactory values. There was a wide range in achievement indicating that the test was able to differentiate between students with different skill levels.

3. Results

3.1. Preliminary analyses

Descriptive analyses of the study variables are presented in Table 1. The majority of the students (71.8%) had no prior experience with identifying species before the experiment and very few of the students (4.2%) had experience with this particular group (sedges). A large majority of the participants preferred the mobile application to the textbook as the primary identification tool (mobile application = 71.8%, textbook = 19.7%). Students with previous experience of identifying species in general had a higher mean achievement score (experience $M = 7.82$, $SD = 3.75$, no experience $M = 6.5$, $SD = 3.27$), although the difference is not significant, $t(69) = 1.45$, $p > 0.05$. No significant difference is found between students with experience of species identification for intrinsic motivation ($t(68) = -0.187$, $p > 0.05$) or perceived competence ($t(68) = -0.017$, $p > 0.05$). We find no significant difference between those students with previous experience in identifying sedges and those with no experience in achievement ($t(69) = 0.899$, $p > 0.05$) for intrinsic motivation ($t(68) = 0.142$, $p > 0.05$) or in perceived competence ($t(68) = 0.158$, $p > 0.05$). Further, no significant difference in achievement is found between students who preferred the mobile application or the textbook ($t(63) = 0.089$, $p > 0.05$) for intrinsic motivation ($t(62) = 0.375$, $p > 0.05$) or in perceived competence ($t(62) = 0.674$, $p > 0.05$). A test of homogeneity was conducted to test for gender effect on the three dependent variables – achievement, interest in species identification, and importance of knowing species. No gender effect was found (p 's > 0.05), thus gender was collapsed across all variables for subsequent analyses.

3.2. Primary analyses

To test our first hypothesis, we compared the relative effect of the mobile application vs. textbook on intrinsic motivation, perceived competence, and achievement scores. Several independent sample t-tests were conducted. Fig. 2 a–c presents the results of the comparison along with mean scores and standard deviations. The t-tests suggest a significant difference between participants in the experimental (mobile application) and control (textbook) condition for all variables: participants using the mobile application have higher intrinsic motivation ($M = 5.44$, $SD = 1.23$) compared to using the textbook ($M = 3.24$, $SD = 1.31$; $t(69) = 7.24$, $p < 0.001$), perceived competence (mobile application; $M = 3.41$, $SD = 1.19$, textbook; $M = 2.54$,

Table 1
Descriptive statistics of the study variables.

Measures	M	Variable range	Min.	Max.	Range	SD	Skewness	Kurtosis
Achievement	6.88	0–26	0.50	16.50	16.0	3.44	0.72	0.19
Intrinsic motivation	4.36	1–7	1.0	7.0	6.0	1.69	-0.23	-0.97
Perceived competence	2.98	1–7	1.0	5.80	4.80	1.13	0.29	-0.42
Autonomy support	4.85	1–7	3.0	7.0	4.0	0.99	0.03	-0.58
Autonomous motivation	6.30	1–7	4.33	7.0	2.67	0.74	-0.92	0.14
Controlled motivation	2.69	1–7	1.0	5.0	4.0	1.06	0.37	-0.52
Importance of knowing species	5.64	1–7	2.0	7.0	5.0	1.20	-0.88	0.40
Interest in identification of species	4.38	1–7	1.0	7.0	6.0	1.47	-0.42	-0.56

Note: All variables shown are treated as continuous variables. $n = 71$ for all variables.

$SD = 0.89$; $t(69) = 3.44$, $p < 0.001$), and achievement scores (mobile application; $M = 7.78$, $SD = 3.21$, textbook; $M = 5.95$, $SD = 3.46$; $t(69) = 3.41$, $p < 0.05$). The results indicate that the experimental-condition (use of mobile application), relative to the control-condition (use of textbook), has a strong effect size (Cohens's d) on intrinsic motivation ($d = 1.73$) and perceived competence ($d = 0.82$), and a medium to strong effect on achievement ($d = 0.54$).

