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Mobile-based Assessment:
A literature review of publications in major referred journals from 2009 to 2018

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ABSTRACT

Mobile devices not only provide a medium for delivering personalized and context-aware learning but also facilitate the delivery of assessment activities anytime and anywhere. With the growing adoption of the Bring Your Own Device (BYOD) practices in education, Mobile-Based Assessment (MBA) is an emerging field in the context of mobile learning research. Although a considerable number of literature reviews exists about mobile learning, there is no such review study to provide insight into mobile-based assessment. The current study is a review of forty-three (43) articles about mobile-based assessment published in seven major educational technology research journals from January 2009 to February 2018. Major findings include that most mobile-based assessment studies focused on formative assessments with elementary students and in STEM subjects. Most of the reviewed articles reported a significant positive impact on student learning performance, motivation and attitudes. Moreover, the study identified several gaps in the mobile assessment literature. More research is needed to investigate issues and concerns related to negative perceptions against mobile assessment, especially form the teachers' point of view. Also, a stronger alignment needs to be developed between student motivation and different mobile-based assessment practices. The study can be a valuable reference for educators and researchers working in the field of mobile-based assessment.

KEYWORDS: mobile learning, mobile devices, mobile-based assessment, mobile assessment, feedback, literature review

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1. Introduction

With the rapid growth of mobile technologies and the extensive usage of mobile devices, there is a continuously increasing adoption of mobile learning in both formal and informal educational settings. Moreover, Bring Your Own Device (BYOD) policies are gaining popularity in both learning and working environments (Adams Becker, 2017). Mobile technologies provide new and enhanced learning opportunities, such as personalization and adaptivity, context-awareness and ubiquity, interactivity, communication and collaboration among learners, and seamless bridging between contexts in both formal and informal learning (Sung, Chang, & Liu, 2016; West & Vosloo, 2013).

There exist a large number of literature review studies about mobile-based learning. Most of these studies feature positive outcomes (Chee, Yahaya, Ibrahim, & Noor Hassan, 2017, Wu et al., 2012). Sung, Chang, & Liu (2016) found that mobile devices such as laptops, personal digital assistants, and mobile phones are a learning tool with great potential in both classrooms and outdoor learning. Chiang et al. (2016) provided a content analysis of mobile learning patents in selected databases from 1976 to 2013. Common mobile learning patents characteristics were found to be multi-presentation, supporting seamless learning, adopting learner analysis, improving learner diversity and context awareness. Hwang and Wu (2014) reported that mobile learning is promising in improving students' learning achievements, motivations and interests.

Mobile devices not only provide a time- and location-independent medium for delivering personalized and context-aware learning content but also facilitate Mobile-Based Assessment (MBA), a new delivery mode of assessment with the use of mobile devices. While many MBA implementations exist in the related literature, to the best of our

knowledge, no review study exists to provide an overview of the current status in the research about Mobile-Based Assessment (MBA).

The current review has two objectives. The first objective is to provide a current synthesis of Mobile-Based Assessment research addressing relevant features. This objective is approached by addressing the following research question R1.

R1. In studies involving mobile-based assessments, what are the journal and year of publication of the articles, age and education level of the participating subjects, country context, learning domain, assessment types and supported technologies, research design and research purpose?

The second objective is to investigate the impact that MBA has on students' learning performance, motivation and attitudes. This objective is approached by addressing the following research questions R2, R3, and R4.

R2. What is the impact of mobile-based assessment on student learning performance?

R3. What is the impact of mobile-based assessment on student learning motivation?

R4. What are students' and/or teachers' attitudes and perceptions about mobile-based assessment?

The authors conducted a literature search in seven major educational technology research journals and identified 43 relevant articles published from January 2009 to February 2018. These articles have been analyzed according to the aforementioned set of research questions.

The review study is organized as follows. First, a background section draws on mobile-based assessment, existing mobile learning reviews and the rationale for a mobile-assisted assessment literature review study. Then, the methodology section follows with the inclusion and exclusion criteria, search strategy, study selection and analysis framework and coding. Study results along with discussions and study limitations come afterwards. Next,

identified gaps in the literature with potential future research are presented. Finally, there is the conclusions section that summarizes the study discussions strengthening the contribution of the study.

2. Background

2.1Mobile-Based Assessment

Assessment is a critical process in education that features both measuring and supporting student learning. We follow the definition by OECD (Nusche, 2012) that assessment refers to the process of measuring and/or collecting and using evidence about the outcomes of students' learning. Assessment can be distinguished as summative assessment (takes place after a cycle of learning and measures what has been learnt, i.e. "assessment of learning") or formative assessment (takes place throughout the cycle of learning gathering evidence of learning and providing teachers and/or students with feedback information in order to improve learning. i.e. "assessment for learning") (Black, 2008).

