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Mobile-Based micro-Learning and Assessment: Impact on learning performance and motivation of high-school students

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ABSTRACT

Mobile-based micro-learning has gained a lot of attention lately, especially for work-based and corporate training. It combines features of mobile learning and micro-learning to deliver small learning units and short-term learning activities. The current study uses the lens of the Self Determination Theory (SDT) of motivation and proposes a series of Mobile-Based micro-Learning and Assessment (MBmLA) homework activities to improve high-school students' motivation and learning performance in science. An experiment was conducted to evaluate the effectiveness of the proposed approach. One hundred and eight students of a senior-level high school in Europe were randomly assigned into either a control condition (conventional paper-based homework approach) or an experimental (MBmLA approach) condition. The study carried out for a period of five weeks. From the experimental results it was found that, in comparison to the conventional paper-based approach, the proposed MBmLA approach enhanced students' basic psychological needs of self-perceived autonomy, competence and relatedness and improved students' exam performance in terms of factual knowledge. Moreover,

students self-reported greater learning satisfaction with the mobile-based micro-assessment and micro-learning homework tasks. Implications on educational practices as well as future research are discussed.

Keywords

secondary education; Self-Determination Theory; homework; mobile learning; mobile-based assessment; micro-learning; micro-assessment; motivation

Introduction

Low learning motivation and poor student performance are core issues in science education (Kearney, 2016; UNESCO, 2010; Rocard, 2007). About 20% of 15-year-old-students across the Organization for Economic Co-operation and Development (OECD) countries who participated in the Programme for International Students Assessment (PISA) 2015 performed below the baseline level of proficiency in science (OECD, 2016). Student performance is related to motivation to learn (Wijsman, et al., 2016). Therefore, a critical challenge in most educational systems worldwide is to reduce the number of unmotivated and low-performing students.

Previous research in the domain of K-12 science education (Tingir et al., 2017; Liu et al., 2014) provided evidence that the use of mobile devices improves students' performance and motivation in a wide range of formal or informal educational contexts, i.e. natural science courses (de-Marcos et al., 2010), Physics courses (Nikou, & Economides, 2016; Zhai, Zhang, & Li, 2016), botany courses (Huang, Lin, & Cheng, 2010), inquiry investigations (Ahmed & Parsons, 2013; Hwang, Wu, Zhuang, & Huang, 2013), context-aware ubiquitous learning activities (Shih, Chu, Hwang, & Kinshuk, 2011) or inquiry-based ubiquitous gaming (Hwang

& Chen, 2017). Mobile-based micro-learning is a relatively new approach that combines features of mobile learning and micro-learning, by delivering small learning units and short-term learning activities (Hug, Lindner, & Bruck, 2006) through mobile devices, in a manner that can be personalized, adaptive, ubiquitous, context-aware (Bruck, Motiwalla, & Foerster, 2012).

According to our literature review, there is a gap as regards empirical research about mobile-based micro-learning delivered as homework assignments in the context of secondary science education. Homework is an important part of student learning (Epstein & Van Voorhis, 2012). A 30-year meta-analysis on the homework-achievement relationship by Fan et al. (2017) suggests that homework is positively associated with students' achievement in science, especially for K-12 students. Moreover, since homework completion requires a more autonomous oriented type of motivation (Katz, Eilot, & Nevo, 2014; Katz, Kaplan, & Gueta, 2009), this allows a direct connection to Self-Determination Theory of motivation (Deci & Ryan, 1985).

The current study uses the lenses of the Self-Determination Theory of motivation and proposes a Mobile-Based micro-Learning and Assessment (MBmLA) homework intervention for secondary school students of science and investigates, in comparison with the conventional paper-and-pencil homework approach, its impact on student learning performance, motivation and learning satisfaction.

The research questions that the current study investigates are the following:

R1. Do students who learn with a Mobile-Based micro-Learning and Assessment (MBmLA) homework intervention have better learning achievements in

terms of factual knowledge, than those who learn with the conventional paper-based homework approach?

