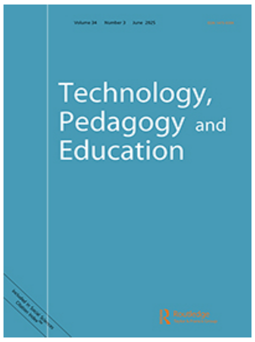

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An experimental comparison between two mobile apps for species identification from the lens of self-determination theory

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ABSTRACT

Different mobile apps may offer students different motivational and learning benefits. This study was grounded in self-determination theory and compared students´ experiences with two different mobile apps for identifying species. The authors conducted a randomised experiment to compare the effects of a dynamic interactive app with those of an image recognition app on 86 upper-secondary students. The results of the *t*-test showed only one significant effect, relative to the image recognition app, whereas the dynamic interactive app improved achievement scores. Finally, the results of the regression analyses showed that, for achievement, the dynamic interactive app, competence and class year were significant predictors. Whereas, for effort, competence and internalisation were significant predictors. More research is needed to better understand the motivational mechanisms of mobile apps and their effects on learning.

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Mobile apps; intrinsic motivation; basic psychological needs; upper-secondary students; achievement

Introduction

The use of mobile learning in education has grown as the digitisation of society has spread (Gómez-García et al., 2020; Keller, 2008). Mobile learning tools include tablets, personal computers and smartphones, which, due to their capacity to personalise and contextualise learning, may be useful for learning purposes (Crompton, 2013; Crompton et al., 2017; Looi et al., 2010). In Norway, smartphones are the most accessible mobile learning tools, as well as the tool used most frequently for learning (Fjørtoft et al., 2019). Although smartphones when used for learning may have different motivational and learning effects than traditional tools (e.g. Jeno et al., 2017), differences among smartphone mobile apps may also lead to different effects on motivation and learning (Mayer, 2020; Villalobos-Zúñiga & Cherubini, 2020). For instance, the interface design and user experience of mobile apps vary depending on the psychological learning theory that a given app is based on (Bernacki et al., 2020) and, as such, may lead to different types of motivation for learning. This in turn leads to different 'paths', which account for different

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outcomes. That is, certain mobile apps designed on the basis of a specific pedagogical or motivational theory provide a different motivational and learning path than other mobile apps that are based on a different pedagogical or motivational theory (Peters, 2022). Thus, it is important to address how these different mobile apps create different paths affecting students' motivation and learning to further our understanding of how to optimise mobile app design.

Motivational theories have rarely been used to investigate the effects of different apps applied to biology learning on upper-secondary students' motivation (Crompton et al., 2017; Valtonen et al., 2022). Investigating different mobile apps designed to solve the same task provides an understanding of how these affect personal attributes such as motivation and achievement and is an important research avenue to solve both theoretical and practical problems (Clark, 1983). That is, which mobile app design is more effective at solving a task and enhancing performance is an important practical problem to solve, whereas understanding the mechanisms driving this difference is an important theoretical problem to solve. This is a research area that is still less understood (Shi & Kopcha, 2022).

Hence, to address these limitations, this study seeks to investigate the motivational and achievement effects of two different mobile apps designed for species identification. The purpose is to ascertain whether differences in how the students interact with the technology affect their motivational processes and whether these differences affect these students' achievement outcomes.

Theoretical framework

In this study, we employ self-determination theory (SDT: Ryan & Deci, 2017) to investigate our hypotheses. We have chosen SDT for several reasons. Firstly, SDT offers a broad framework that specifies the conditions under which students exhibit intrinsic and self-determined motivation as well as the conditions under which these types of motivation are undermined (Deci et al., 1991). Secondly, SDT makes clear assumptions about what constitutes optimal learning conditions for students (Ryan & Deci, 2001). This may be useful for investigating whether different mobile learning tools, theoretically, should have an optimal effect on student motivation and achievement. Finally, SDT has been applied in similar domains, such as video gaming, watching television and technology design (Adachi et al., 2017; Peters et al., 2018; Rigby & Ryan, 2011), which allows us to build on both theory and previous empirical research.

According to SDT, the psychological need for competence (experiencing effectance and mastery) and for autonomy (experiencing choice and agency) must be satisfied for one to exhibit intrinsic motivation and internalisation (Ryan & Deci, 2002). Intrinsic motivation refers to doing an activity because they find it inherently enjoyable and interesting, whereas internalisation refers to the transformation of external behaviours into internal behaviours (Ryan & Deci, 2017). Intrinsic motivation has been shown to have a positive impact on a host of behavioural, affective and cognitive outcomes (Fishbach & Woolley, 2022; Howard et al., 2021), and is characterised by curiosity, interest and exploration (Ryan & Deci, 2017). Internalisation, when compared to intrinsic motivation, has a differential effect on achievement, effort and behavioural outcomes as the result of activities being experienced as more useful or valuable

(Burton et al., 2006; Deci et al., 1996). In other words, in contrast to intrinsic motivation, internalisation is characterised not by interest and enjoyment but by persistence and the investment of effort in valuable or meaningful activities (Koestner & Losier, 2002).