To test our second hypothesis, we performed a path analysis to test for the multivariate relation of the indirect effect of experiment vs. control condition on achievement through intrinsic motivation and perceived competence (Fig. 3). Five thousand bootstrap samples were conducted using maximum likelihood (ML). Model fit for our model was excellent ($p > 0.05$, $\chi^2/df = 1.0226$, CFI = 1.00, NFI = 0.98, TLI = 0.99, RMSEA = 0.019, 95% CI = 0.000–0.318). The model as a whole predicts 7 percent of the variance in achievement scores, with a significant total indirect effect ($p < 0.008$). Results from the model indicate that experimental condition (mobile application) predicts students' intrinsic motivation ($\beta = -0.60$, CI: -0.75 to -0.41) and perceived competence ($\beta = -0.38$, CI: -0.58 to -0.15), but only intrinsic motivation significantly predicts achievement scores ($\beta = 0.25$, CI: 0.018–0.44). Given these significant paths, we then conducted a Sobel test (Sobel, 1982) with unstandardised regression weights and standard errors to test the specific indirect effect of condition (mobile

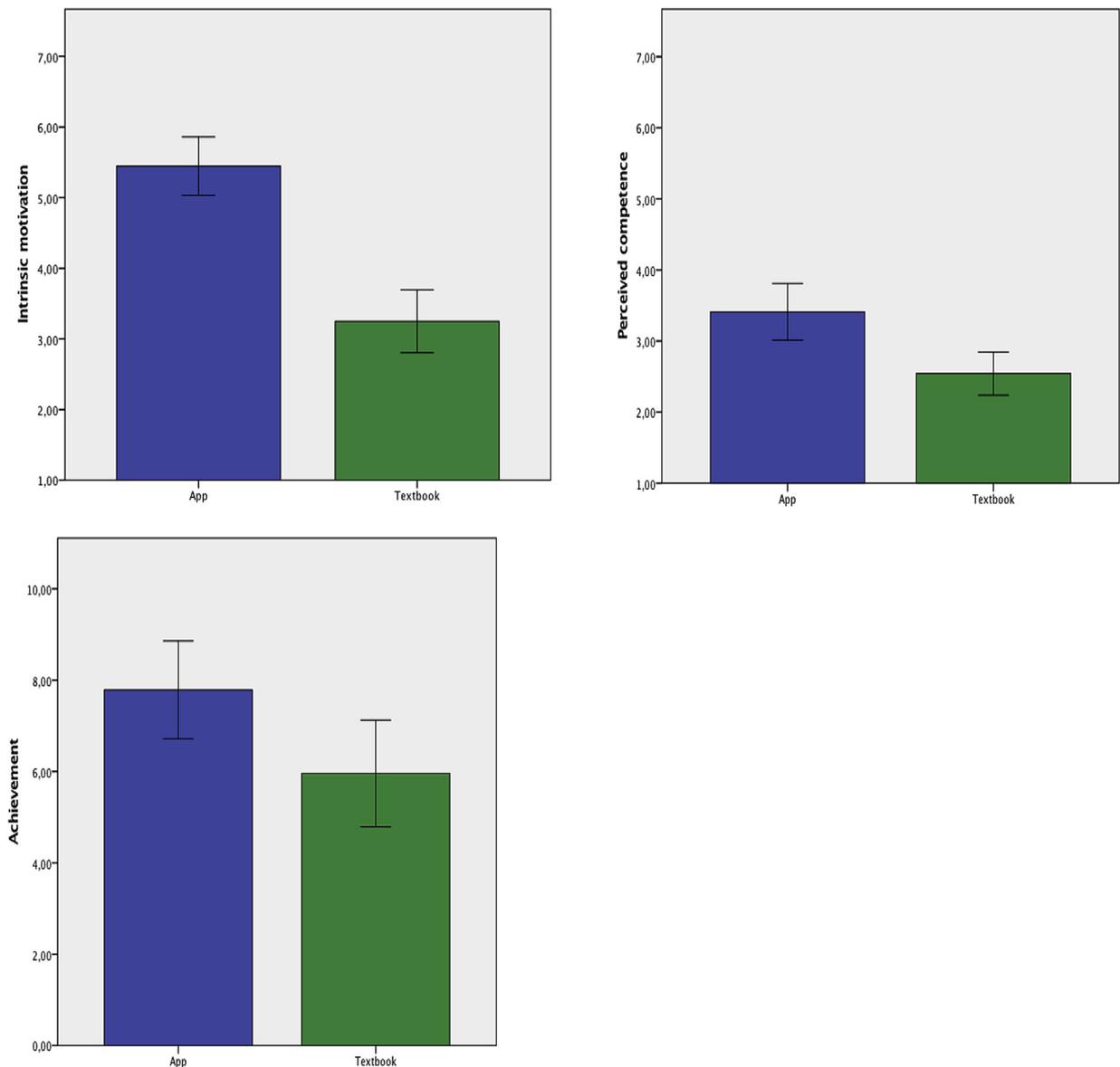


Fig. 2. a–c: Comparison of the mean results between the experimental condition (mobile application) and control condition (textbook) on the dependent variables.

