Mobile learning as instruction prompt guidance to support the inquiry-based learning process: an experimental study on primary school students

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Abstract

The effect of guidance for supporting student inquiry-based learning in a computer learning environment has been investigated. However, the effect of mobile learning guidance tools during an inquiry-based learning session in a non-virtual learning environment has rarely been investigated. The aim of this study was to investigate the impact of mobile learning guidance tools specifically on the learning experience and learning outcomes of primary students involved in an inquiry physical (non-virtual learning) science training session. A control group was involved in a conventional learning inquiry-based learning and an experimental group used mobile learning guidance for studying astronomy during an inquiry-based learning session. The findings showed that the mobile learning approach improves the learning experience of primary students, regardless of their initial knowledge of the subject studied. The mobile learning and the conventional approaches significantly improved primary students' learning outcomes with no clear benefit for either condition.

Keywords

Mobile learning, learning experience, learning outcomes, inquiry learning, Primary school students

Résumé

L'effet d'un outil de guidage en mobile learning au cours d'une session d'apprentissage basée sur l'investigation dans un environnement d'apprentissage non virtuel a *rarement été étudié. L'objectif de cette étude est d'examiner l'impact des outils de ce guidage sur l'expérience d'apprentissage et les apprentissages des élèves du primaire participant à une session de formation en sciences. Un groupe contrôle a participé à une formation conventionnelle basée sur l'investigation et un groupe expérimental a utilisé des outils de guidage mobile lors d'une même session de formation en astronomie. Les résultats ont montré que l'approche guidée via mobile learning améliore l'expérience d'apprentissage des élèves du primaire, quelles que soient leurs connaissances initiales du sujet étudié. Les deux approches ont néanmoins amélioré de manière significative les résultats d'apprentissage des élèves du primaire, sans aucun avantage significatif pour l'une ou l'autre des conditions.*

Mots–Clés
Apprentissage mobile, expérience d'apprentissage, résultats d'apprentissage, démarche d'investigation, élèves du primaire

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Introduction

The use of digital technology in schools and more particularly mobile learning is growing (Crompton et al., 2016). Mobile learning refers to the act of learning using handheld devices such as digital tablets, mobile phones or laptops. It involves the mobility of learning, technology and the learner (El-Hussein & Cronje, 2010; El-Sofany & El-Haggar, 2020; Ligi & Raja, 2017).

Much research on the use of digital tools and especially mobile learning is ongoing in multiple domains and at all levels (Arain et al., 2018; Chen & Huang, 2023; Crompton et al., 2016; Huang et al., 2020; Rusmono et al., 2019), including for science in primary schools (Crompton et al., 2016). In many studies, the use of mobile learning in the classroom improves learning outcomes (Crompton et al., 2016; Rusmono et al., 2019; Suprianto et al., 2019) as well as the learning experience of students (Chen et al., 2022; Huang et al., 2016; Leung & Cheng, 2019). Moreover, recent evidence highlights that digital tools may have varying impacts on low and high achievers in terms of engagement and learning performance: it facilitates high achievers' engagement (Chen et al., 2022) and improves low and high learning students' achievement (Li et al., 2021).

Through a scope literature review on inquiry-based mobile learning in secondary school science education, Liu et al. (2021) demonstrated how the topic has already been investigated in the past decade. Nevertheless, according to our knowledge, inquiry-based mobile learning applied to primary school science education has been much more rarely investigated. Moreover, when mobile learning is integrated in the inquiry-based approach, this technology is usually used as an autonomous learning environment and not as a support for guiding students across non-virtual activities (Zacharia et al., 2015). Considering, the few studies investigating the use of mobile learning in the inquiry-based learning approach for primary school students in astronomy (Fleck & Simon, 2013; Fleck et al., 2015; Midak et al., 2020) none of them used mobile learning as a guidance tool through the different stages of the investigation process.

In this study we will pay particular attention on the role of the mobile learning approach for an astronomy subject in primary schools. The main objective of this research is to study the impact of the use of a mobile learning for guiding students across the inquiry-based learning activities and its specific influence on the learning outcomes and learning experience. According to the previous studies we expect to find a difference in the impact of learning experience, especially engagement and learning outcomes in favour of the high achiever students (Chen et al., 2022).

Theoretical framework

Mobile learning as cognitive support

Despite the lack of studies investigating the role of mobile learning in inquiry-based learning at primary school, the effect of using mobile learning on learning outcomes has been investigated in different classroom contexts at primary schools (Crompton et al., 2016; Rusmono et al., 2019; Suprianto et al., 2019). In most studies, such as Arain et al. (2018) and Rusmono et al. (2019), the approach was to apply experimental methods to compare the use of a mobile learning tool with the use of more conventional classroom tools, showing that mobile learning improves students' learning outcomes (Arain et al., 2018; Chen & Huang, 2023; El-Sofany & El-Haggar, 2020; Huang et al., 2020; Rusmono et al., 2019; Suprianto et al., 2019; Zhonggen et al., 2019).

Rusmono et al. (2019) noted significant changes in the learning outcomes of primary school students compared with the use of conventional teaching materials. The use of mobile learning allows primary school students to significantly increase their learning outcome scores regardless of their starting level.