Mobile apps, motivation and learning

Several characteristics of mobile apps are of potential benefit for achievement. For instance, affordances such as interactivity, adaptivity, feedback, choice, linked representations and communication with others have been identified as being of benefit for motivation and achievement (Graesser et al., 2022). Furthermore, the potential for seamless learning in both formal and informal contexts provides unique opportunities (Wong & Looi, 2019). Several studies support this line of reasoning. For instance, in a study by Hwang and Chang (2011), a mobile app designed as a tour guide to provide scaffolding and formative feedback in a local culture course was better at improving student motivation and achievement than a tour guide mobile app that gave students summative feedback, presumably because formative feedback and scaffolding support the need for competence. Similarly, in a study of biology students, researchers found that students who used a dynamic interactive mobile app rather than a digital textbook scored significantly higher on the psychological need for competence and autonomy (Jeno, Vandvik, et al., 2019).

In contrast, other studies partially support the difference among mobile learning tools and apps. In a pre-test/post-test quasi-experiment, Nicolaidou et al. (2021) found higher achievement scores among students using a virtual reality app rather than a mobile app for language learning, but made no such finding with regard to interest. Similarly, a recent study found that an interactive e-book enhanced student achievement but not intrinsic motivation when compared to a static PDF book (Yorganci, 2022). In general, mobile learning has had mixed results in terms of effectiveness. For instance, while some meta-analyses and systematic reviews show positive effects on achievement (e.g. Güler et al., 2021; Tingir et al., 2017), others show negative effects (e.g. Amez & Baert, 2020; Kates et al., 2018).

Mechanisms potentially accounting for these discrepancies may relate to the design of the technologies and how the technologies are used and implemented to support student achievement (Lillejord et al., 2018; Marker et al., 2018; Schmid et al., 2014). For instance, mobile apps that satisfy the psychological need for competence and autonomy at the user interface and task-specific levels are more likely to be engaging, motivating and growth-promoting (Peters et al., 2018). As such, when a study is investigating the impact of different mobile apps on student motivation and achievement, it is important to consider the differences in how the apps have been designed when interpreting the results. In other words, when evaluating motivational and learning effects, it is important to consider the differences in the technologies in the various apps' affordance of satisfaction of the need for competence (such as scaffolding, dense feedback, achieving goals, levelling-up) and for autonomy (such as authenticity and realistic situations and meaningful choices) (Ryan & Deci, 2017).

Research purposes and hypotheses

The context of this study is biology education and species identification, specifically of seaweed species. Species identification, within biology, is the process of identifying a species on the basis of its traits and characteristics. Traditionally, this process has been carried out by way of dichotomous ‘keys’ that allow the user to employ a series of sequential questions with only two possible answers each. One typically starts at a higher taxonomical level before moving on to more specific characteristics. This is a hierarchical process that requires students to have a high level of content knowledge to correctly identify a species. With technological advances, several alternatives have been developed. We report on two such alternative approaches which are available to students seeking to identify biological species in Norway and which are easier for novice students to use: dynamic interactive keys (ArtsApp) and machine-learned image recognition (Artsorakel).

Features of mobile apps

‘ArtsApp’ (University of Bergen, 2017) is a dynamic interactive app that allows the user to start by choosing any trait or characteristic in the process of species identification. ArtsApp informs the user of how many species remain following the selection of different traits in the identification process and provides detailed information about each species, including drawings and pictures of the species. The user can reset the identification process at any time and start over. See Figure 1a for images of ArtsApp being used for the identification process.

‘Artsorakel’ (Norwegian Biodiversity Information Centre, 2021) is a machine-learned image recognition app that allows the user to identify a species by either directly taking a picture of the species or by uploading a picture of the species from the photo library. The app compares the image uploaded by the user with species observations previously uploaded to the database and provides the user with several suggestions as to what species it might be. The app provides the user with an accuracy percentage for each suggestion according to how well the image matches previous species’ observations. See Figure 1b for images of the identification process in Artsorakel.