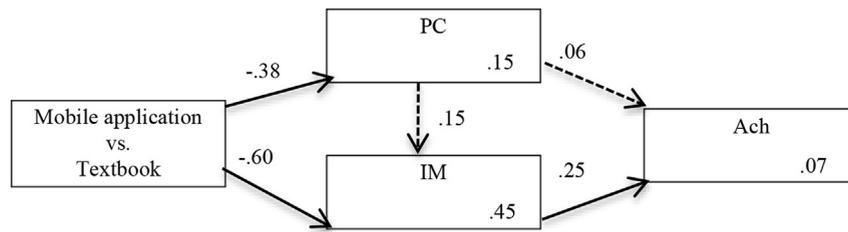


Fig. 3. Path-analysis with standardised estimates. IM = Intrinsic motivation, PC = Perceived competence, Ach = Achievement. Stippled arrows indicate non-significant paths. Total effects (R^2) are shown in mediators and dependent variables.

application vs. textbook) → intrinsic motivation → achievement. The results show that the mobile application indirectly predicts achievement, via intrinsic motivation ($z = -1.93, p < 0.05$).

To test our third hypothesis of how different motivational constructs explain participants' interest in identification of species and the importance of knowing species, we conducted a hierarchical multiple regression analysis. The results show, for interest in identification species, that models 2–5 are significant. All predictors except for autonomy support accounted for a unique and significant proportion of students' interest in identification of species (Table 2). Specifically, intrinsic motivation explains an additional 14.2 percent (sig. F change = 0.001), while autonomous motivation contributes an extra 5.7 percent of the explained variation (sig. F change = 0.002). For importance of knowing species only intrinsic motivation (beta = 0.33, $p < 0.05$) and autonomous motivation (beta = 0.39, $p < 0.001$) are significant contributors in explaining independent variance in the dependent variable. Specifically, intrinsic motivation explains an additional 6.6 percent in the model (sig. F change = 0.03), while autonomous motivation explains 12.4 percent (sig. F change = 0.002).

4. Discussion

The present study investigated the relative effect of a mobile application vs. a traditional identification tool on students' achievement and motivation in species identification using a Self-Determination Theory approach. We find a significant difference in intrinsic motivation and perceived competence between students using the mobile application compared to students using the textbook, both with a substantial effect size. Students also scored significantly higher on the achievement test when using the mobile application compared to the textbook, with a medium effect size. Thus the first hypothesis of the study, that ArtsApp contributes to higher achievement scores, perceived competence, and intrinsic motivation compared to the traditional identification tool is supported. Several interpretations can be made to account for these effects. First, the results may be a result of ArtsApp's in-built functions, which allow students more choice and effectance-relevant feedback, as

Table 2

The results of the hierarchical regression analysis along with the five predictors of our two dependent variables. Condition = Mobile application vs. textbook, IM = Intrinsic motivation, Aut. Sup = Autonomy support, Con. Mot = Controlled motivation, Aut. Mot = Autonomous motivation. $n = 71$. * $p = 0.05$, ** $p = 0.01$, *** $p = 0.001$.

Hierarchical regression analysis								
Dependent variables:	Predictor variables	Interest in identification of species			Predictor variables	Importance of knowing species		
		F	R ²	β		F	R ²	β
Step 1	Condition	0.006	0.000		Step 1	0.206	0.003	
Step 2	Condition	5.646**	0.142**	−0.010	Step 2	2.501	0.069	0.055
Step 3	IM	4.348**	0.163**	0.319*	Condition			0.278
Step 4	IM			0.501***	IM			0.340*
Step 5	IM			0.254	Step 3	1.915	0.079	
Step 5	Aut. Sup			0.437**	Condition			0.231
Step 5	Con. Mot			0.153	IM			0.294
Step 5	Aut. Mot			0.251*	Aut. Sup			0.109
Step 5	Condition	4.554**	0.216**	0.249	Step 4	2.039	0.110	
Step 5	IM			0.429**	Condition			0.227
Step 5	Aut. Sup			0.057	IM			0.288
Step 5	Con. Mot			0.251*	Aut. Sup			0.036
Step 5	Aut. Mot			0.266*	Con. Mot			0.191
Step 5	Condition	4.898***	0.274***	0.307*	Step 5	3.966**	0.233**	
Step 5	IM			0.457**	Condition			0.312*
Step 5	Aut. Sup			−0.058	IM			0.330*
Step 5	Con. Mot			0.236*	Aut. Sup			−0.133
Step 5	Aut. Mot			0.266*	Con. Mot			0.170
					Aut. Mot			0.391**

