Article

A Framework for Mobile-Assisted Formative Assessment to Promote Students' Self-Determination

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Abstract: Motivation is an important issue to consider when designing learning activities, including mobile learning and assessment. While previous research provides evidence for the motivational impact of mobile learning, not many pedagogical frameworks exist for the design of mobile-assisted learning and assessment. The current study is grounded in the Self-Determination Theory of motivation and proposes a pedagogical framework for mobile-assisted formative assessment, aiming at enhancing student motivation. For a preliminary evaluation of the framework, fifty-one students from a public European high school participated in a series of formative assessment activities. The tasks that were implemented according to the proposed mobile-based formative assessment framework had a significant positive impact on student perceived levels of autonomy, competence, and relatedness, enhancing students' intrinsic motivation levels. Study findings highlighted the capacity of the proposed framework to guide the design of mobile-based formative assessment activities that enhance and promote student motivation. The study makes a theoretical contribution by proposing a framework that aligns mobile learning and assessment with elements of the Self-Determination Theory of motivation and also has a practical contribution by implementing mobile learning and assessment practices that have the potential to promote student motivation.

Keywords: mobile-based assessment; assessment for learning; self-determination theory; mobile learning; motivation

1. Introduction

Formative assessment or assessment for learning is defined as the "assessment for which the first priority in its design and practice is to serve the purpose of promoting students' learning" (p. 10) [1]. Formative assessment shifts the purpose of assessment from a measurement focus to a learning focus [2]. With the latest developments in mobile technologies, there is an increase in adoption of mobile technologies in educational practice. Research has shown that the integration of mobile technologies in learning has a significant impact on motivation [3,4]. The use of mobile technologies for formative assessment, when compared with traditional paper-based means, can be beneficial [5,6]. Features of mobile technologies, such as ubiquity and context-awareness, personalization and adaptivity, interactivity and immediate feedback provision, facilitate the integration of assessment within teaching and learning and therefore have the potential to transform formative assessment into a more embedded and pervasive instructional method [7–9]. However, the integration of mobile technologies in learning and assessment introduces both opportunities and challenges, and therefore necessitates the rethinking of the underlying pedagogical frameworks [7].

While studies exist that provide evidence for the motivational impact of mobile-based assessment for learning [5,6], with few exceptions [10], not many frameworks exist to better guide the development of mobile-based assessment [11–13]. The current study proposes a framework that is grounded on a motivation theory and leverages mobile technologies to guide the design of mobile-assisted formative assessments that can promote motivation.

The underlying theory is the Self-Determination Theory of Motivation (SDT) [14]. SDT has been already successfully used in mobile-supported learning environments [15]. The importance of developing an SDT-based framework for mobile-learning activities is due to the following reasons. First, mobile-based assessment can be part of a blended learning strategy that often complements and extends other more traditional modes of learning. Second, seamless and ubiquitous formative assessment is connected with the growing need for a continuous evaluation and support of learners' knowledge and skills throughout lifelong learning in the 21st century [16].

1.1. Background

With few exceptions [10], not many frameworks exist that focus on the development of motivation in mobile-based learning and assessment activities. Moreover, the majority of these frameworks address motivation either indirectly or partially [17]. The conceptual framework in [18], based on the activity theory, acknowledged the role of mobile-supported collaborative learning activities in enhancing motivation. The pedagogical framework in [19], based on the transactional distance theory, addressed the role of social interactions in supporting motivation, especially for activities with low transactional distance. Interactivity, as a means of supporting motivation, has been proposed in [20]. The framework in [21] acknowledged the inherent relation between self-regulation and mobile learning, and suggested that the student-centered, personal, and ubiquitous characteristics of mobile learning can enhance learners' self-regulation and motivation. Context-awareness, defined as the detection of the situation of the learner in the real world and the provision of adaptive support or guidance [22], is another feature of mobile technologies that has been linked to motivation. In [23], the context-aware personalized mobile self-assessment framework suggested that learning adapted to the learning context can positively influence motivation. Based on the framework of participatory simulation for mobile learning [24], augmented reality scaffolding can also support motivation.

To shed more light on the motivational impact of mobile learning and assessment, the current study proposes a framework that utilizes the capacity of mobile technologies to support formative assessment activities having the potential to promote student motivation by enhancing their autonomy, competence, and relatedness.

1.2. Self-Determination Theory of Motivation

Our proposed framework is based on the Self-Determination Theory (SDT) of motivation [14]. Motivation is the process that initiates and sustains human behavior and it is a fundamental issue in learning and in online learning environments as well [25]. Self-Determination Theory of motivation distinguishes between two basic types of motivation: intrinsic and extrinsic motivation [26]. Intrinsic motivation refers to doing something because it is interesting and enjoyable, while extrinsic motivation refers to doing something due to an externally imposed control, e.g., a reward or punishment. SDT argues that intrinsic motivation is sustained when the three basic and universal human psychological needs of autonomy, competency, and relatedness are satisfied. Autonomy refers to the desire of people to regulate and self-control their own behavior. Competence refers to the desire of being effective and sufficient when performing an activity. Relatedness refers to the desire of people to feel connected and associated with others. When students' perceptions of autonomy, competence, and relatedness are high enough, students feel self-determined and autonomously motivated [27]. Autonomous motivation in turn, in contrast to controlled motivation, fosters positive change [28] and leads to better learning [29]. The Self-Determination Theory of motivation has been already successfully applied in online [30–32] and mobile [33] learning. Moreover, since assessment for learning has the potential to motivate learners [2], SDT can be an appropriate foundation for our proposed framework.