Hypotheses

The literature review shows mixed results in terms of differences in the impact of mobile learning on motivation and achievement. While some studies find positive motivational and achievement effects (e.g. Hwang & Chang, 2011), other studies find no or little difference (e.g. Nicolaidou et al., 2021) between the effects of mobile apps and the effects of other mobile learning tools on motivation and achievement. In accordance with the theoretical framework of SDT (Ryan & Deci, 2017), we expect that the dynamic interactive app ArtsApp (University of Bergen, 2017), compared to the image recognition app Artsorakel (Norwegian Biodiversity Information Centre, 2021) will satisfy the students’ need for autonomy and competence because the dynamic interactive app provide optimal challenges, feedback and information, and meaningful choice. Previous studies testing the effect of dynamic interactive apps support this assumption (Jeno, Adachi, et al., 2019; Jeno et al., 2017). Further, because of the satisfaction of autonomy and

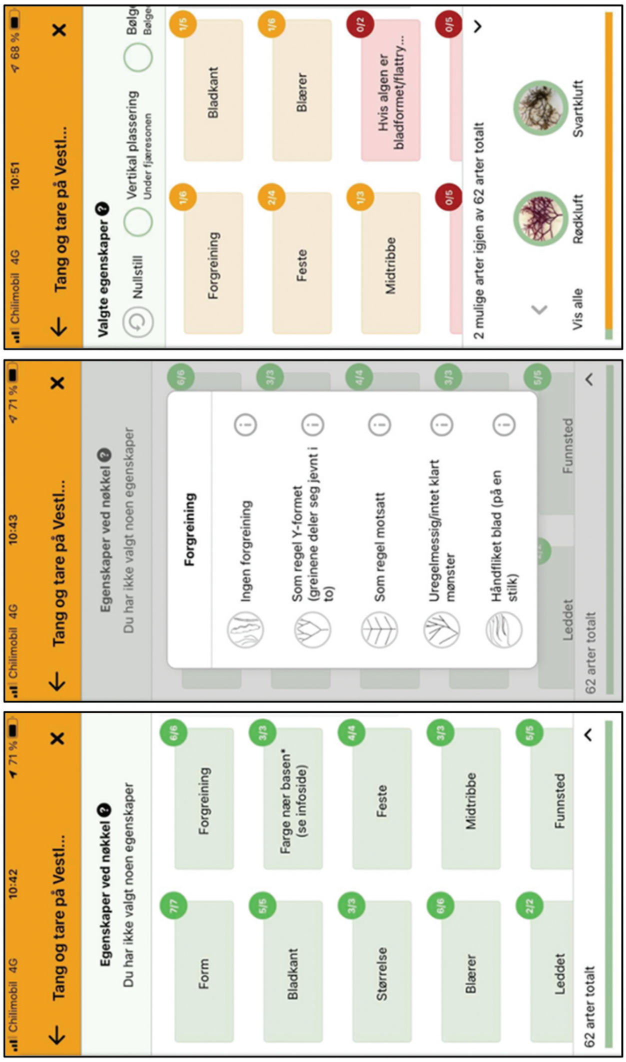

Figure 1a. Screenshot of the identification process in ArtsApp. The text is in Norwegian.

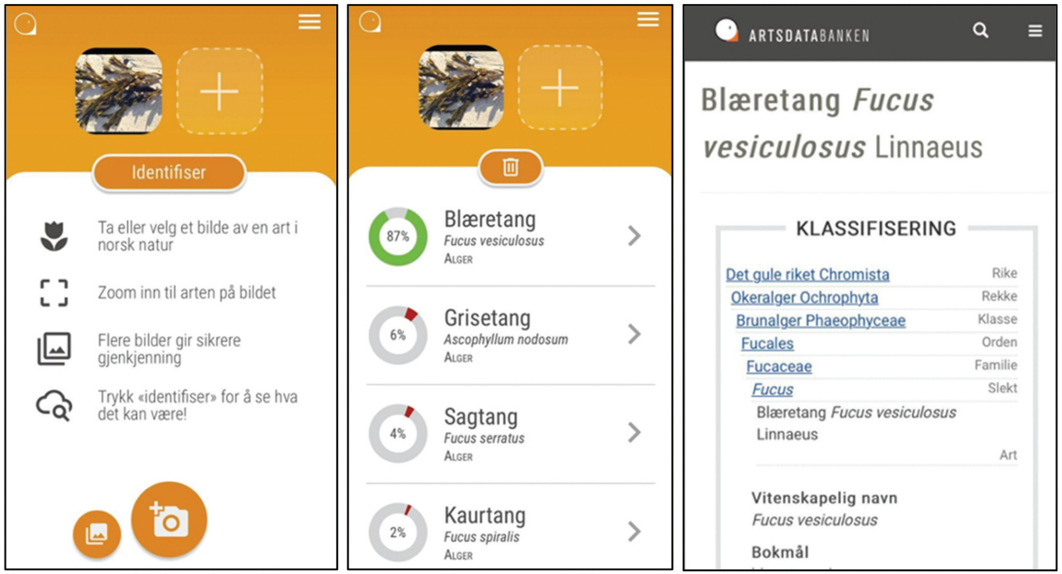

Figure 1b. Screenshot of the identification process in Artsorakel. The text is in Norwegian.