The use of mobile learning may be coupled with human intervention in order to improve students' learning outcomes (Huang et al., 2016). Similarly, Huang et al. (2020) showed that cooperative learning around a mobile learning tool improved the learning outcomes of primary school students on natural science topics.

Mobile learning for learning guidance

The level of guidance across learning activities may strongly impact the learning process. Moli et al. (2016) showed that a high level of guidance during learning simulation about density helped students better understand such a complex scientific concept. In the same way, Chamberlain et al. (2014), explored how the level of guidance may affect student engagement with an interactive simulation. Interestingly, they found that a high degree of guidance negatively impacted student engagement. While a correct proportion of guidance during learning activity has to be respected, there is no unique way to guide learners across activities. Hence, de Jong and Lazonder (2014) proposed a first typology of guidance composed of three main types: heuristics, scaffolds and direct presentation of information. Later and based on other studies on guidance in computer-supported inquiry learning (de Jong, 2006; Van Joolingen & de Jong, 2003; Veermans, 2003 etc.). Zacharia et al. (2015) updated this first typology: process constraints, performance dashboard, prompts, heuristics, scaffolds, direct presentation of information. In our study, mobile guidance is considered as prompt guidance. Prompts come in the form of assignments asking them to explain the observed phenomenon or in the form of question-prompts (and feedback) allowing students to assess their own learning.

Mobile learning as learning experience support

Learning experience refers to the process by which students reflect on their personal experience. Through the interactive process of learning experience, students gain personal experience with which they understand the main elements of learning tasks (Huang et al., 2016; Kolb et al., 2001). While the learning experience may be analysed in different ways, in this study, we focused our approach on the studies by Huang et al. (2016) and Fu et al. (2009). Fu et al. in 2009 defined the experience of "egame flow" in dimensions including autonomy, feedback, immersion and social interaction, also called peer instruction. Huang et al. (2016) identified learning experience through other dimensions: engagement, competence, challenge and interest. Hence, in our study four dimensions from those previous studies were investigated: engagement, challenge, interest and peer instruction.

Mobile learning impact on low and high achievers' learning activities

Li et al. (2021) showed that the device offered to students, whether high or low achievers, had no impact on the students' experience. Mobile learning improves the intrinsic motivation and learning strategy (metacognition and resource management) of low achiever students (Wang & Jou, 2023). The use of mobile learning allows low achiever students to improve their learning outcomes as they have the opportunity to practise the lesson for a longer time (Figueiredo et al., 2016). As with low achiever students, the use of inquiry-based digital learning allows high achiever students to increase their performance including their problem-solving skills used in inquiry-based learning (Sotiriou et al., 2020). This positive impact of digital skills is stronger for low-achieving students (Pagani et al., 2016; Vavasseur et al., 2020). Moreover, Yusoff and Mazwati (2018) showed that during inquiry-based learning, low achievers express their opinions more easily and show a higher capacity for concentration and engagement whereas low performing students were led to develop better reasoning skills.

Inquiry-based learning approach

The concept of inquiry-based learning can be defined in many different ways (Suárez et al., 2018). However, Pedaste et al. (2015) based on a meta-analysis of 32 articles tried to identify a trend among the multiplicity of studies approaching this teaching method. They constructed an inquiry-based learning framework with five phases, as summarized in Table 1: Orientation (fostering the learners' "curiosity"), conceptualization (drawing up research questions and hypotheses), investigation (exploring and experimenting phase), conclusion (phase of identifying the main findings), discussion (a phase which is transversal to the other phases, fostering communication and reflection). This framework is seen as a circle including many relationships and feedback loops between the different phases (Mayer et al., 2014; Pillar et al., 2018; Yanto et al., 2019; Zimmerman, 2000).

TABLE 1

Summary of the five phases of the inquiry-based learning framework

Phases	Definition
Orientation	The phase fostering the learners' curiosity and the statement of the problem to be solved.
Conceptualization	The phase of the generation of research questions and hypotheses.
Investigation	The phase allowing learners to explore or experiment, to collect and analyse data based on the designed protocol.
Conclusion	The phase allows learners to note findings and compare them with the tested hypotheses. At the end it is possible to identify the main findings extracted from the data analysis.
Discussion	Is a transversal phase including communication and reflection. Communication is defined as the process of debating, discussing or sharing with others any information seen during the other phases of the inquiry. Reflection is connected to the idea that the learners have to make sense about what they are learning during the different phases of the inquiry circle.

It is important to note that, in our context, the French curriculum promotes the inquiry approach at primary school. The teaching scenario proposed in this study is based on the inquiry model drawn up by Pedaste et al. (2015).

Common misconceptions about the alternation of night and day

Apart from the use of innovative tools, one of the main obstacles to learning about the alternation of day and night comes from pupils' misconceptions. These misconceptions deal with the conceptions that students may have. When students come to the classroom, they already have a few ideas and beliefs about the world and phenomena around them. These ideas influence how children perceive the world, how they interpret it and how they acquire new knowledge. However, misconceptions, the conceptions with which students comes to the classroom, can be a hindrance to understanding a concept, even when it is a complex concept such as the alternation of day and night. This is why it is necessary for the teacher to gather the students' conceptions from the beginning of the class (Megalakaki & Labrell, 2009).