1.3. The Proposed Framework

The proposed pedagogical framework for the design of formative assessments is aiming at enhancing students' perceived levels of autonomy, competence, and relatedness in mobile-assisted learning and assessment activities.

The framework incorporates autonomy, competence, and relatedness as its main constructs and is organized over three layers corresponding to the Self-Determination Theory of motivation (L1), pedagogies supported into mobile learning environments (L2), and mobile technologies that can support the delivery of the aforementioned pedagogies (L3). As Figure 1 shows, the intersections of the three main constructs (autonomy, competence, and relatedness) with the three horizontal layers (SDT practices, pedagogies, and mobile technologies) result in the nodes of the framework. The following notation is being used: the letters a, c, and r correspond to the autonomy, competence, and relatedness constructs of the Self-Determination Theory of motivation, while numbers 1, 2, and 3 correspond to the layers of the framework (L1, L2, and L3); e.g., (a1.1) stands for layer 1 autonomy support, (acr3.1 or acr3.2) stand for layer 3 autonomy, competence, and relatedness support. The underlying idea is that the nodes of the framework address different design components that can be integrated into the framework in order to support and enhance the learner's motivation.
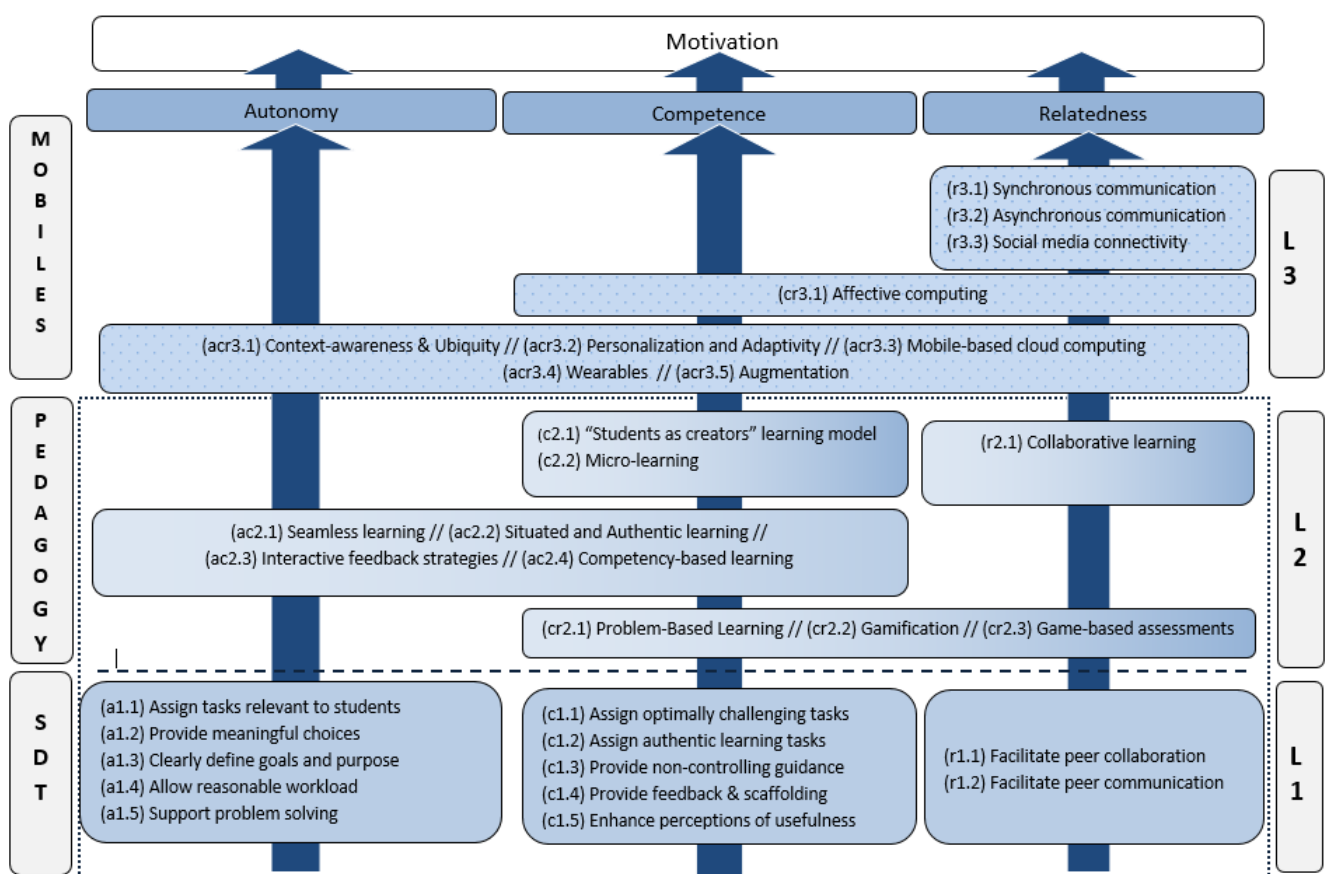