competence within the dynamic interactive app, we expect higher levels of intrinsic motivation, internalisation and effort. In contrast, due to the machine learning technique and differences in students' species identification skills, we expect the image recognition app to lead to a greater increase in student achievement scores, compared to the dynamic interactive app. This is due to the step-by-step identification process inherent in the dynamic interactive app which may be prone to more error, compared to the ability to recognise a species using the image recognition app.

Finally, the within-app experience of need satisfaction (i.e. competence and autonomy), intrinsic motivation and internalisation are expected to enhance student achievement and effort with regard to species identification (e.g. Ryan et al., 2006). We expect this independent of app (dynamic interactive app vs. image recognition app), although previous studies (e.g. Jeno et al., 2017) and theoretical propositions within SDT would suggest that the dynamic interactive app would enhance achievement and effort due to the satisfaction of autonomy and competence.

On the basis of previous studies, theoretical propositions and the differences in the user interfaces of the two mobile apps in question, we propose the following list of hypotheses:

- The dynamic interactive app, compared to the image recognition app, will enhance intrinsic motivation, internalisation and effort (H1a).
- The image recognition app, compared to the dynamic interactive app, will enhance student achievement scores (H1b).
- Achievement and effort will be predicted by the dynamic interactive app (relative to the image recognition app), need for competence and autonomy, intrinsic motivation and internalisation (H2).

Methods

Participants

The participants ($n = 86$) were biology/natural science upper-secondary students from three different schools in Norway. Five different upper-secondary schools in a large city in Norway were contacted to participate, of which three schools accepted. Biology/natural science students were chosen because species identification is part of the curriculum for these students, and the mobile apps are designed for use with some basic level of biology knowledge. The gender distribution based on students own responses was as follows; women = 70.9%, men = 18.6%, other = 7%, and did not want to respond = 3.5%. The mean age of the participants was 17.44 (min = 16, max = 25). The gender distribution between women and men is common in biology and the natural sciences in upper-secondary education (Norwegian Directorate for Education and Training, 2022). Students from all three class years participated; 46.5% ($n = 40$) were year one, 18.6% ($n = 16$) were year two and 34.9% ($n = 30$) were year three (i.e. senior year).

Procedure

After we received permission from the school principals and class teachers to conduct our study, the students were asked to participate. Participation was voluntary, and the participants were allowed to withdraw from the study at any time. After the students arrived in their respective classes, their desks were separated from each other by one metre in order to signal that each student should work independently. Each desk had a large sheet of paper on which eight pieces of seaweed were laid out. These seaweeds were used by the students to identify to species level. Each species was given a number from one to eight. The students were given a glass with fresh seawater and a plastic glove for use in the inspection and identification of the species. The students in the present study already had substantial background knowledge from their original curriculum. However, to diminish any differences in prior knowledge of general ecology, seaweed and species identification in general, a 15-minute presentation on seaweeds was given by the second author. This presentation contained the basic information the students needed to know about the identification of species and the ecology of the species group. The validity of this information was ensured by conferring with an ecology expert. Students were then given a three-part questionnaire consisting of 1) information about the study, 2) a species identification test, and 3) a questionnaire for self-reporting. In the first part, addressing information about the study, the students were randomised to use either ArtsApp ($n = 43$: experimental condition) or Artsorakel ($n = 43$: control condition) as their tool for species identification. The front page and the length of the text were identical, with the only difference being the identification tool they were to use in the experiment. The purpose of the identical appearances was to reduce the likelihood of the students detecting any differences in their conditions. Similar approaches have been used by Vansteenkiste et al. (2004) and Jeno et al. (2020). The students were asked to use their smartphones to identify the species and download their respective apps. We were prepared to offer students a tablet, but none was needed. The students were asked to stick with their designated identification tool and, when they were done with the species identification test and the questionnaire, to sit quietly at their desks and use their smartphones. This request was made to further minimise differences between the two conditions, given that one of the tools takes longer to use (i.e. the dynamic interactive app takes longer than the image recognition app). After the experiment, the students were thanked, given some information about the study and permitted to ask follow-up questions. The students had no questions. No compensation was given for participation. The experiment lasted one hour.