This misconceptions deal with different categories like : (1) the construction of the Earth-Sun system, which may or may not include the Moon in its generality, (2) the position and apparent movement of the Sun, (3) the shape of these objects (Earth and Sun), (4) the place occupied by people (a specific point on the Earth), (6) the movements and interactions between them and (7) conceptions of the model of the alternation of day and night (Frède & Venturini, 2006; Jelinek, 2020). These misconceptions must be considered by teachers from the outset, since it is these conceptions that will evolve as students learn. Six misconceptions that students bring into the classroom have been clearly identified in the literature : (1) the Sun goes behind hills, (2) clouds cover the Sun, (3) the Moon covers the Sun, (4) the Sun goes behind the Earth once a day, (5) the Earth goes around the Sun once a day, (6) the Earth spins on its axis once a day (Baxter, 1989).

In tackling a demanding scientific subject, it becomes crucial for researchers and education practitioners to discern learning scenarios that facilitate knowledge acquisition and foster engaging learning experiences. Consequently, this study aims to delve into the utilization of mobile learning as prompt instruction guidance during inquiry-based education for young students. Given the limited exploration of this objective in the scientific literature, this study seeks to contribute to bridging the gap between research and practice in science education.

Research question and hypotheses

The aim of this study is to investigate the impact of a mobile learning tool, as prompt instruction guidance, on learning outcomes and learning experience in a primary school inquiry-based science learning context. We ask the following question: how does the use of mobile learning as prompt guidance impact the learning experience and learning outcomes of primary school students?

Based on the literature review, three hypotheses are tested:

1. The use of mobile learning as a guidance tool improves primary students' learning outcomes.
2. The use of mobile learning as a guidance tool enhances primary students' learning experience.
3. The use of mobile learning as a guidance tool enhances specifically the learning experience of low achiever primary students.

Material and method

Samples

An experimental protocol was set up to address the research questions. The sample consisted of 42 primary students (9.7 years old) from French primary schools. The students participated in a face-to-face training session for 90 minutes. The session was run by the two usual teachers.

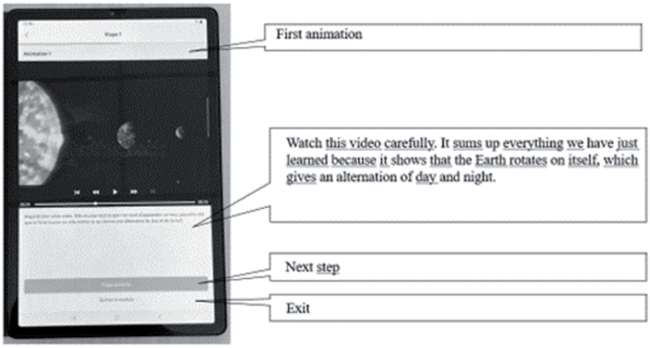
The experimental group (n=23) learned with the mobile learning prompt guidance system and the control group (n=19) learned with conventional learning materials. In both groups, the inquiry process allowed students to alternate between individual work, small work groups (3 students) and a whole-class group for the discussion phase.

Materials

Both groups (control and experimental) followed a very similar science education training about the alternation of day and night. The course content for the two groups is identical. During the activities, students dealt with concepts necessary to understand the alternation of night and day.

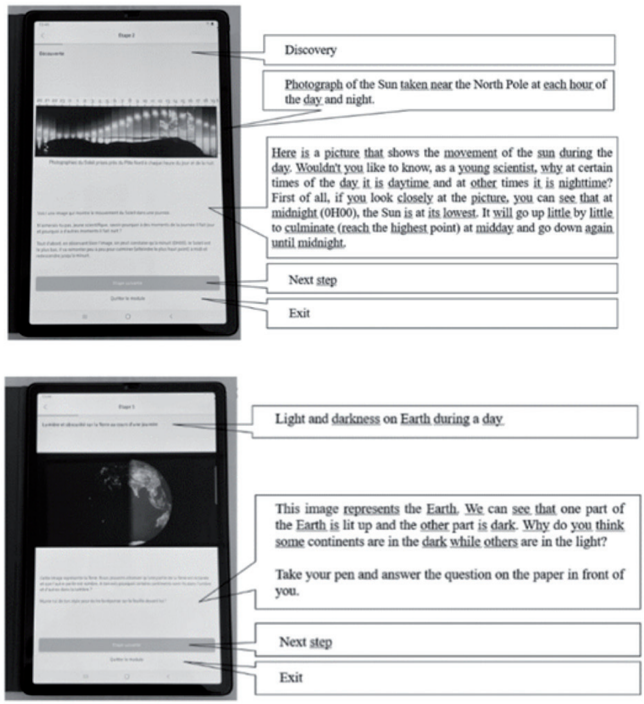
The experimental group used tablets integrating the guidance tool designed beforehand by the authors of the study on the *ARTEfac* app. *ARTEfac* (Aix-Marseille-Université, 2020) is a free mobile learning application which created at Aix-Marseille University by researchers and an instructional designer with the support of university science trainers. In this application it is possible for teachers to create multimedia mobile activities. The inquiry scenario was composed of documents, 3D animation, videos and quizzes (Figure 1a and Figure 1b). with digital prompt guidance coming to reinforce the teacher guidance for the experimental group. In our research context, the use of the mobile learning tool (*ARTEfac*) did not require any prior learning. The students used the application for the very first time. And they were not familiar with using a digital in different leaning contexts. But we considered that the affordance of the tool makes *ARTEfac* easier to use.