R2. Do students who learn with a Mobile-Based micro-Learning and Assessment (MBmLA) homework intervention self-report higher levels of perceived autonomy, competence and relatedness, than those who learn with the conventional paper-based homework approach?

R3. Do students who learn with the Mobile-Based micro-Learning and Assessment (MBmLA) homework intervention show higher learning satisfaction, than those who learn with the conventional paper-based homework approach?

Background

Micro-learning

Micro-learning is a learning approach that is based on small learning units and short-term focused activities (Lindner, 2007; Hug, Lindner, & Bruck, 2006). In micro-learning, learners make use of micro-media in order to obtain micro-content such as definitions, formulas, small paragraphs, brief video segments, mini podcasts, flash cards or quizzes (Zhang & Ren, 2011). Also, with micro-assessment, small chunks of student knowledge and skills can be evaluated in less time and without the need to make special testing arrangements (Bundovski, Gusev, & Ristov, 2014). Research has shown that micro-learning fits into the human model of processing information in small manageable chunks and therefore enables better retention (Bruck, Motiwalla, & Foerster, 2012). Furthermore, micro-learning can better engage students in on-line and blended learning (Semingson, Crosslin, & Dellinger, 2015). Micro-learning and micro-assessment, easily integrated into

everyday activities, can support a more flexible model of learning reflecting the needs of mobile users (Buchem & Henrike, 2010).

Mobile-based micro-learning

One effective delivery medium for micro-learning and micro-assessment are mobile devices (Hug, Lindner, & Bruck, 2006). There are many benefits associated with micro-learning delivered through mobile media: learning becomes more accessible anytime and anywhere, ubiquitous, just-in-time and on-demand, adaptive and learner-centric (Coakley, Garvey, & O'Neill, 2017).

Mobile-based micro-learning has been acknowledged as a successful learning strategy in the workplace (Werkle, Schmidt, Dikke, & Schwantzer, 2015; Bruck, Motiwalla, & Foerster, 2012). It also improves learning performance and motivation in professional and corporate working environments (Wen & Zhang, 2015; Pimmer & Pachler, 2014; Munoz-Organero, Munoz-Merino, & Kloos, 2012) as well as in Massive Open Online Courses (MOOCS) (Sun et al., 2015).

While previous research in the domain of K-12 science education (Tingir et al., 2017; Sung et al. 2016; Hwang & Wu, 2014, Liu et al., 2014) provided evidence that the use of mobile devices improves students' performance and motivation, our review of the literature reveals a gap as regards empirical research about a mobile-based micro-learning homework methods in high school science education. Moreover, according to the mobile learning review by Zydney and Warner (2016), a stronger alignment is needed between the general underlying theories and measured outcomes. Researchers agree that further investigation is needed in order to understand the motivation mechanisms of mobile micro-learning (Sha, Looi, Chen, & Zhang, 2012). There are previous works reporting on mobile learning and

motivation. Ciampa (2013) reported on the motivational affordances of challenge, curiosity, control, recognition, competition and cooperation when using mobile devices for learning in primary school. Su and Cheng (2015) developed and implemented a mobile gamification learning system to improve motivation of elementary students in terms of attention, relevance, confidence and satisfaction. Sha et al. (2012) proposed an analytic self-regulated learning model of mobile learning as a conceptual framework for understanding mobile learning for elementary students also. However, further investigation, grounded in a solid theoretical framework, regarding the motivational impact of mobile micro-learning in the context of secondary education would be valuable (Chee et al., 2017; Semingson, Crosslin, & Dellinger, 2015). The current study uses the Self-Determination Theory (Deci & Ryan, 2002) of motivation as a theoretical framework to study motivation in the context of mobile-based micro-learning homework in high-school science classes.

Self-Determination Theory of motivation

Considering the design issues related to micro-learning, micro-content units are small, focused and autonomous and therefore micro-learning has the potential to support learners' sense of autonomy and facilitate self-directed learning (Buchem & Henrike, 2010). Moreover, in the context of social networking, micro-learning artifacts are suitable for sharing in social networks or social online learning environments (Liao & Zhu, 2012) enabling thus interactions among learners and supporting their sense of relatedness. This allows direct connections with the Self-Determination Theory of Motivation.