Figure 1. Formative assessment framework to enhance student motivation using mobile technologies (notation explained: (a) stands for autonomy, (c) for competence, and (r) for relatedness support, e.g., (a1.1) supports autonomy, (cr2.3) supports competence and relatedness).

1.3.1. Layer 1: Self-Determination Theory

Implementation of the following instructional practices suggested by SDT can support the three basic psychological needs of autonomy, competence, and relatedness. Regarding autonomy support (a1.1 to a1.5), educational activities should be relevant to students'

interests [34] with a clearly defined purpose and value [35]. Students should be offered a reasonable workload with meaningful choices and options [36], in low-anxiety autonomy-supportive learning environments [37] with the minimum controlling guidance [27]. Furthermore, self-regulated problem-solving activities are a preferable instructional approach for self-determined learning [34].

Regarding competence support (c1.1 to c1.5), the assignment of optimally challenging tasks that match to students' skills and learning contexts [38] can enhance perceived competence levels. Learners have the opportunity to optimally perform and therefore experience high competence levels when they practice meaningful and useful 'real-world' learning scenarios in authentic settings [8]. Moreover, appropriately delivered non-controlling guidance and feedback can effectively support perceived competence [39]. Moreover, for competence support, studies have highlighted the importance of immediate, informational, and elaborative feedback [9].

Regarding relatedness support, we promote collaboration (r1.1) and communication (r1.2) among learners. Lack of interactions with the class undermines perceived relatedness [34], while working collaboratively to accomplishing a goal reinforces the social nature of learning and enhances the feelings of 'related to others'.

1.3.2. Layer 2: Pedagogies

The following pedagogical methods have been integrated into the proposed framework. These pedagogical choices were selected based on the review of the literature on the different pedagogical methods that mobile devices can support due to their special features, such as bite-size content presentation, ubiquity and context-awareness, connectivity and sharing capabilities, and personalization and interactivity [2,19,21].

Micro-learning (c2.2), the delivery of micro-learning content (e.g., definitions, small paragraphs, flash cards, small quizzes) to learners' mobile devices, makes learning more learner-centric and accessible just-in-time anytime and anywhere [5] and has the potential to promote learners' competence levels [40]. Delivering learning in small manageable learning units makes learners capable of working on one competency at a time in order to master specific skills (competencies).

The students' capacity to create and share learning content instead of just consume it refers to another innovative learning strategy called "students as creators" (p. 18) [41] (c2.1). Features of mobile devices, such as note-taking, recording, photos or videos capturing and sensing data, facilitate content creation and storage [42]. Students' almost effortless capability to generate, upload, and share learning content promotes their competence level [43].

The competency-based learning approach (ac2.4) not only enables students to master their skills at their own pace and strengthen their competency levels but it also promotes their learning autonomy as well [44]. Students can progress by demonstrating their competences and receiving automated or tutor feedback through their mobile devices.

The provision of immediate interactive cognitive and/or affective feedback (ac2.3) can support learners in developing their knowledge and skills while offering more control over learning. Studies in mobile learning environments have highlighted the importance of immediate, informative, and elaborative feedback in promoting student competence and autonomy [5,9,33].

The interaction of the learners with their mobile devices, as being location and time independent, introduce a situated and authentic learning (ac2.2) approach. Situated learning can happen in authentic learning environments or in immersive artificial environments [45]. The introduction of the continuity of learning across different educational settings including formal and informal learning contexts, individual and social learning, and physical world and cyberspace offers a seamless learning (ac2.1) experience [46]. Situated and authentic learning are associated with strong implications for autonomy and competence support [10].

Learners have the opportunity to optimally perform and therefore experience higher autonomy and competence levels when they practice meaningful 'real-world' learning scenarios in seamless, ubiquitous, contextualized, and authentic assessments that match their skills and contexts [8]. Students can learn by working in real-world scenarios, e.g., vocational training or scientific inquiries to solve open-ended meaningful problems following a problem-based learning (cr2.1) approach. Problem-based learning refers to the instructional approach that uses real and contextualized problems of practice to initiate content learning and skill development [47]. Scholars agree that problem-based learning fosters self-regulated learning [48]. Using mobile devices in problem-based learning is a promising approach to support students' learning and enhance their motivation [49].

All aforementioned learning activities can also be performed with the students to work together in peers or larger groups following a collaborative learning approach (r2.1). Collaborative learning has received great emphasis from educators and researchers not only because it promotes student engagement and learning achievement, but also because it is important for developing social experiences [50]. Studies have shown that collaborative learning enhances the feelings of relatedness among students [29]. Mobile technologies can facilitate collaborative learning [51].