FIGURE 1a



Example of a 3D animation and prompt guidance (English translation from French)

FIGURE 1b



Example of images and prompt guidance (English translation from French)

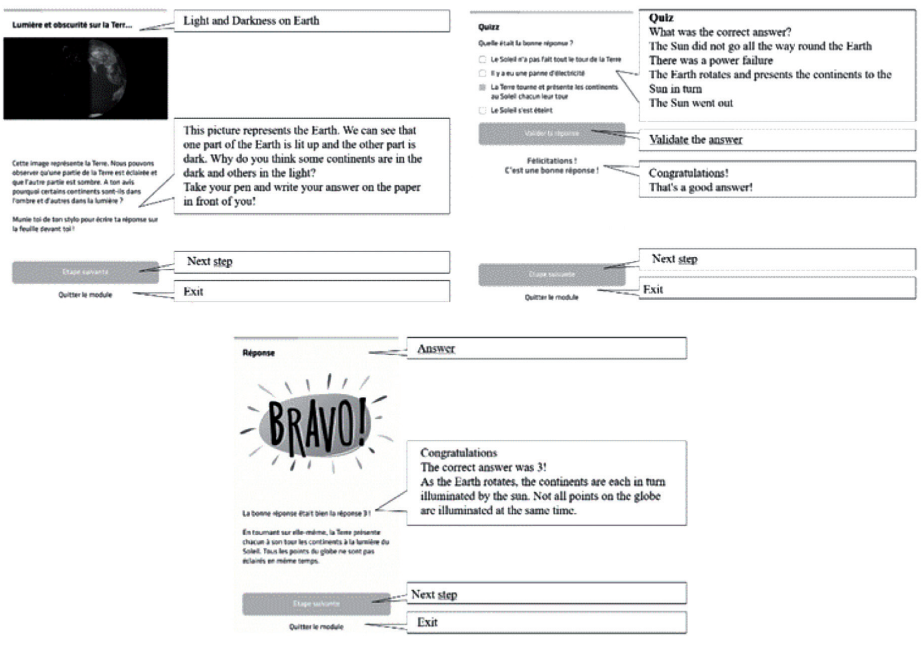
The control group used conventional materials (mainly paper documents, images and videos projected on the board) and benefited only from the teacher guidance across the different inquiry-based steps (whereas the same learning material with prompt guidance was available on the tablets for the experimental groups).

Teaching scenario

The main objective of the training session was to understand the phenomenon of the alternation of day and night. The teaching scenario tackled the common misconception about the alternation of night and day. Hence, the students had to follow an educational scenario consisting of six main steps following an inquiry-based approach.

The teacher began with a context and introduction by putting the student in the position of an experimenter and more particularly a "young scientist" through a role-play scenario that presents the objective of the session. The students were guided through the first steps by pictures with explanations in text format representing the apparent movement of the Sun, the Earth in shadow and light and a quiz (quiz to focus their attention on the most important concepts).

FIGURE 1c



Example of images (as quiz) proposed to the students (English translation from French)

Once the students had taken the quiz (Figure Ic) and had understood that the Earth rotates on itself and that not all points on the globe are lit at the same time, they moved on to the second phase of the scenario: experimentation. Then, the teacher started the experimentation phase where the students were able to use the different models proposed by the teacher for the experimentation. This stage begins with a whole-class experiment. The teacher proposed a class activity based on the manipulation of a globe and a torchlight. Throughout this activity, students worked in small groups with torchlights representing the Sun and Earth globes in order to check their hypotheses. In this way, the teacher introduced the Earth's direction of rotation, its axis of rotation and its rotational motion to help students continue the activities on their own. Afterwards, to stabilize understanding of the night-day process, the students observed two 3D animations covering the different themes discussed above as well as the Earth's revolution around the Sun, supported by explanatory texts. Finally, the teacher led the students to answer the question posed at the beginning of the session. The students concluded with the experiments carried out in class (Table 2).

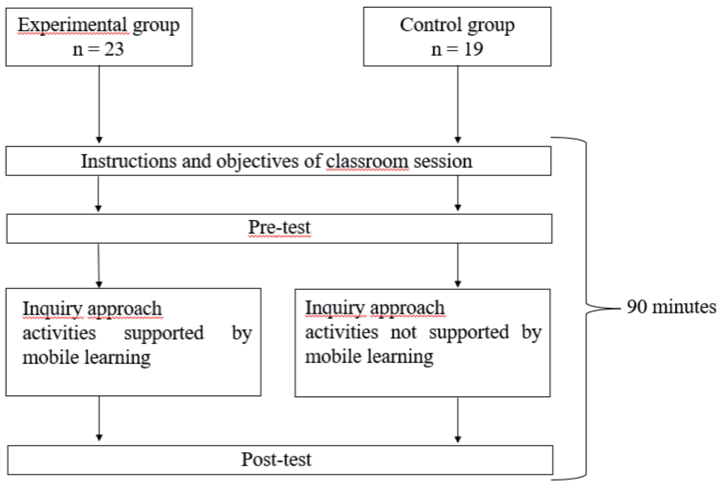
TABLE 2

Treatment conditions in experimental and control groups across the inquiry phases