Self-Determination Theory (SDT) of motivation is a well-established and empirically well-supported theory of motivation (Deci & Ryan, 1985; 2002). SDT distinguishes between intrinsic motivation, “doing an activity for its inherent satisfactions” and extrinsic motivation “doing an activity for its instrumental value” (Ryan & Weinstein, 2009). Intrinsic motivation is associated with better performance and human well being. According to the theory, a basic set of basic psychological needs must be satisfied in order to enhance intrinsic motivation: autonomy, competence and relatedness. Autonomy refers to the desire to self-initiate and self-regulate own behavior. Competence refers to the desire to feel effective in attaining valued outcomes. Relatedness refers to the desire to feel connected to others.

SDT has been successfully applied in education (Reeve, 2002; Reeve, Ryan, Deci & Jang, 2008), technology enhanced learning (Chen & Jang, 2010; Roca & Gagné, 2008; Sorebo, Halvari, Gulli, & Kristiansen, 2009) and mobile learning as well (Nikou & Economides, 2017). Research provides evidence that raising the satisfaction levels of perceived autonomy, competence and relatedness enhances self-determination and intrinsic motivation (Niemiec & Ryan, 2009; Chen & Jang, 2010) and also improves learning performance (León, Núñez, & Liew, 2015). Therefore, developing a homework intervention that integrates SDT principles into a mobile technology-supported micro-learning environment is expected to help students to promote their learning motivation and to improve their learning outcomes.

A Mobile-Based micro-Learning and Assessment (MBmLA) homework environment

In probe the aforementioned issue, a learning environment was designed and implemented to support mobile-based micro-learning after-school learning activities. The system was developed based on the jQuery mobile framework for the user interface and PHP and MySQL for the questions database, providing the appropriate flexibility needed in order to be implemented for other teaching topics as well. Each homework assignment was consisted of a series of fifteen micro-content units, each one followed by a true/false or multiple-choice type question with feedback and also an extra collaborative task that students were asked to complete.

The micro-content units were self-contained, focusing on a single important point, with the information they provided to be autonomous and comprehensible to students without the need to search for additional external information (for autonomy support). After each micro-content unit, a question was presented to student. Each question was accompanied with immediate appropriate emotional and cognitive feedback. Students were provided with encouraging and elaborated with knowledge-of-correct-response feedback (for competence support). Moreover, students could use a peer-learning on-line forum to share information and materials with classmates. Also, the task of using a cloud-based shared document (i.e. Google Docs) or a mind-map and submit a collaborative group solution to a problem (groups of four students were formed in advance), for teachers' input, was part of each assignment (for relatedness support).

The aim of the assignments was to reinforce content covered in class with special attention to improve the retention of factual knowledge. There were ten such

homework assignments, prepared by the course instructor and delivered in a five-week period (two per week), and indented to be completed during non-class hours. Students were free to access the on-line homework whenever they needed to and complete, for each assignment, ten out of the fifteen questions of their choice.

Figure 1 illustrates an example of (a) a micro-content unit about Ohm's law, (b) a true/false question with the corresponding feedback and (c) the cloud-based document for students to submit their collaborative group work. The example shown has been translated in English from the native language of the students.