Another emerging trend that can be applied in mobile-assisted learning and assessment is gamification (cr2.2), the integration of gaming elements and mechanics, into non-game situations and scenarios for training and motivational purposes [52]. Integrating game mechanics (e.g., badges) into assessments promotes intrinsic motivation and perceived competence [28]. Furthermore, game-based assessment (cr2.3), the assessment that is performed through games, can provide opportunities for social interactions (relatedness support) and enhanced competence through personalization and adaptation tailored to the skills of each individual student [53]. Figure 2 depicts autonomy, competence, and relatedness supportive pedagogies as these are suggested by related studies.
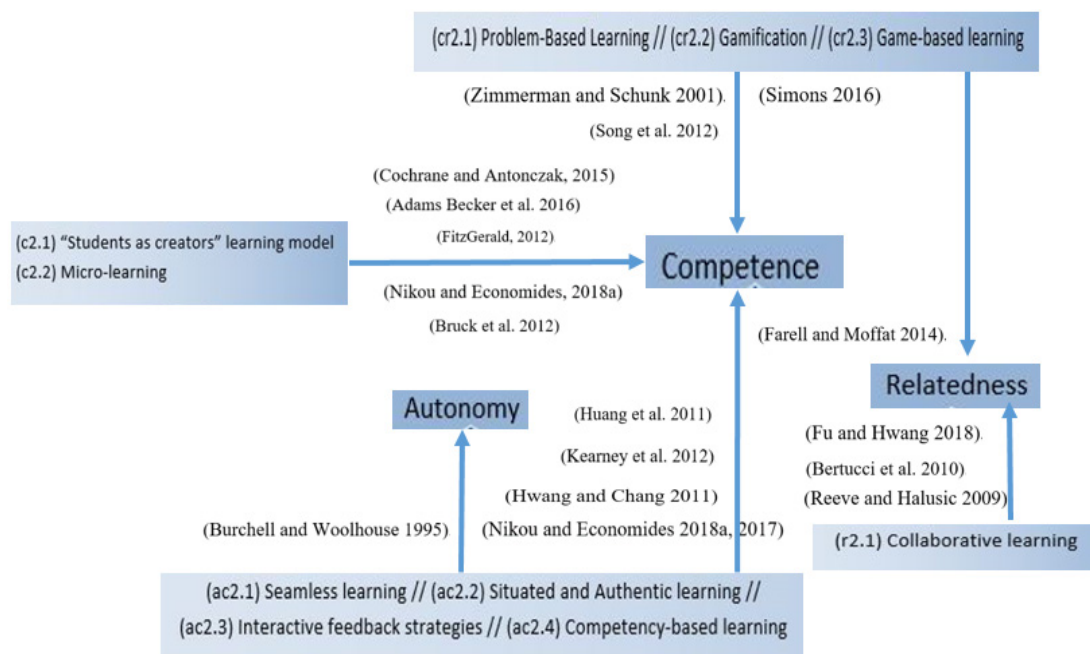

Figure 2. Motivation supportive pedagogies.

1.3.3. Layer 3: Mobile Technologies

The proposed framework utilizes the following affordances offered by mobile technologies.

Context-awareness (acr3.1) is the ability of the mobile technologies to detect the learner's context, i.e., the learner's state, the educational activity's state, the infrastructure's state, and the environment's state [54]. The ubiquity and context awareness of mobile

devices have strong implications for learning autonomy [10]. Based on the detected context in authentic environments, learners can receive personalized guidance [55] which has implications for competence support. Communication facilitated with mobile technologies supports collaboration [8]. Learners participating in collaborative context-aware "in-situ" authentic scenarios, have the potential to achieve higher levels of perceived autonomy, competence, and relatedness [6].

Adaptivity (acr3.2) and personalization (acr3.2) are two other mobile devices features with strong implications on student motivation. Adaptivity (acr3.2) is the application's ability to automatically adapt to the user context [56]. The flexibility to adapt to different environments (physical or social) and provide choice and adaptive feedback fulfills the need for autonomy [57]. Research has shown that the mobile-based delivery of adaptive and personalized learning and assessment facilitates student perceived competence [49]. Personalization (acr3.2) is the system's ability to adapt to a particular user's needs (knowledge, experiences) [45] and provide personalized cognitive or affective feedback. Personalized learning content delivery fulfills the autonomy dimension [58], enhances perceived competence, and facilitates student collaboration and engagement as well [36,59].

The provision of tutor or automated affective (cr3.1) feedback (e.g., an empathetic emotion or an encouragement provided by a computer agent) is also able to support perceived competence [34] and relatedness [60]. Moreover, it can promote student collaboration and engagement [37,59].