Inquiry phases	Steps of the learning scenario	Experimental group: mobile learning material and digital guidance	Control group: conventional material and guidance not digitally supported
Orientation	Step 1: introduction	Image of the apparent movement of the Sun with explanatory prompt guiding text inviting students to focus on the most important information.	Image of the apparent movement of the Sun with overhead projector and oral explanation.
	Step 2: questioning students	Image of the Earth (day and night) and quiz available on tablets with prompt feedback inviting students to reflect and respond again if the answer is wrong or continue if the answer is right.	Image of the Earth (day and night) with overhead projector and pen and paper quiz with oral teacher feedback.
Conceptualization	Step 3: hypothesis generation	Tablet prompt guidance inviting students to discuss and list hypotheses with the teacher.	Teacher invites students to discuss and list hypotheses.
Investigation	Step 4: experimentation Step 5: experimentation viewing 3D animation	Modelling night and day alternation using Earth globes and flashlights. Short movie of day and night alternation on tablets with prompt guidance inviting students to be focused on the most important aspects of the movie.	Modelling night and day alternation using Earth globes and flashlights. Short movie of day and night alternation with overhead projector.
Conclusion	Step 6: conclusion viewing 3D animation	Reading a text and viewing a short movie of the solar system on tablets with prompt guidance inviting students to focus on the most important aspects of the text and the movie.	Reading a text and viewing a short movie of the solar system with overhead projector with teacher guidance.

The protocol for testing our hypotheses is summarized in Figure 2. The time devoted to completing in pre- and post-tests was approximately 10 min for each of them. Hence, slightly more than one hour was devoted to the science training session for each treatment condition.

FIGURE 2

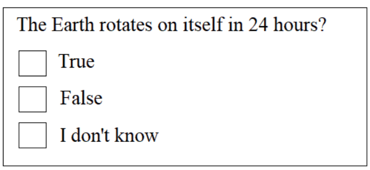


Summary of the protocol: difference and similarity between experimental and control groups

Testing learning outcomes and learning experience

The pre-test consisted of a questionnaire measuring the students' initial knowledge (see example of an item in Figure 3). The questionnaire is identical for the experimental and the control groups and was based on five closed questions on the targeted knowledge of the alternation of day and night. The students could choose to tick only one of the three answers given ("true", "false" or "I don't know"). A correct answer is coded 1 while an incorrect or "don't know" answer is coded 0. We chose to include a "don't know" answer to avoid random answers. The total score for learning outcomes is calculated out of five points.

FIGURE 3



Item 3 assessing learning outcomes (English translation from French)

During the post-testing phase, the questionnaire measuring knowledge was used just after the training session (strictly identical to the pre-test knowledge questionnaire) (Figure 3). Moreover, a second questionnaire assessing the students' learning experience was also administrated during this phase (Figure 4). In our study, we chose to use closed questions to measure the different dimensions of the students' learning experience. We made this choice to compensate the different levels of written expression of the students. Indeed, it will be easier for a young student to self-assess his or her level of agreement by choosing an answer to tick, rather than arguing in writing. Hence, this questionnaire consisted of 12 closed questions. Each group of three items measures different dimensions of the learning experience (engagement, challenge, interest and peer instruction). We are aware that the dimension of student engagement comprises three axes: the behavioural dimension, the cognitive dimension, and the affective dimension. However, in the context of our study we will focus on the affective dimension of students, i.e. the attitudes and feelings of the student towards the activities proposed in class (Archambault & Vandenbossche-Makombo, 2014). The students' answers were coded as follows: 0 for totally disagree, 1 for disagree, 2 for agree and 3 for totally agree. This test was adapted from Huang et al. (2016) and Fu et al. (2009).

FIGURE 4

(1) The activities made me happy ☐ Totally agree ☐ Agree ☐ Disagree ☐ Totally disagree	(4) I think that the activities proposed by the teacher are difficult ☐ Totally agree ☐ Agree ☐ Disagree ☐ Totally disagree
(7) Participating in this activity increased my curiosity about science ☐ Totally agree ☐ Agree ☐ Disagree ☐ Totally disagree	(10) I think that the activities allowed me to work in a group with my classmates ☐ Totally agree ☐ Agree ☐ Disagree ☐ Totally disagree

Learning experience assessment, some examples: items 1 (engagement), 4 (challenge), 7 (interest) and 10 (peer instruction) (English translation from French)

Statistics

None of the sample comparisons met the assumption of normality (Shapiro-Wilk test; $p<0.05$. Thus, nonparametric tests were used in the present study. However, an exception was found when considering the comparison of experimental and control groups regarding learning experience (Shapiro-Wilk test; $p>0.05$). Thus, parametric tests were used in this specific case. The significance level is considered at $p=0.05$ or lower. More specifically, significant results were interpreted as follows: $p<0.05$, significant (*); $p<0.01$, highly significant (**); $p<0.001$, very highly significant (***) and $p>0.05$, not significant (NS). All the statistical analyses were computed using the R software (V. 4.1.3).