--- FIGURE 1 ---

Figure 1: (a) Micro-learning unit (b) Example question (c) Example of on-line collaborative task

Methodology

Participants

The participants were 108 students drawn from four science classes from a senior-level high school in Europe. The students were on average 17.1 (SD = 1.1) years old. There were 51 (47%) males and 57 (53%) females. All students had already used mobile devices for communication, web searching and entertainment purposes, and occasionally for study support (e.g. searching and accessing educational resources). The median mobile self-efficacy score was 82 out of 100, on a scale adopted from Kenny, et al. (2012), indicating that students were considered themselves as highly efficacious to use mobile devices. All students had the same instructor (an experienced STEM teacher). They all were following the same science curriculum. Based on their previous grades and according to their instructor, all students were equivalent in terms of academic performances before being

assigned to the two different groups. Students were randomly assigned to the control group (n = 54) and to the experimental group (n = 54). Students in the control group followed a conventional paper & pencil-based homework intervention while students in the experimental group followed the Mobile-Based micro-Learning and Assessment (MBmLA) homework intervention. Students in the experimental group used smartphones (88%) and tablets (12%). Screen sizes however were comparable and the application was optimized to support multiple screen sizes. Students were not allowed to change groups during the intervention. Students and the instructor were informed in advance about the research procedure and the study's intention, appropriate permissions were requested and approved, participation was voluntarily and all data were collected anonymously.

Measuring instruments

The subject taught was "Electric fields and Currents" which is among the core subjects in the high school students' national science curriculum. In order to evaluate students' knowledge on electric fields and currents, a pre-test and a post-test were developed with "multiple-choice with comments" type questions. Both tests were scoring from 0 to 7. The aim of the pre-test was to evaluate students' prior background factual knowledge while the aim of the post-test was to evaluate students' factual knowledge after the intervention. Factual test questions examined knowledge of basic facts (such as a definition or formula) presented in class (e.g. Bloom's taxonomy; Krathwohl, 2002). Example of a factual question is: "Let *I* be the current through a conductor, *V* be the voltage measured across the conductor's ends and *R* the resistance of the conductor. What happens to the current when the voltage across the conductor's is doubled? Select the right answer: (a) 2I, (b) I^2 (c) I, (d) I/2 and explain."

Both pre-test and post-test were developed by the course instructor with the assistance of two experienced physics teachers in order to ensure content validity.

In order to assess students' levels of self-perceived autonomy, competence and relatedness, a pre-questionnaire and post-questionnaire were developed. The pre-questionnaire was designed to assess pre-existing levels of students' motivation while the post-questionnaire was designed to assess levels of students' motivation after the intervention.

In order to develop the questionnaire used in our research, we adopted items from previously validated instruments. For the perceived autonomy, competence and relatedness we adopted items from Basic Psychological Need Satisfaction (BPNS) Questionnaire (Baard, Deci, & Ryan, 2004; Deci & Ryan, 2002) and the Intrinsic Motivation Inventory (IMI) Questionnaire (McAuley, Duncan, & Tammen, 1989). BPNS assesses the degree to which people feel satisfaction of the basic SDT psychological needs. IMI assesses participants' subjective experience related to intrinsic motivation and self-regulation. A total of 12 question items were used to assess these motivational needs on a 7-points scale (1 = strongly disagree to 7 = strongly agree). Sample items are: for perceived autonomy, "I feel a sense of choice and freedom while participating in the MBmLA activities", for perceived competence, "After working at the MBmLA for a while, I felt pretty competent" and for perceived relatedness, "I feel connected with my classmates when I participate in the MBmLA". The three basic needs satisfaction factors had good internal reliabilities (alpha values were 0.84, 0.80 and 0.85 for autonomy, competence and relatedness respectively).

Regarding learning satisfaction we adopted six items from Hwang et al. (2013). Cronbach's alpha value was 0.91. All items of the questionnaire were appropriately modified to fit to our research context. Also, all items were translated (from English) into the native language of the students from a language expert.

Experimental procedure

The study employs a two-group pretest–posttest experimental design procedure in order to test the efficacy of the proposed Mobile-Based micro-Learning and Assessment (MBmLA) homework approach compared to the conventional paper-based homework. Figure 2 illustrates our experimental procedure. Students were randomly assigned to one of the two conditions: conventional paper-and-pencil approach (control) and the MBmLA approach (experimental).

First, an orientation section with the all necessary information was offered to students. Also, before the experiment, students took a pre-test to assess their level of pre-existing factual knowledge about electric fields and currents. Furthermore, an independent-samples t-test was conducted in order to compare the means between the control and experimental groups on pre-existing levels of factual knowledge. Students also completed a questionnaire reporting their perceived levels of autonomy, competence and relatedness before the intervention.