Measures

Below we provide information for the scales used to measure the SDT-relevant constructs employed in our study. We also provide information on the reliability of each scale (Cronbach's alpha), usually with reliability levels of ≥ .75 considered acceptable (Crano et al., 2015). All items from our measures are provided in the Appendix.

Competence

To measure the participants' need for competence when using the identification tools we employed the three-item Player Experience of Need Satisfaction (PENS) scale (Ryan et al., 2006). The participants responded according to a 7-point Likert scale ranging from 1 (*not true at all*) to 7 (*very true*). An example item is: 'My ability to use ArtsApp/Artsorakel matches the challenges of identifying species'. Cronbach's alpha was satisfactory ($\alpha = .79$).

Autonomy

The three-item PENS scale (Ryan et al., 2006) was used to measure the participants' need for autonomy when using the identification tools. Participants responded using a 7-point Likert scale ranging from 1 (*not true at all*) to 7 (*very true*). An example item is: 'I experienced a lot of freedom in ArtsApp/Artsorakel'. Cronbach's alpha was good ($\alpha = .88$).

Intrinsic motivation

To measure the participants' intrinsic motivation, we used the seven-item 'interest/enjoyment' subscale from the Intrinsic Motivation Inventory (IMI) (McAurley et al., 1989). An example item is: 'I enjoyed identifying species using ArtsApp/Artsorakel'. Participants responded using a 7-point Likert scale ranging from 1 (*not true at all*) to 7 (*very true*). Cronbach's alpha for this scale was $\alpha = .92$.

Internalisation

Internalisation was measured using the seven-item 'value/usefulness' subscale derived from the IMI (McAurley et al., 1989). The participants responded using a 7-point Likert scale ranging from 1 (*not true at all*) to 7 (*very true*). An example item is: 'I believe species identification has some value for me'. Cronbach's alpha for this scale was $\alpha = .94$.

Effort

To measure the participants' effort, we used the five-item 'effort' subscale from the IMI (McAurley et al., 1989). Participants responded using a 7-point Likert scale ranging from 1 (*not true at all*) to 7 (*very true*). An example item is: 'I did not put much energy into species identification' (reversed). Cronbach's alpha was satisfactory ($\alpha = .74$).

Achievement

To measure achievement, the participants were asked to identify eight different seaweed species. The species were differentiated by number, and the students were asked 'Which species is number 1, 2, 3' etc. To quantify the achievement, the student was given four points for each correct species identification. If the student suggested a species that bore a high level of resemblance to the correct species, the student was given two points, whereas for suggestions that had only a slight resemblance the student was given one point. For incorrect identification (i.e. neither correct nor with a resemblance in accordance with our criteria), the student received no points. This scoring system was predetermined in consultation with a biologist. A similar procedure has been used in studies with a similar methodological design (e.g. Jeno et al., 2017, 2020). We created a composite score of achievement with a maximum score of 32 and a minimum of 0.

Data analysis

All statistical analyses were conducted using the statistical program R version 4.2.0 (R Core Team, 2018). All codes are openly available for reproducibility purposes at GitHub (https://github.com/artsapp). To conduct preliminary analyses we used the package 'psych' (Revelle, 2018), to conduct descriptive statistics and correlational analysis of our study variables.

To analyse our main hypotheses, we first conducted independent *t*-tests to investigate the main effect of the study condition (dynamic and interactive app vs. image recognition app) on intrinsic motivation, internalisation, effort, and achievement (H1a and H1b). To test for the assumption of homogeneity of variance, we conducted Levene's Test, and *p*-values > .05 were necessary before we could test for main effects. To see the effect sizes for the main effect, we employed the R-package 'pwr' (Champely, 2018) and 'effectsize' (Ben-Shachar et al., 2020). We used Cohen´s *d* as a measure of effect size with effects considered small, medium and large when at 0.2, 0.5 and 0.8, respectively (Cohen, 1988). Secondly, two forward stepwise linear regression models were conducted to investigate whether our study variables predicted achievement and effort (H2). The selection criteria for final model were based on AIC (Akaike Information Criteria). In forward stepwise linear regression, we started with an intercept-only model and added independent variables, one at a time (Tabachnick & Fidell, 2007). It is important to note that all variables included in the forward stepwise linear regression models are either theoretically founded, or control variables. Before inspecting the models and the contribution of each predictor, we tested for the following assumptions: homogeneity of variance, linearity, collinearity and normality of residuals. To test for the assumptions, we employed the packages 'performance' (Lüdecke, Ben-Shachar, et al., 2021) and 'see' (Lüdecke, Patil, et al., 2021).