In order to investigate the impact of mobile learning on lower and higher achievers, each student in both conditions was classified as a lower achiever when his or her initial pre-test score was below the class median (experimental: n=14; control: n=12) or a higher achiever when the pre-test score was above the median.

Results

Influence of mobile learning on learning experience

Table 3 shows that the experimental group has a significantly higher average learning experience (composed of the four learning experience dimensions) than the control group (experimental group=1.70 and control group=1.02). This difference was tested using an independent samples t-test, which revealed a very highly significant difference between the two groups, $t(33)=4.67$, $p<0.001$.

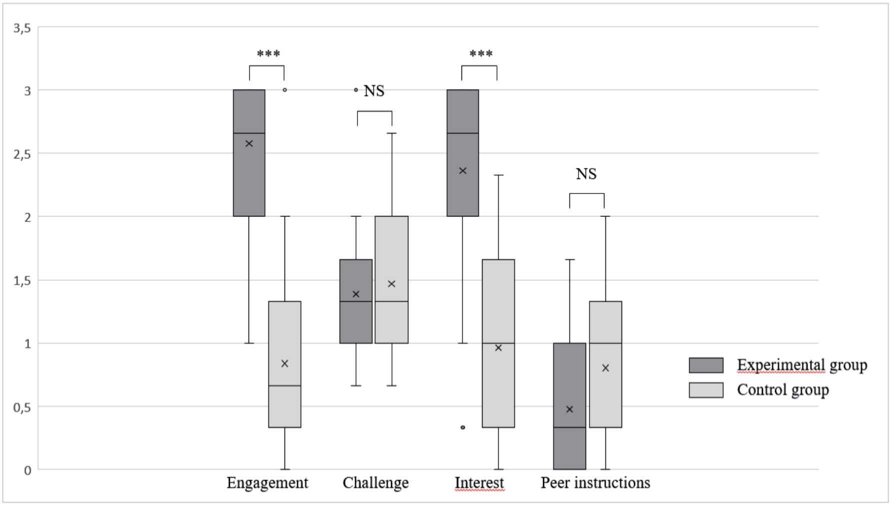
Table 3

Comparison of learning experience scores of the experimental and control groups

	Learning experience, global mean (out of 4)	P-value (Mann-Whitney)
Experimental	4.35	p=0.002**
Control	3.21	

Figure 5 details the four analysed dimensions of the learning experience. The experimental group has better learning experience in engagement (M=2.58) and interest (M=2.36) than the control group (engagement=0.84 and interest=0.96). This difference was tested using a Mann-Whitney test, which revealed highly or very significant differences between the two groups (engagement: $p<0.001$ and interest: $p<0.001$). By contrast, we find no significant differences between the two groups for the two indicators challenge ($p=0.58$) and peer instruction ($p=0.06$).

FIGURE 5



Comparison of learning experience scores (means) of the experimental and control groups. The cross represents the average score, the horizontal bars represent inter-individual medians, amplitude of rectangles the 25%-75% deviation of the individual data and the vertical bars the min-max deviations of the individual data

Impact of mobile learning on learning experience of lower and higher achiever students

Table 4 and Table 5 illustrate learning experience global scores of lower achievers (Table 4) and higher achievers (Table 5) in experimental and control groups. The lower achievers obtained a significantly better score in the experimental group (M=1.69, p=0.004) than in the control group (M=1.08). Similarly, the higher achievers in the experimental group obtained a better learning experience score (M=1.72) than those in the control group (M=0.92, p=0.007).

TABLE 4

Comparison of learning experience means of the lower achievers in the experimental and control groups

Lower achiever students	Learning experience, global mean (out of 4)	P-value (Mann-Whitney)
Experimental	1.69	p = 0.004**
Control	1.08	

TABLE 5

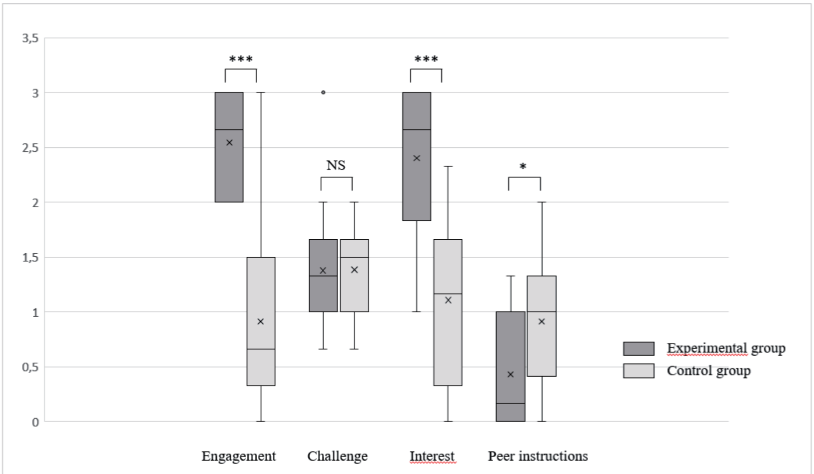
Comparison of learning experience means of the higher achievers in the experimental and control groups

Higher achiever students	Learning experience, global mean (out of 4)	P-value (Mann-Whitney)
Experimental	1.72	$p = 0.007^{**}$
Control	0.92	

According to Figure 6, the lower achievers obtained significant better engagement (M=2.55) and interest (M=2.40) scores in the experimental group than in the control group (engagement: M=0.92, p< 0.001 and interest: M=1.11, p=0.001). However, the low achievers in the control group tend to interact more with one another. Hence, the peer instruction dimension is significantly higher (p=0.05) in the control group (M=0.92) than in the experimental group (M=0.43). No significant difference is noted for the challenge (experimental: M=1.38 and control: M=1.39; p=0,69).