Collaboration among students can be facilitated through synchronous (and/or asynchronous) communication (r3.1 and r3.2) and social media (r3.3). The synchronous real-time communication (through chat rooms, instant messaging applications, virtual classroom technologies) or asynchronous communication (e.g., blogs, wikis, email), both implemented as standalone applications or embedded in learning management systems, can enhance student perceived relatedness [61]. Moreover, social media and Web 2.0 applications that allow users to create and share information and user-generated content, have been extensively used in education for communication and peer-to-peer content sharing among learners supporting their feelings of relatedness [61,62].

All above features are feasible through mobile-based cloud-computing technologies (acr3.3), the combination of cloud computing, mobile computing, and wireless networks that can provide rich computational resources to mobile users. In mobile-based cloud computing, students have ubiquitous access to learning resources, they can experience authentic learning anytime and anywhere, and they can share learning resources with peers participating in collaborative problem-solving activities or peer-assessments. Mobile-based cloud computing can potentially have strong implications on learner autonomy (through ubiquity and seamlessness), competence (through situated and authentic learning), and relatedness (through communication and resource sharing) [63].

Among other mobile technologies with potential impact are wearables and augmented reality. Wearables (acr3.4) are devices that are worn by users and can conveniently integrate tools that track movement, location, social media, etc. [41]. Augmented reality (acr3.5) is the layering of virtually available information or objects over the user's view of the physical environment [45] and can be beneficial to students' perceived authenticity and motivation [64]. Figure 3 depicts affordances of mobile technologies that can support motivation, as these are suggested by related literature.
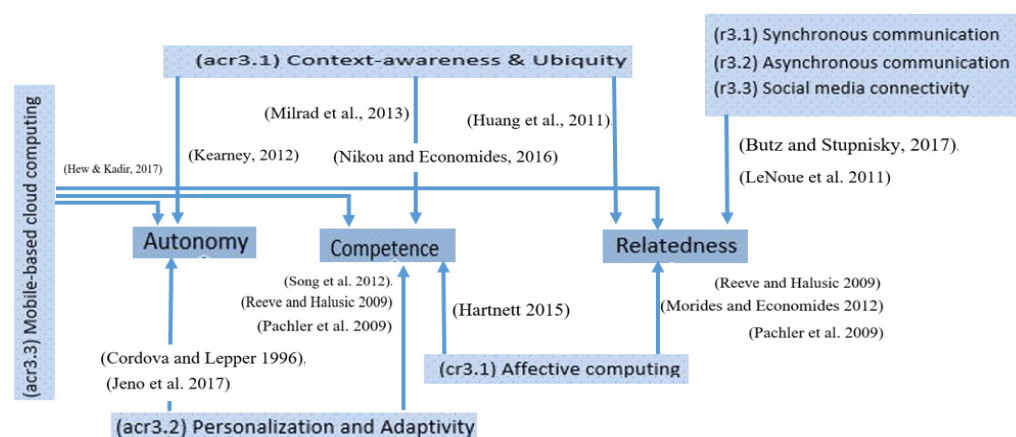
Figure 3. Motivation supportive mobile technologies.

2. Materials and Methods

2.1. Participants

Using convenience sampling, fifty-one (average age = 16.1, SD = 1.8) students from a public urban European high school participated in the study. There were twenty-seven female (53%) and twenty-four male students (47%). All participating students had already previously used mobile devices (smartphones and tablets) for personal purposes (gaming, web searching, communication, etc.). Most of them (92%) had used mobile devices for their own personal study (e.g., search and download educational resources), while 85% had already used mobiles in the classroom, mostly as polling devices. Therefore, mobile devices were not a completely novel learning tool for participants. Two experienced science teachers tutored both groups. Students' participation was voluntarily; they were all informed about the research procedures in advance, appropriate permission was taken, and all the data were collected anonymously.

2.2. Instruments

The competence and autonomy subscales of the Intrinsic Motivation Inventory (IMI) [65] and the autonomy subscale of the Basic Psychological Need Satisfaction (BPNS) questionnaire [66] were used to assess the students' basic psychological needs. Sample items were: "I feel a sense of choice and freedom while participating in the assessment activities" (for perceived autonomy), "I think I am pretty good in the assessment activities" (for perceived competence), and "I feel close to my classmates" (for perceived relatedness). Necessary assumptions for the statistical tests were satisfied. The instruments used have been validated by previous studies. The three basic psychological needs satisfaction factors had good internal reliabilities with the alpha values to be 0.81, 0.82, and 0.87 for the autonomy, competence, and relatedness subscales, respectively, which were all above the minimal recommended value of 0.7.