--- FIGURE 2 HERE ---

Figure 2: Experimental procedure

During the next five-week period, students in the control group participated in a conventional paper-and-pencil homework intervention while students in the experimental group participated in the MBmLA homework intervention.

The two homework approaches were the independent variable whereas learning achievement, the perceived levels of autonomy, competence, relatedness, and learning satisfaction were the dependent variables. Figure 3 shows students of both groups working on their assignments.

--- FIGURE 3 HERE ---

Figure 3. Students working on their assignments (mobile-based and paper-based groups)

Both learning environments (paper-and-pencil and MBmLA), aligned with the SDT principles (Deci & Ryan, 2002) ensured: i) autonomy support, by providing optimally challenging assignments relevant to students' interest, background knowledge and skills (Hartnett, 2015; Csikszentmihalyi, 1990), with meaningful choices (Reeve & Halusic, 2009) and defined purpose and value (Ryan & Deci, 2000) in an autonomy and non-controlling learning environment (Wang et al., 2015); ii) competence support, by providing appropriate guidance and feedback with motivational support (Burgers et al., 2015; Gikandi, Morrowa, & Davis, 2011), and iii) relatedness support, by facilitating social interactions through peer communication and collaboration for the group work (Hartnett 2015; Sorebo, Halvari, Gulli, & Kristiansen, 2009).

Most aspects of the two learning interventions (e.g. instructor, learning content and questions, learning aim and expected outcome) were the same except for the delivery and presentation mode (conventional paper-and-pencil vs. mobile-based micro-learning) along with their distinctive features of each mode. The homework requirement for students in the MBmLA condition was to answer, using their mobile devices, a set of questions that followed the related autonomous micro-learning units. Students also received interactive feedback with motivational

support. The homework requirement for students in the conventional paper-and-pencil condition was to answer, using the paper-worksheets they were given, the same questions that followed the related book study material. Students could check the correctness of their responses in a separate sheet of paper with the knowledge-of-correct-response answers. Furthermore, students in the MBmLA condition encouraged to participate in on-line synchronous or asynchronous social interactions and share material and information, while students in the paper-and-pencil condition were instructed to participate in face-to-face collaboration sessions after-class. However, this was not always feasible due to timing constraints in a busy class schedule. After the intervention, students took a post-test in order to evaluate again their level of factual knowledge about electric fields and currents. They also self-reported their perceived levels of motivation (autonomy, competence, relatedness) and learning satisfaction.

Data Analysis and Results

Learning performance

In order to answer the first research question i.e. to compare the learning achievement of the two groups, we conducted a one-way analysis of covariance (ANCOVA) with the studying mode (conventional paper-based homework vs. MBmAL homework) as the independent variable and the posttest and pretest scores as the dependent variable and covariate respectively. Moreover, the independent samples t-test that conducted to compare the means between the control and experimental groups on pre-existing levels of factual knowledge, revealed no statistically significant difference on the pre-existing levels of factual knowledge between the two student groups ($t = 2.41$, $p > 0.05$).

Regarding the performed analysis of covariance, the assumptions of normality of distribution and the homogeneity of regression were confirmed ($F = 0.11$, $p > 0.05$).

Table 1 shows that, after excluding the impact of the pre-test scores on the post-test, the learning achievement for the two groups were significantly different ($F = 7.49$, $p < 0.01$, $\eta^2 = 0.07$). Compared with the adjusted mean of 4.36 for the control group, the experimental group scored 4.88. The significantly better score of the experimental group than that of the control group suggests that students who learn with the MBmLA approach have better learning achievements in terms of factual knowledge, than those who learn with the conventional paper-based homework approach.

From the adjusted means it can be concluded, that the MBmLA approach can enhance students' learning achievement in terms of factual knowledge. The effect size ($\eta^2 = 0.07$) of the ANCOVA results of the MBmLA approach represented a moderate effect size, as proposed by Cohen (1988).