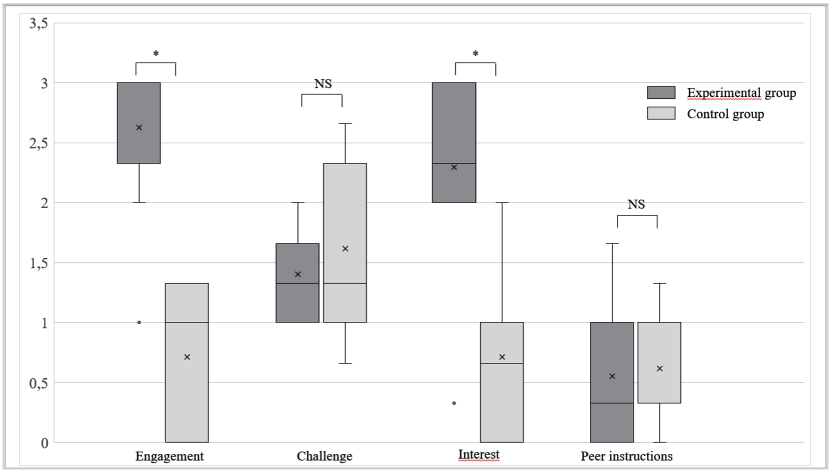
The higher achievers in the experimental group obtained significantly better scores in engagement (M=2.62, p=0.002) and interest (M=2.30; p=0.006; Figure 7) than those in the control group (engagement=0.71 and interest=0.71). However, there is no significant difference for the dimensions challenge (experimental=1.40 and control=1.61, p=0.66) and peer instruction (experimental=0.55 and control=0.62, p=0.7) for the higher achievers.

Figure 6



Learning experience scores (means) of the lower achievers in the experimental group and the lower achievers in the control group. The cross represents the average, the horizontal bars represent inter-individual medians, amplitude of rectangles the 25%-75% deviation of the individual data and the vertical bars the min-max deviations of the individual data

Figure 7



Comparison of learning experience scores (means) of the experimental higher achiever and control higher achiever groups. The cross represents the average, the horizontal bars represent inter-individual medians, amplitude of rectangles the 25%-75% deviation of the individual data and the vertical bars the min-max deviations of the individual data

Impact of mobile learning on learning outcomes

Table 6 illustrates a significant improvement in learning outcomes for the experimental group and the control group in pre-test (p=0.002) and in post-test (p=0.04). However, as shown, there was no significant difference in progression for either group (p=0.68).

TABLE 6

Learning outcome scores of the experimental and control groups in pre- and post-tests

	Mean learning outcomes: pre-test (out of 5)	Mean learning outcomes: post-test (out of 5)	p-value (Wilcoxon paired)
Experimental	4.35	4.78	p = 0.004**
Control	3.21	4.16	p = 0.022*
p-value (Mann-Whitney)	p=0.002*	p=0.04*	

The low achiever primary students obtain better learning outcomes in the experimental group (pre-test=3.93 and post-test=4.71) than those in the control group (pre-test=2.42 and post-test=4). Table 7 shows a significant difference between the two groups for pre-test (p<0.001) but not for post-test (p=0.07). The low achiever students in the control group tend to progress more than the low achiever students in the experimental group (p=0.036).

TABLE 7

Learning outcome scores of the low achiever students in experimental and control groups in pre-test, post-tests and progress

Low achiever students	Mean learning outcomes: pre-test (out of 5)	Mean learning outcomes: post-test (out of 5)	Progression
Experimental	3.93	4.71	0.78
Control	2.42	4	1.58
p-value (Mann-Whitney)	p<0.001***	p=0.07	p=0.036*

Discussion

Mobile learning influences learning experience and low achiever students' learning outcomes

The aim of this study was to investigate the impact of a mobile learning guidance tool on learning outcomes and the learning experience in a primary school context.

Firstly, through the analysis of the learning experience, the use of a mobile learning guidance tool can improve the learning experience of primary students around an astronomy question. As demonstrated by Huang et al. (2016) mobile learning guidance coupled to human guidance can improve students' learning experience, especially regarding their engagement and interest. These dimensions are important in students' learning. Indeed, when mobile learning is coupled with a collaborative learning approach (Huang et al., 2020) and human intervention (Huang et al., 2016), the mobile learning device has a positive impact on the learning experience. According to our results, inquiry-based learning supported by a mobile learning guidance tool has a positive impact on the learning experience especially on interest. The inquiry-based learning is a fundamental approach in everyday life, but it can be complex to understand and learn. In fact, the inquiry approach is a complex overall process requiring many interactions between phases (Pedaste et al., 2015). However, it is divided into different phases. The advantage of mobile learning guidance is therefore that each phase of the process can be clearly split into different stages. We think that, making the inquiry process much more evident allowing better students' attitudes concerning the learning experience (except for peer instruction dimension). However, even when properly guided, the use of digital tools requires teacher support (Huang et al., 2016). As suggested by Franklin & Peng (2008), mobile learning offers the potential of enhancing the educational process.