2.3. Procedures

The study was implemented in the context of a secondary science course, during a period of two weeks. Figure 4 displays the experimental procedure. Participating students were randomly assigned to two groups: twenty-five students for the control group and twenty-six students for the experimental group. Before the experiment, students completed a pre-questionnaire about their pre-existing levels of motivation. All students attended the same tutorial sessions (same subject content knowledge) about electrical circuits and biodiversity in the context of their Physics (week 1) and Biology classes (week 2).
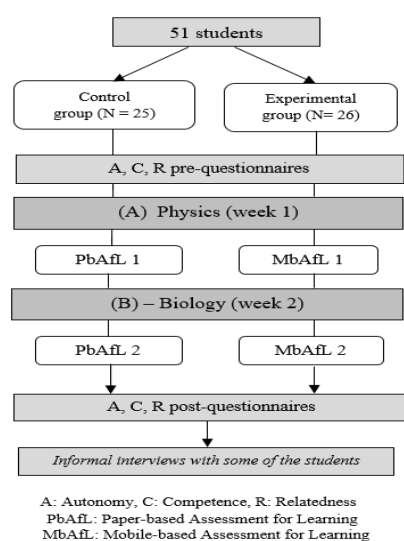
A: Autonomy, C: Competence, R: Relatedness
PbAfL: Paper-based Assessment for Learning
MbAfL: Mobile-based Assessment for Learning

Figure 4. The experimental procedure.

Our research design incorporates multiple contexts in order to gain a more meaningful and comprehensive insight into students' motivation (across two subject of the science curriculum and across inside and outside the classroom boundaries, i.e., physics lab—relatively fixed location and botanic gardens—outdoors). The significance of the multiplicity of contexts for understanding motivation and learning has been acknowledged by previous studies [67]. Following each tutorial session, students participated in formative assessment (assessment for learning) activities that had been developed by the two class teachers in cooperation with the researchers. Table 1 shows the learning and assessment activities for both groups.

Table 1. Assessment for learning (formative assessment) tasks (AfL1 in the Physics Lab and AfL2 in the Botanic Gardens).

	Learning and Assessment Activities	Control Group	Experimental Group
	Self-assessment		
AfL1	Electrical circuits	Paper worksheets with face-to-face tutor feedback	Mobile-based guided activities using QR-codes with mobile-based feedback
AfL2	Biodiversity *Assessment of student portfolios*		
AfL1	Assembly of electrical circuits	Paper sketches	Mobile device camera
AfL2	Leaf morphologies and taxonomy of plants		
	Assessment of collaborative learning		
AfL1	Electrical measurements	Collaborative answers on paper worksheets	Collaborative answers on cloud-based shared documents
AfL2	Plant taxonomies *Peer Assessment*		
AfL1	Electrical circuits artifacts	Face-to-face discussions and peer feedback on paper worksheets	Face-to-face discussions and on-line peer feedback using class social media
AfL2	Plant taxonomy artifacts and biodiversity		

The design of the learning and assessment activities for both the control and the experimental group was based on layer 1 and layer 2 of the proposed framework (Figure 5). However, the experimental group experienced specific affordances of mobile technologies (layer 3): context-aware learning through mobile-readable QR-codes (acr3.1), mobile-based digital artifacts (e.g., photos) (c2.1), automated knowledge-of-correct-response feedback

provided by the mobile devices (ac2.3), cloud-based shared learning space for collaboration (acr3.3), social network connectivity for on-line discussions (r3.3).

Figure 5. Implemented components of the framework.

The mobile-based version of the assessment was developed using the jQuery mobile framework for the user interface and PHP and MySQL for the server backend support. Students were presented with instructions to perform their required assessment tasks (e.g., a collaborative task) and short questions that had to be answered (true/false or multiple choice with knowledge-of-correct-response feedback).

Figure 6 presents two screenshots of the mobile version of the assessment. The screenshot on the left illustrates an activity of creating a knowledge artefact and uploading it on a wiki. The screenshot on the right illustrates the task of locating a learning object in the physical world and then uploading its digital representation to a shared folder. Both activities were accompanied by answering closed-type questions with feedback.
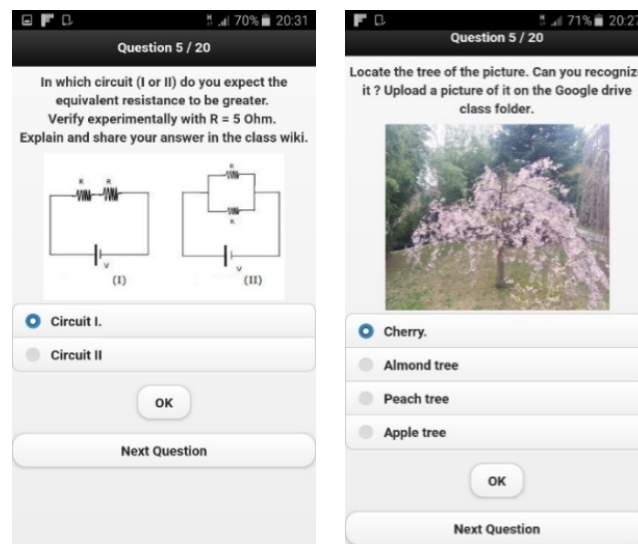

Figure 6. Screenshots of the mobile-based formative assessment.

In Figure 7, the left side shows students during the assessment in the electricity lab and the right side shows students during the mobile-assisted assessment in the botanic gardens.