Results

Descriptive statistics of the study variables

The results from the descriptive statistics for the motivational measures and achievement are presented in Table 1. There is no sign of violation of normality for any of the study variables. The correlation matrix of the study variables is all in the expected direction (Table 2). Specifically, competence, autonomy, intrinsic motivation and internalisation all correlate positively with achievement. The findings were similar for effort and the same variables.

Main effects of study variables

To test the mean differences between the mobile apps on the motivational and achievement measures, we conducted a range of independent *t*-tests (Table 3). The results

Table 1. Descriptive statistics of the study variables.

Variables	*n*	Mean (*SD*)	Skewness	Kurtosis	Min	Max	Range
1. Competence	81	4.00 (1.43)	.04	−.93	1.33	7	5.67
2. Autonomy	83	4.49 (1.59)	−.50	−.39	1.00	7	6.00
3. Intrinsic motivation	83	4.70 (1.52)	−.29	−.72	1.14	7	5.86
4. Internalisation	83	4.48 (1.51)	−.19	−.68	1.00	7	6.00
5. Effort	85	5.25 (1.13)	−.29	−.69	2.60	7	4.40
6. Achievement	86	14.30 (8.35)	−.11	−1.07	0.00	30	30.00

Table 2. Correlational matrix of the study variables.

Variable	1	2	3	4	5
1. Competence					
2. Autonomy	.64**				
	[.49, .75]				
3. Intrinsic motivation	.70**	.75**			
	[.56, .80]	[.63, .83]			
4. Internalisation	.41**	.50**	.57**		
	[.21, .58]	[.31, .64]	[.40, .70]		
5. Effort	.43**	.45**	.40**	.40**	
	[.23, .59]	[.26, .61]	[.21, .57]	[.20, .56]	
6. Achievement	.45**	.35**	.42**	.27*	.46**
	[.26, .61]	[.14, .52]	[.22, .58]	[.06, .46]	[.27, .61]

M and *SD* are used to represent mean and standard deviation respectively. Values in square brackets indicate the 95% confidence interval for each correlation. *indicates $p < .05$. **indicates $p < .01$.

Table 3. Mean differences between study conditions and study variables.

	Artsorakel	ArtsApp			
Variables	Mean	Mean	*t* (df)	95% CI	*d*
1. Competence	3.86	4.13	−.85 (77.57)	−.90–.36	−.19
2. Autonomy	4.35	4.63	−.79 (80.98)	−.97–.41	−.17
3. Intrinsic motivation	4.57	4.81	−.72 (80.45)	−.90–.42	−.16
4. Internalisation	4.57	4.38	.55 (77.55)	−.48–.85	.12
5. Effort	5.09	5.38	−1.16 (82.57)	−.77–.20	−.25
6. Achievement	11.69	16.90	−3.02 (83.86)**	−8.63 – −1.78	−.65

** indicates $p < .01$. 95% confidence interval (CI) indicates that the true difference in mean between the study conditions is not equal to 0. *d* indicates the effect size between the conditions measured in Cohen's *d*.

showed one significant difference for achievement, suggesting that students who used ArtsApp (the experimental condition) scored significantly higher on the achievement test than did the students using Artsorakel (the control condition). The effect size for this mean difference was medium (Cohen, 1988).

Linear models of achievement and effort

Finally, two linear regression models were performed to investigate how well condition (ArtsApp vs. Artsorakel), competence, autonomy, intrinsic motivation and internalisation together predicted achievement and effort. We also used gender and class year as control variables. We initially employed multiple regression analyses. Due to overlapping variance among our predictors, one should interpret the final model with care with any multiple linear regression, but this merely gives an impression of how well the study variables potentially can explain the variance in the response variables. Thus, we preceded with forward stepwise linear regression. The results are presented in Table 4. When modelling achievement (Model 1), we found that condition (ArtsApp), class year (second- and third-year students), and competence positively predicted achievement. The model accounted for 33% of the variance in achievement, $F(5,76) = 8{,}44$, $p < .001$. Finally, when modelling effort (Model 2), only internalisation and competence positively and significantly predicted effort. The model accounted for 29% of the variance in effort, $F(3,78) = 12{,}04$, $p < .001$.

Table 4. Linear regression models.