the users can make mistakes while constantly monitoring progress. Such functions that exist in the application are assumed to increase students' motivation. According to SDT, support for autonomy (i.e. choice) and competence (i.e. feedback) leads to a shift from an external to internal locus of causality, which in turn leads to intrinsic motivation (Deci & Moller, 2005; Deci & Ryan, 1985). Several empirical studies have found support for this. For instance, Vallerand and Reid (1984) found in a study among physical education students, that positive feedback predicted students' intrinsic motivation, mediated by perceived competence. In a study by Zuckerman, Porac, Lathin, Smith, and Deci (1978), students who were given choices in a puzzle with respect to activity and time had significantly higher intrinsic motivation compared to students without such choices. Second, mobile applications may enhance learning for students because of the technological aspect. Specifically, ArtsApp may facilitate student learning because it is more dynamic, game-like, and interest evoking, and thus supports a student's deep psychological need for autonomy and competence (Rigby & Przybylski, 2009). Third, as a result of the construction of ArtsApp that gives immediate feedback to students on how many sedges have been excluded from the identification process, and how many are left before identifying the sedge, the students are able to exercise their capacities during the identification process (Deci & Ryan, 1985). Thus, it provides the students with feedback, it is clear in its goals, and matches each student's skills and challenge (difficulty) closely (Csikszentmihalyi, 1990; Csikszentmihalyi, Abuhamdeh, & Nakamura, 2005; Vallerand & Reid, 1984).

A further aim of the study was to test the hypothesis that intrinsic motivation and perceived competence have an indirect effect between the study condition (mobile application vs. textbook) and achievement. Results from the path-analysis partly support this, indicating that only intrinsic motivation could be uniquely related to achievement. Specifically, the path-analysis shows that the use of ArtsApp predicts students' intrinsic motivation, which in turn predicts higher achievement. The analysis shows that the use of ArtsApp also predicts perceived competence, however perceived competence does not predict achievement. This is especially important because it explains not only the "what" association a mobile application has on achievement, but also the "how" relation. Self-Determination Theory states that when students' perceived choice and competence are facilitated, they will demonstrate higher levels of intrinsic motivation (Deci & Ryan, 1985). Intrinsically motivated students in an autonomy-supportive environment exhibit, in turn, more creative thinking, higher conceptual understanding, and more positive emotions (Benware & Deci, 1984; Koestner et al., 1984; Ryan et al., 1990), as well as a preference for challenging tasks (Deci, Schwartz, Sheinman, & Ryan, 1981). These by-products of intrinsic motivation contribute to higher achievement, but the behaviour is not performed for the external reason of achievement but for the inherent satisfaction of the behaviour (Ryan & Deci, 2000a, 2006).

The last hypothesis we tested was that intrinsic motivation, autonomous motivation, and autonomy support would independently account for interest in identifying species and the importance of knowing species. The results from the hierarchical multiple regression analysis generally support this hypothesis and are consistent with SDT reasoning. SDT suggests that when students transform an outer regulation to an inner regulation, and thus internalise the value of a behaviour, the student becomes more self-regulating (i.e. autonomous) (Deci, Ryan, & Williams, 1996). Autonomously motivated students understand the value and identify with the importance of the behaviour. Intrinsic motivation and autonomous motivation has previously been found to predict lower dropout rates (Vallerand & Bissonnette, 1992), less procrastination with schoolwork (Katz, Eilot, & Nevo, 2014; Senecal, Koestner, & Vallerand, 1995), future intentions to persist in college, and grade-point average scores (Guiffreda, Lynch, Wall, & Abel, 2013). Both interest and importance of knowing species are important aspects of biology. Therefore, having students that value vital aspects of biological knowledge and are autonomously motivated for these behaviours is expected to be beneficial at the individual-level (student learning) and the contextual-level (environmentally conscious individual able to address climate challenges). Finding ways to facilitate autonomously motivated students is hence recommended for a shift from rote-learning knowledge to higher-order cognition in species knowledge. However, based on our results, we suspect that the condition (mobile application vs. textbook) might have a suppressor effect due to its significant appearance in the last step when all predictors are included in the model (Lancaster, 1999; Smith, Jr., & Williams, 1992). That is, the condition only predicts a unique and significant proportion of importance of knowing species when controlling for intrinsic motivation, autonomy support, and autonomous and controlled motivation, indicating that the condition (using mobile application or textbook) is not important for students' perceived importance of knowing species.