After the intervention, all students completed a post-questionnaire about their perceived levels of autonomy, competency, and relatedness. Following the post-test, short informal face-to-face interviews with seven randomly selected students (four from the experimental group and three from the control group), were also conducted, in order to elicit extra information for the participant's perceived levels of autonomy, competence, and relatedness.
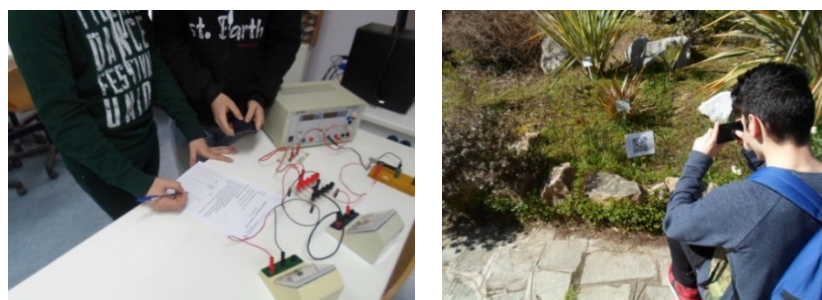
Figure 7. Students participating in the formative assessment activities.

3. Results

Data analysis includes computation of one-way ANCOVA procedures in order to analyze the data collected from the pre- and post-questionnaires about the perceived levels of motivation. SPSS 22.0 was used for the data analysis. To test the differences between the two groups after the learning procedure, one-way analysis of covariance (ANCOVA) was conducted. Pre-questionnaire scores for autonomy, competence, and relatedness were used as covariates, in order to remove possible effects of pre-existing individual differences among students and the post-test scores as the dependent variables. Before proceeding to ANCOVA tests, the assumptions of normality of distribution and the homogeneity of regression were confirmed ($F = 1.09$, $p > 0.05$ for autonomy, $F = 0.33$, $p > 0.05$ for competence, and $F = 2.80$, $p > 0.05$ for relatedness).

The results for the perceived levels of autonomy, when adjusted for the covariate, revealed a significant difference after the intervention between the two groups ($F = 12.43$, $p < 0.001$), as Table 2 shows. The adjusted mean for the experimental group (5.05) was significantly higher than that of the control group (4.21). The significantly better score of the experimental group than that of the control group indicates that the use of mobile technologies in the proposed assessment for learning framework benefits the students in enhancing their perceived levels of autonomy.

Table 2. ANCOVA of the post-test results for perceived autonomy.

Variable	Group	*N*	Mean	SD	Adjusted Mean	Std. Error	*F* Value
Autonomy	Control	25	4.23	0.89	4.21	0.17	12.43 ***
	Experimental	26	5.04	0.91	5.05	0.16	
Competence	Control	25	4.58	0.96	4.59	0.09	10.18 **
	Experimental	26	4.99	1.05	4.99	0.08	
Relatedness	Control	25	3.22	0.83	3.29	0.06	14.03 ***
	Experimental	26	3.69	1.17	3.63	0.06	

*** $p < 0.001$, ** $p < 0.01$.

The results for the perceived levels of competence, when adjusted for the covariate, revealed a significant difference after the intervention between the two groups ($F = 10.18$, $p < 0.01$), as Table 2 shows. The adjusted mean for the experimental group (4.99) was significantly higher than that of the control group (4.59). The significantly better score of the experimental group than that of the control group indicates that the use of mobile technologies in the proposed assessment for learning framework benefits the students in enhancing their perceived levels of competence.

The results for the perceived levels of relatedness, when adjusted for the covariate, revealed a significant difference after the intervention between the two groups ($F = 14.03$, $p < 0.001$), as Table 2 shows. The adjusted mean for the experimental group (3.63) was significantly higher than that of the control group (3.29). The significantly better score of the experimental group than that of the control group indicates that the use of mobile technologies in the proposed assessment for learning framework benefits the students in enhancing their perceived levels of relatedness.

The mobile-based formative assessment tasks have a significant positive impact on student perceived levels of autonomy, competence, and relatedness, enhancing their intrinsic motivation levels. The effect sizes of the ANCOVA results (η2) were found to be relatively small (0.21 for the perceived autonomy, 0.17 for the perceived competence, and 0.23 for the perceived relatedness) [68].

The post-test adjusted mean values for perceived autonomy, competence, and relatedness for both the control and experimental group were all above the average (in the 7-point Likert scale). The proposed assessment for learning framework supported students' perceived levels of autonomy, competence, and relatedness as Figure 8 shows.
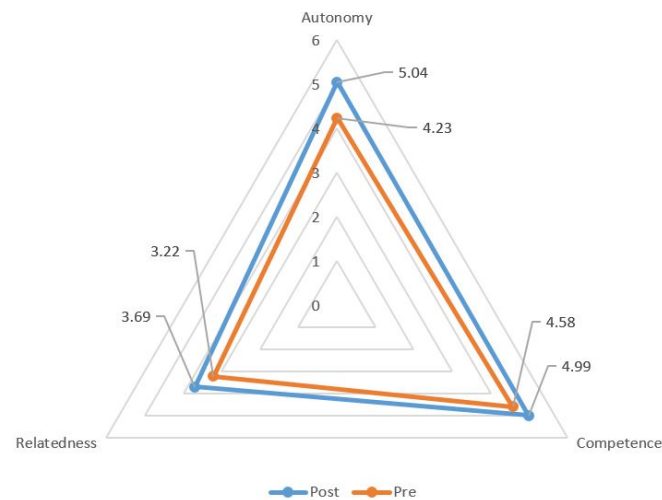

Figure 8. Perceived pre- and post-levels of autonomy, competence, and relatedness.