Variable	Beta	β	t-value	p	Adjusted R^2
Model 1: Achievement					.314***
Intercept	−1.82		−.63	.52	
Condition (ArtsApp)	4.09	.25	2.68	.008**	
Class year (second year)	2.94	.13	1.36	.177	
Class year (third year)	4.70	.27	2.81	.006**	
Competence	1.65	.28	2.25	.027*	
Intrinsic motivation	1.08	.19	1.55	.123	
Model 2: Effort					.29***
Intercept	2.89		7.24	.000***	
Competence	.19	.24	2.00	.048*	
Autonomy	.16	.22	1.75	.083	
Internalisation	.16	.22	2.01	.047*	

Condition coded 0 =Artsorakel and 1 = ArtsApp. Gender coded 0 = Men, 1 = Women.
Class years coded 1 = Year 1, 2 = Year 2, 3 = Year 3. * indicates $p < .05$, ** indicates $p < .01$.
***indicates $p < .001$.

Discussion

This study sought mainly to investigate the motivational and achievement effect of two different apps for species identification. In general, we found little support for our hypotheses. Below we provide an interpretation of these unexpected results.

The results from our comparison between the dynamic interactive app (ArtsApp) and the machine-learned image recognition app (Artsorakel) provide no support for our hypotheses. Specifically, we found no mean differences between our two mobile apps on the motivational variables, which is in line with similar studies measuring different mobile learning tools and student motivation (e.g. Nicolaidou et al., 2021; Yorganci, 2022). That is, we did not find that either mobile app enhanced competence, autonomy, intrinsic motivation, internalisation or effort. This was surprising given that previous research has found support for increases in motivational variables with similar dynamic interactive apps used as species identification tools (Jeno, Adachi, et al., 2019; Jeno et al., 2017). One explanation for this surprising finding may be the novelty effect (Rogers, 1983); that is, when students are introduced to new, complex and modern products, they are more curious about and interested in these products (Kashdan & Silvia, 2009). This has been corroborated within the mobile learning literature (e.g. Jeno, Vandvik, et al., 2019) in which two mobile learning tools have been rated by students in a randomised experiment as more novel than a traditional tool. Thus, the novelty of the mobile apps may account for the absence of a difference between the conditions in our study, especially for intrinsic motivation. That is, the differences in the levels of interest and enjoyment (i.e. intrinsic motivation) in the two conditions may be the result of similarities in the novelty and aesthetic pleasures (proxies of interest) of the mobile learning tools (Deci, 1992). Further work is needed to verify this. Similarly, the process of internalisation may require more maturity and personally held values and commitments, which may not have occurred during this experimental study (Vansteenkiste et al., 2018). This may explain why we failed to find any effect of study condition on internalisation.

The only significant finding indicated that the students using the dynamic interactive app scored significantly higher on the achievement test than the students using the automatic image recognition app. The effect size for this difference was medium. This finding was surprising, given that we expected the students using the image recognition app to score higher on the achievement test. This unexpected finding may be due to the differences in the user interfaces of the apps. For instance, although the image recognition app provides the user with a percentage of accuracy, one can never be certain that this recognition is correct. Furthermore, this app does not itself provide the user with the means to identify the species further to confirm or falsify the names suggested by the app, which thus requires either an additional identification tool or prior knowledge. It may also be the case that the classroom setting in which the experiment was conducted did not allow the image recognition algorithms to fully capture the species characteristics. This may account for the lack of correct recognition. In contrast, the dynamic interactive app provides several features that allowed the students to identify the species and use drawings and photos of species to compare species. Furthermore, because the dynamic interactive app provides users with informative information about species traits and characteristics, it may depend less on the user having prior knowledge in order to correctly identify the species. These are features that facilitate the satisfaction of the psychological need for competence and autonomy (Ryan & Deci, 2017; Villalobos-Zúñiga & Cherubini, 2020).

Our final hypothesis was supported only in part. The results from our regression model showed that competence and the dynamic interactive app were significant predictors of achievement. The model as a whole explained a third of the variance in the achievement measure. These results are in line with previous studies on mobile apps (Felisoni & Godi, 2018; Jeno, Vandvik, et al., 2019), video games (Ryan et al., 2006; Tamborini et al., 2010) and watching television (Tamborini et al., 2011) that have shown that competence and within-technology need-support are key drivers of performance. Specifically related to competence, our findings may suggest that clarity and mastery of functionalities and clear and representational feedback (such as visualising progress) are important factors in satisfying the need for competence (Rigby & Ryan, 2011), which in turn has been shown to enhance a range of outcomes. It was surprising that the dynamic interactive app (relative to the image recognition app) predicted achievement. Yet, as discussed above, the natural surroundings required for an image recognition app may have explained the lack of correct species identification. An additional result of our regression model showed that third-year students scored higher on the achievement test. This suggests that more advanced students scored more highly than less advanced students. This is not surprising, given that more experienced students have greater abilities and more prior knowledge than less experienced students. As regards effort, only internalisation and competence were unique contributors in explaining effort. It was surprising that internalisation predicted effort, and not intrinsic motivation, as have been shown in previous research (e.g. Jeno et al., 2020). However the co-occurrence of these factors can be distinctive given the context (Vansteenkiste et al., 2018), which may explain these findings. Furthermore, when students see the importance and value of a behaviour, it energises goal commitment and goal orientations (Johansen et al., 2023; Koestner & Losier, 2002). Finally, in line with our expectations, and SDT (Ryan & Moller, 2017; White, 1963), competence positively predicted effort,