In light of our results, some practical recommendations are suggested to facilitate students' learning species-identification skills. Teachers (and development of technological solutions) are thus encouraged to provide students with choices and options, optimal challenging tasks, and effectance-relevant feedback (Deci et al., 1994). Importantly, m-learning provides an informal aspect to learning, thus furthering students' learning outside of a classroom context (Sandberg, Maris, & Geus, 2011), and could also enhance learning and intrinsic motivation, as our results indicate. Some scholars argue against technological implementations in higher education, highlighting paradoxes and consequences of having technology in education (Guri-Rosenblit, 2005). Critiques suggest that m-learning may pose some challenges, for example, there might be technological difficulties, frustration with the device, time consumption, and antipathetic teachers (Gikas & Grant, 2013). Specifically, challenges such as small keypads, network issues, and using smartphones for other purposes than educational, are important concerns that could interfere with learning. However, using a smartphone in the field has several advantages for the student. Studies by Gikas and Grant (2013) and Mouza and Barrett-Greenly (2015) find that students reported that m-learning has the advantages of being able to access information rapidly, make communication with both peers and teachers easier, provides a different way of learning, and that learning is more situated, as smartphones allow greater possibilities to interact more dynamically with the real-world and with the teacher. Awareness concerning the use of technology and its limitations is important when integrating technology in an educational setting. Assurance of basic academic skills is a prerequisite of

technological skills (OECD, 2015), a notion that is also supported meta-analytically (Archer et al., 2014). Although not tested explicitly in the present study, the correlational results show that teachers' provision of autonomy support is positively associated with students' interest in identification of species, but is not a unique contributor of interest in identification of species or importance of knowing species. Our results suggest that self-motivation (i.e. autonomous and intrinsic motivation) is more important, independent of identification tool/teaching method, with respect to interest in identification and importance of knowing species.

Several limitations of the study are worth mentioning while interpreting the results. One limitation is the students' short amount of time to learn species identification. Students were introduced to sedges, ArtsApp, and Lids Flora on the first day and the experiment was conducted on the second day, which may explain the low mean scores on the achievement test. However, the results do show a difference between the mobile application and the textbook as expected. Thus, the experimental manipulation was successful. Moreover, the present study has a homogeneous sample (i.e. undergraduate students). Future studies should assess more advanced and heterogeneous students, including both undergraduate and graduate students. Motivational problems, in terms of species identification might be more prominent at the undergraduate level since the students may not have internalised the value of the behaviour (Williams & Deci, 1996). Thus the preliminary study on undergraduates is adequate for the purpose of this study. A last limitation identified is the lack of adequately assessing the novelty effect a mobile application tool might have on students' intrinsic motivation and interest in identification of species. New technologies might have a novelty effect on students, which in turn increases the students' intrinsic motivation (Lepper, 1985). On the one hand, according to Hartnett (2016), students using e-learning tools are more intrinsically motivated compared to students using traditional methods. On the other hand, Keller and Suzuki (2004) argue that the novelty effects wanes as students become accustomed to the technology. In our study we tested for differences between students with previous experience in identifying species, experience with sedges, and preference for identification tool (i.e. mobile application or textbook): we find no significant difference for intrinsic motivation, perceived competence or achievement. Although the experimental intervention (using the mobile application or textbook) was only done shortly after learning the different identification tools, these non-significant results provide initial support for a lack of novelty effect, suggesting instead the main effect of the mobile application has on intrinsic motivation, competence and achievement.

This paper presents the results of a new mobile application tool for biologists. We generally find support for our hypotheses and the basic tenets of Self-Determination Theory in the m-learning realm. Importantly, the present study adds to the m-learning literature in several important ways. First, the mobile application tool increased students' motivation and learning. Compared to the textbook, the mobile application tool facilitated students' perception of the importance of learning about identification and sedges. Furthermore, the present study has found important indirect results in line with SDT. Future studies should expand upon the design and include autonomy supportive and controlling conditions to further assess the validity of SDT in relation to m-learning. Lastly, few studies have investigated the effect of m-learning in a SDT-approach; this study narrows this gap. Future studies are needed to further understand how SDT-concepts relate to e-learning in higher education, and why students are more intrinsically motivated when employing mobile applications.

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