Informal interviews with the students further supported the quantitative data. Students in the experimental group indicated that they enjoyed the situated assessment activities using the QR-codes to navigate through the assessment tasks and they also stated that "mobile devices helped them to keep themselves interested and motivated providing them with a sense of freedom". Students in the experimental group mentioned that the immediate feedback given from the mobile app was very helpful because "it was keeping them more engaged". On the other side, students in the control group indicated, "they could not always have the time/chance to get immediate tutor feedback and that delay was resulted in difficulties in the task progression". Discussions with students of the experimental group revealed also that online communication complemented face-to-face interactions and gave the opportunity to less extroverted students to participate in the class dialogues.

4. Discussions

The current study proposes a framework that is based on the Self-Determination Theory of motivation and is aimed at guiding the design of mobile-based formative assessment activities enhancing student motivation. An empirical study was conducted to make a preliminary evaluation of the framework. Study findings highlight the capacity of the proposed framework to guide the design of mobile-based formative assessment activities that support student motivation by enhancing their autonomy, competence, and relatedness.

The results are in line with previous studies about computerized assessments where students were more favorable towards computer-based instruction compared to those who used paper-based assessments [69]. In addition, the study is in line with findings from review studies about the motivational impact of mobile technologies on student learning motivation [70–72]. Moreover, the study complements and extends previous mobile learning research by better aligning affordances of mobile technology with SDT. Students that participated in the mobile-assisted assessment for learning activities self-reported

higher levels of perceived autonomy support. Online learning environments have the potential to provide students with optimal autonomy-supportive learning experiences [30,55]. The proposed framework, by taking advantage of the context-aware features of mobile-devices, facilitated student orientation and navigation through the authentic learning environment and offered an autonomy supportive instructional approach. Students in the mobile-assisted assessment for learning activities self-reported higher levels of perceived competence support. Competence support provided by the paper worksheets and tutor feedback may be not always effective due to time, curriculum, and other constraints [73]. Students in the mobile-assisted assessment for learning activities self-reported also higher levels of perceived relatedness. Face-to-face interactions in the experimental group were blended and enhanced with online interactions resulting in more groups and classroom dialogues, and communication and collaboration through shared media spaces. Social networking integrated in online learning platforms for sharing information facilitates the interaction and collaboration among members of the learning community [74]. Research has shown that collaborative learning enhances the feelings of relatedness among students [27]. Higher level of relatedness is not attributed to the postulate that online communication is of better quality than face-to-face communication but due to the fact that it may have a complementary or additive effect. Moreover, all three basic psychological needs of autonomy, competence, and relatedness link to the factors contributing to the behavioral intention to use mobile learning, such as user profiles, educational content, and environmental factors [33]. In addition, the autonomy, competence, and relatedness dimensions of our proposed model can be linked with the personalization, authenticity, and collaboration features of the pedagogical framework developed by [10]. Under the lenses of motivation theories, the personalization feature has strong implications for autonomous learning. The authenticity feature also privileges context-aware ubiquitous learning. The collaboration feature highlights opportunities for online networking and data sharing.

5. Conclusions

The findings of the current study can provide a good reference for educational researchers, instructional designers, and educators. Our study is based on existing literature and aims to consolidate previous evidence related to the motivational impact of mobile learning and assessment in one framework for mobile-based assessments. Implementing pedagogies that leverage mobile technologies in order to create effective learning and assessment experiences still remains a challenge in many cases [75]. The proposed framework can be considered as an effort to present a general guidance on developing mobile-assisted formative assessments based on features of mobile devices, SDT principles, and pedagogical choices used in the mobile learning context. For researchers, the study can provide a conceptual connection between mobile learning and the Self-Determination Theory of motivation. Therefore, understanding the relation between mobile learning and basic psychological needs would lead to more motivating mobile learning design. For instructional designers and educators, the proposed framework can be helpful in designing and developing more motivating and engaging learning and assessment practices. The use of mobile technologies embedded in learning and assessment can facilitate different pedagogies, such as learning through situated and contextualized assessment, self- and peer-assessment, constructive feedback, collaboration, and sharing. Since motivation is among the best predictors of learning performance [76], the framework may help to improve learning achievement as well. Moreover, since the study has been conducted in the context of secondary science education and considering the lack of students' interest towards science subjects and careers [10], the findings can be useful in promoting science education among secondary students.

One of our study limitations is its small sample size. Our research plans include evaluating other components of the framework, such as collaborative and personalized game-based learning that promises to promote motivation and engagement as well [77].

Moreover, evaluation of the framework will be extended to other educational contexts, such as in higher education where mobile-based assessment is gaining further adoption [78].

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