We observed that the students in the experimental group asserted to communicate less with peers than the students in the control group (peer instructions dimension). Our findings would seem to show that the use of a mobile learning tool as a guide in inquiry approach allows students to stay focus more on the learning objectives. Hence, they do not feel the necessity to communicate with peers. From our point of view, this aspect can be as well seen as an issue. Because all the dimensions of the learning experience, it is peer instructions that contributes most to improve learning outcomes. Since peer communication is one of the important aspects of inquiry-based learning, we recommend to any instructor to pay attention to that dimension during inquiry phases when using mobile learning guidance.

Mobile learning as an instruction prompt tool during inquiry-based science activities improved students' learning experience regardless of their initial knowledge (higher or lower achievers). The impact is particularly high on the learning experiment dimensions of engagement and interest. These results confirm previous studies showing that the level of engagement (Skilling et al., 2021) and interest (Huang et al., 2016) are enhanced. We found that mobile learning as an instruction prompt is efficient on high and low achiever students' learning experience, especially on engagement, whereas Chen et al. (2022) show that mobile learning only facilitates high achiever students' engagement. We found that mobile learning as an instruction prompt is effective on the learning experience and especially on engagement for both high and low achiever students, whereas Chen et al. (2022) showed that mobile learning could facilitate the engagement of high achiever students.

We have shown that whatever the student's initial level, guidance via a mobile learning tool improves the student's level of engagement and interest. The improved levels of engagement and interest in the use of mobile learning could be explained by the novelty of this tool. When students discover the digital tool, it could provoke more attention than a tool usually used in the classroom because of its novelty. Primary school students are not used to using digital tablets in the classroom. Consequently, this new use would increase their engagement and interest because of their attitudes towards digital technology. Students would focus all their attention on the use of digital technology, which would enable them to engage with the affective dimension of the concept of engagement (Archambault & Vandenbossche-Makombo, 2014). However, the low achievers' students' attitude towards digital tools and the inequalities in their initial results could also explain the fact that the low achievers' students have lower learning progress than the control group. Indeed, we supposed that when students use a new tool, they focus mainly on its overall use and less on the content it offers. This could also explain why the lowest-performing students receive more help and communicate more with each other when they use more traditional learning tools. The lowest-performing students would concentrate more on the fun aspect and on the use of the digital tool rather than on its content and on the collaboration, they could have with their peers.

Also, each group independently improves its learning outcomes. Our study revealed that the use of mobile learning does not improve students' learning outcomes compared with a much more conventional approach. This is in contradiction with many studies (Arain et al., 2018; El-Sofany & El-Haggar, 2020; Huang et al., 2020; Rusmono et al., 2019; Suprianto et al., 2019; Zhonggen et al., 2019, etc.), since we found that despite the clear difference in the level of learning experience, students did not reach better learning outcome scores with mobile learning.

Study limitations and perspectives

We are aware that our research may have three limitations. The first is that we used mainly nonparametric statistical tests because the restricted number of primary students in the sample did not allow us to use parametric statistical tests, especially for low achiever students (type II error may occur). Using nonparametric statistical tests is limited for detecting significant differences. For this reason, to support the results, it would be interesting to extend the sample size and perform parametric tests (by improving the power of the statistical tests).

The second and third limitations are related to the initial level of the students. For a large proportion of the students, the experimental group already had a better initial level in comparison with the control group. This raises two main limitations: (1) this difference does not allow us to have two exactly similar samples in terms of initial knowledge, (2) the scope for improvement of learning outcomes is much more limited when the initial knowledge is already high.

Conclusion

The aim of this study was to investigate the impact of a mobile learning tool as prompt guidance for supporting inquiry-based learning on learning outcomes and the learning experience in an inquiry-based primary school learning approach. This study showed that the use of a mobile learning approach compared with the conventional approach: (1) improved the learning experience of primary students, (2) improved the learning experience of primary students regardless of their initial knowledge, (3) impacted primary student learning outcomes compared with a group which was not using mobile devices.

The use of inquiry-based mobile learning as a guide to learning about the alternation of day and night has a positive impact on primary school students' perception of their own learning experience. Usually, when students perceive their learning experience as positive, it enhances the learning of knowledge and skills related to the topic (Tsai et al., 2021). However, to low achievers' students this was not the case in our study. This could be explained by the very positive learning experience of the low achievers' students towards the use of an innovative tool in the classroom. Students would focus more on the tool than on the content knowledge. Consequently, the use of mobile learning based on the inquiry approach as a guide has a favourable impact on learning, even though there are no clear benefit for either condition, and is of pedagogical interest in science learning.

Our study adds value to the science education research field by investigating the impact of incorporating mobile devices as a straightforward prompt guidance tool, complementing teacher activities. Our results indicate a notable enhancement in the learning experience and, to a lesser extent, in knowledge acquisition. We believe that this study holds potential benefits for education practitioners seeking to create engaging and valuable learning scenarios in science education.

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