Limitations

Several limitations are worth mentioning prior to interpreting the results. Firstly, the sample size was small. Although comparable studies have used similar sample sizes (e.g. Jeno, Adachi, et al., 2019; Jeno, Vandvik, et al., 2019) and found statistical significance, the lack of statistical significance for most of the variables in our study using this particular sample (i.e. upper-secondary students) and form of manipulation (i.e. comparing two apps) may be due to low power. Future studies should strive for larger sample sizes and more heterogeneous samples.

Secondly, the experiment was of short duration. A longer period spent interacting with the technologies and getting accustomed to them might have affected intrinsic motivation and internalisation in particular. Internalisation is a process that may take more time because full internalisation requires awareness, maturation and self-understanding (Vansteenkiste et al., 2018). Hence, we recommend that future studies have a longer period of experimentation to allow participants more time to familiarise themselves with the identification tools, the species and the identification techniques and thus allow for a more integrated and harmonious process of internalisation. This may be more prominent in achievement, as the internalisation was a significant predictor of effort.

Finally, we did not measure actual learning but, rather, the extent to which the students were able to identify species correctly. An interesting line of research would be to investigate whether students can identify species without the mobile apps and the extent to which they have learnt the different characteristics of the species, and ability to identify species during a follow-up test. This might give us an indication of the extent to which the students had a different learning process based on the two mobile apps. We recommend that future studies test for this learning effect.

Conclusion

Despite these limitations, this study contributes to our understanding of how differences in mobile apps affect upper-secondary students' motivational processes and achievement. The lack of significant differences in many of the motivational constructs suggests that neither of the mobile learning tools is superior with regard to increasing student motivation. This may suggest that, in a given context, students may benefit equally from either mobile learning tools in terms of motivation. However, with regard to achievement outcomes, there was a clear benefit to using the dynamic interactive app. Hence, in a classroom context, there is the potential for students to identify more correct species on average using the dynamic interactive app. Although more research is needed to establish generalisation across samples and educational levels, the present study has provided some initial evidence (or lack thereof) of how differences in mobile apps affect student achievement and effort.

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Appendix

Competence

- My ability to use ArtsApp/Artsorakel matched the challenges of identifying the species
- I feel very capable and effective when identifying species with ArtsApp/Artsorakel
- I feel competent at identifying with ArtsApp/Artsorakel

Autonomy

- I experience a lot of freedom in ArtsApp/Artsorakel
- I can always find something interesting to do with ArtsApp/Artsorakel
- ArtsApp/Artsorakel provides me with interesting options and choices

Intrinsic motivation

- I enjoyed identifying species with ArtsApp/Artsorakel
- Identifying species with ArtsApp/Artsorakel was fun to do
- I thought it was boring to use ArtsApp/Artsorakel (R)
- Identifying species with ArtsApp/Artsorakel did not hold my attention at all (R)
- I would describe identifying species via ArtsApp/Artsorakel as very interesting
- I thought identifying species via ArtsApp/Artsorakel was quite enjoyable
- While I was using ArtsApp/Artsorakel, I was thinking about how much I enjoyed it

Internalisation

- I believe identifying species could be of some value to me
- I think that this activity is useful for increasing my understanding of species
- Identifying species is important because it can increase my understanding of species
- I would be willing to identify species again because it is of some value to me
- I think identifying species could help me understand more biology/natural science
- I believe identifying species may be beneficial for me
- I think identifying species is an important activity

Effort

- I put a lot of effort into identifying species
- I didn't try very hard to do well at identifying species (R)
- I tried very hard to identify species
- It was important to me to do well at identifying species
- I didn't put much energy into identifying species (R)

Achievement

- Which seaweed is number 1?
- Which seaweed is number 2?
- Which seaweed is number 3?
- Which seaweed is number 4?
- Which seaweed is number 5?
- Which seaweed is number 6?
- Which seaweed is number 7?
- Which seaweed is number 8?