---TABLE 1 HERE ---

Perceived autonomy, competence and relatedness

In order to answer the second research question, i.e. to compare the motivation levels of the two groups, we conducted a one-way analysis of covariance (ANCOVA) with the studying mode (conventional paper-based homework vs. MBmLA homework) as the independent variable and the posttest scores on perceived autonomy, competence and relatedness as the dependent variables. The pre-questionnaires scores for autonomy, competence and relatedness were used as covariates, in order to remove possible effects of pre-existing individual differences

among students. The assumptions of normality of distribution and the homogeneity of regression for perceived autonomy, competence and relatedness were confirmed with $F = 1.65$, ($p > 0.05$), $F = 0.07$, ($p > 0.05$) and $F = 0.11$, ($p > 0.05$) respectively.

For perceived autonomy, table 2 shows that, after excluding the impact of the pre-test scores on the post-test, perceived autonomy for the two groups was significantly different ($F = 29.75$, $p < 0.001$, $\eta^2 = 0.22$). Compared with the adjusted mean of 4.62 for the control group, the experimental group scored 5.61. The significantly better score of the experimental group than that of the control group suggests that students who learn with the MBmLA approach self-report higher levels of perceived autonomy, than those who learn with the conventional paper-based homework approach.

For perceived competence, table 2 shows that, after excluding the impact of the pre-test scores on the post-test, perceived competence for the two groups was significantly different ($F = 14.35$, $p < 0.001$, $\eta^2 = 0.12$). Compared with the adjusted mean of 4.44 for the control group, the experimental group scored 5.18. The significantly better score of the experimental group than that of the control group suggests that students who learn with the MBmLA approach self-report higher levels of perceived competence, than those who learn with the conventional paper-based homework approach.

For perceived relatedness, table 2 shows that, after excluding the impact of the pre-test scores on the post-test, perceived relatedness for the two groups was significantly different ($F = 10.58$, $p < 0.01$, $\eta^2 = 0.92$). Compared with the adjusted mean of 4.18 for the control group, the experimental group scored 4.83. The significantly better score of the experimental group than that of the control group

suggests that students who learn with the MBmLA approach self-report higher levels of perceived relatedness, than those who learn with the conventional paper-based homework approach.

From the adjusted means it can be concluded, that the MBmLA approach can enhance students' perceived levels of autonomy, competence and relatedness. The effect sizes (η^2) of the ANCOVA results of the MBmLA approach represented a moderate effect size for competence (0.12) and large effect sizes for autonomy (0.22) and relatedness (0.92), as suggested by Cohen (1988).

--- TABLE 2 HERE ---

Learning satisfaction

In order to answer the third research question, we conducted independent sample t-tests for the students' learning satisfaction. Table 3 shows the results.

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The results of an independent sample t test show significant difference between the two groups ($t = 3.35$, $p < 0.01$). The mean for the experimental group (5.82) was significantly higher than the mean of the control group (5.24). The significantly higher score of the experimental group than that of the control group suggests that students who learn with the MBmLA approach show higher levels of learning satisfaction, than those who learn with the conventional paper-based homework approach.

Discussions and Conclusions

The current study proposes a Mobile-Based micro-Learning and Assessment (MBmLA) homework intervention that enhances student motivation (in terms of autonomy, competence and relatedness) and improves factual knowledge and learning satisfaction of secondary school students.

Previous studies provided evidence about the positive impact of mobile learning on students' performance and motivation (Tingir et al., 2017; Liu et al., 2014). Nevertheless, further insight regarding the use of mobile micro-learning in the context of homework delivery for high school students would be valuable. While a considerable body of research exists for the effectiveness of mobile micro-learning in the context of work-based and corporate training (Werkle, Schmidt, Dikke, & Schwantzer, 2015; Wen & Zhang, 2015), there is a lack of research focusing on mobile micro-learning homework approaches for high school science (Semingson, Crosslin, & Dellinger, 2015).

Homework is an important part of student learning and it is positively associated with students' achievement in K-12 science (Fan et al., 2017). Furthermore, its role receives greater importance especially in content-heavy curriculums (Ruohoniemi & Lindblom-Ylänne, 2009) and large class sizes (Harfitt & Tsui, 2015). The study builds on existing research about the benefits that computer-based homework offers to students e.g. immediate feedback and step-by-step scaffolding (Hauk, Powers, & Segalla, 2015; Mendicino, Razzaq, & Heffernan, 2009) as well as optimization of student learning (Babaali & Gonzalez, 2015; Kelly K., et al., 2013). In line with previous findings suggesting that use of mobile devices in teaching yielded higher achievement scores than conventional teaching in all subject areas (Tingir, 2017), our MBmLA approach improves student factual knowledge.

Moreover, the current study contributes to the technology enhanced learning literature by aligning design issues of mobile micro-learning with the Self-Determination Theory of motivation. Previous studies suggested different ways to enhance student motivation in mobile learning. To name just a few, Ciampa (2013) proposed challenge, curiosity, control, recognition, competition and cooperation, Su and Cheng (2015) proposed attention, relevance, confidence and satisfaction, Sha et al. (2012) proposed a model based on self-regulation. The current study, based on SDT, proposes that student motivation can be enhanced by supporting the basic psychological needs of autonomy, competence and relatedness.

Regarding autonomy, online learning environments have the potential to provide students with an optimal autonomy-supportive environment for learning (Chen & Jang, 2010; Sorebo, Halvari, Gulli, & Kristiansen, 2009). Perceived autonomy support and autonomous forms of motivation is essential for homework activities (Hagger, Sultan, Hardcastle, Chatzisarantis, 2015). The proposed MBmLA approach, by taking advantage of the anytime-anywhere features of mobile-devices, it offers a series of self-contained micro-learning units, providing thus an autonomy supportive homework environment where students experience a better sense of autonomy.

Regarding competency, research has shown that technological affordances provide students the opportunities to develop and better demonstrate their competencies (Gikandi, Morrowa, & Davis, 2011). Feedback on computer-based homework can benefit students by giving them more control on their learning (Fyfe, 2016) and positively affecting their sense of perceived competence (Hartnett, 2015). In our study, the timely provision of interactive cognitive and emotional feedback in

the mobile-based micro-learning approach enhances students' perceived sense of competence.

Regarding relatedness, research reveals that social networking integrated in online learning platforms for sharing information facilitates the interaction among members of the learning community. Liao & Zhu (2012) described it as "social micro-learning". In our mobile-assisted approach, the on-line sharing of information among high-school students and the collaborative content creation -required for the group tasks-, can be helpful to increase the interacting behaviors among the students and foster the sense of perceived relatedness, which is in-line with previous research in other contexts (Kukulska–Hulme & Shield, 2008). It is not the case that on-line communication can outreach face-to-face communication, but due to issues related to class administration and time management, face-to-face interactions on a specific homework task are not always feasible among class members. Therefore, mobile-based social micro-learning has the potential to provide opportunities to enhance perceived relatedness.

Students perceive mobile-based micro-learning as satisfying in terms of the learning experience. Mobile technologies are very popular among young students and play an important role in their everyday lives. The same can be true for their learning also. The proposed learning approach not only engages today's students in mobile-based micro-learning but it is also a promising instructional method for the lifelong adult learners of tomorrow (Buchem & Henrike, 2010).

The study has some limitations. First, regarding learning performance, it focuses on factual knowledge, i.e. the basic elements (formulas, terminology) that students must know in order to be acquainted with a discipline or solve simple problems.

Further research is needed to investigate if MBmLA can support conceptual knowledge as well, i.e. the interrelationships among the basic elements within a context (classifications, generalizations, theories and models) to solve more complex problems and engage in activities of higher cognitive levels – such as analyzing, evaluating and creating. Also, other question types (i.e. open-ended) as well as gamification elements (e.g. micro-credentials) would be interesting to consider. Future research needs to be applied in more topics beyond science, using larger and more diverse samples. The effect of MBmLA on students with different academic achievement levels (e.g. low- vs. high- achievers) could be investigated. It would be also interesting to incorporate assessment analytics such as learning behavioral patterns and temporal trace data.

Technology-based homework is gaining popularity among many schools. However, more evidence is needed on how to optimize young students' learning (Fyfe, 2016) and therefore, it still remains a challenge to develop technology-supported homework strategies that promote motivation and improve learning performance. Mobile-based micro learning provides a promising medium to promote factual learning and autonomous motivation for high-school students.

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Table 1: ANCOVA results of the post-test results for learning achievement on factual knowledge

Variable	Group	N	Mean	SD	Adjusted Mean	Sdt. error	F value	η^2
Learning	Control	54	4.28	1.00	4.36	0.13	7.49**	0.07
	Experimental	54	4.97	1.22	4.88	0.13		

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

Table 2: ANCOVA result of the post-test scores for autonomy, competence and relatedness

Variable	Group	N	Mean	SD	Adjusted Mean	Sdt. error	F value	η^2
Autonomy	Control	54	4.64	0.97	4.62	0.12	29.75***	0.22
	Exp.	54	5.59	0.90	5.61	0.12		
Competence	Control	54	4.44	0.97	4.44	0.14	14.35***	0.12
	Exp.	54	5.18	1.11	5.18	0.14		
Relatedness	Control	54	4.17	1.00	4.18	0.14	10.58**	0.92
	Exp.	54	4.83	1.21	4.83	0.14		

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

Table 3: t-test results for the learning satisfaction of the two groups

Variable	Group	N	Mean	SD	t value
Learning satisfaction	Control	54	5.24	1.00	3.35**
	Experimental	54	5.82	0.78	

** $p < 0.01$

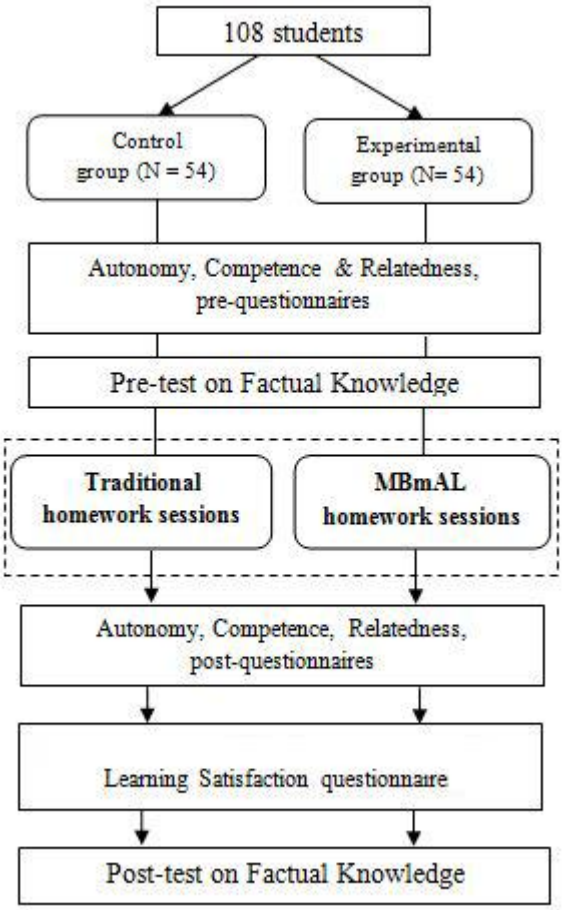
108 students
Control group (N = 54)
Experimental group (N= 54)
Autonomy, Competence & Relatedness, pre-questionnaires
Pre-test on Factual Knowledge
Traditional homework sessions
MBmAL homework sessions
Autonomy, Competence, Relatedness, post-questionnaires
Learning Satisfaction questionnaire
Post-test on Factual Knowledge

Figure 2.