According to the P21's Framework for 21st Century Learning (2018), assessment is one of the critical systems necessary to support the skills, knowledge and expertise students should master in order to succeed in work and life in the 21st century. However, traditional assessment practices are not always appropriate to evaluate competences related to real-world tasks, as well as higher-level skills such as problem-solving, creativity and collaboration which are of great importance (Binkley et al., 2014). Researchers agree that there is a need to redesign educational assessment practices based on modern theories of learning, in order to combine different types of evidence and reflect on what students really know and can do (Harlen, 2013; National Research Council, 2001).

The utilization of wireless technologies and personal mobile electronic devices in assessment procedures facilitate the development of a relatively new assessment mode.

Mobile-Based Assessment (MBA) is the assessment that is delivered with the use of personal electronic mobile devices such as Personal Digital Assistants, smart phones or tablets.

According to UNESCO (2015) Future of Learning series, mobile technologies have the potential to support 21st century learning and assessment. There are many affordances associated with the use of mobile devices in assessment. Mobile technologies provide new and enhanced functionalities and opportunities to assess learning, such as personalization and adaptivity, context-awareness and ubiquity, interactivity, communication and collaboration among learners, and seamless bridging between contexts in both formal and informal learning (Sung, Chang, & Liu, 2016; West & Vosloo, 2013). Mobile devices can effectively support new and advanced question items and assessment activities augmented with virtual or real physical elements (Santos et al., 2012). Mobile devices can support a wide range of assessment practices such as classroom polling (Stowell, 2015), self- and peer-assessments (Chen, 2010; Lai & Hwang, 2015), high-stakes summative testing (Arthur, Doverspike, Muñoz, Taylor, & Carr, 2014), formative assessments (Hwang & Chang, 2011), adaptive and personalized assessments (Song, Wong, & Looi, 2012; Triantafillou, Georgiadou, & Economides, 2007), performance-based (Campbell & Main, 2014) and competency-based assessments (Coulby, Hennessey, Davie, & Fuller, 2010), authentic, context-aware and ubiquitous assessments (Chu, Hwang, Tsai, & Tseng, 2010; Huang & Chiu, 2015; Hwang & Chang, 2011; Santos, Pérez-Sanagustín, Hernández-Leo, & Blat, 2012), game-based assessments (Wang, 2015) and assessments with augmented reality features (Chao et al., 2016).

2.2 Previous review studies

There are many literature reviews and meta-analysis studies about mobile learning focusing on both the effectiveness of mobile learning and the development of mobile learning systems to assist student learning (Chee, Yahaya, Ibrahim, & Noor Hassan, 2017;

Chiang et al., 2016; Hwang & Wu, 2014; Sung, Chang, & Liu, 2016; Wu et al., 2012). Moreover, there are mobile learning review studies that focus on K-12 education (Crompton, Burke, Gregory, 2017; Liu, Scordino, Geurtz, Navarrete, Ko, & Lim, 2014), higher education (Pimmer, Mateescu, & Gröhbiel, 2016) or even specific learning domains e.g. science education (Crompton, Burke, Gregory, & Gräbe, 2016). The majority of these review studies suggest that mobile learning is a promising method in improving students' learning achievements, motivation and learning attitudes.

Many of the studies (e.g., Huang, & Chiu, 2015; Hung, et al., 2013) included in the aforementioned reviews have implemented mobile-based assessment activities embedded in mobile learning scenarios. However, mobile-based assessment can not only be implemented as an embedded educational activity in the wider context of a mobile learning scenario but it can also be administered in its own context as an autonomous educational activity (e.g. in a blended approach, complementing conventional paper-based learning). Therefore, mobile-based assessment should be studied also in its own context. Not many researchers focus primarily or exclusively on the value and the potential of mobile-based assessment and therefore not enough information have been provided so far regarding exclusively mobile assessment procedures. A review by Cheung and Hew (2009) showed that only 7% of the studies that examine the use of mobile devices in education focus in assessment. The same study revealed that in K-12 and higher education settings the use of mobiles as assessment tools is in the fourth place (14%) following other uses such as communication (22%), multimedia access (20%) and task management (18%). Thus, no review study exists to provide an overview of the current status in the research about Mobile-Based Assessment (MBA). This is the first study that provides a review of articles about mobile-based assessment and promotes an evidence-based discussion on the use of mobile devices for assessment purposes.

3. Method

The current study is a literature review about mobile-based assessment. A literature review identifies, selects, and synthesizes primary research studies in order to provide a picture of the topic under investigation (Oakley, 2012).

3.1 Inclusion and exclusion criteria

The current literature search performed based on the well established PRISMA principles (Moher et al., 2009). Both electronic and manual searches were conducted. The four main inclusion criteria for the articles considered in the current review are:

(i) Articles should have been published in peer-reviewed journals.

(ii) The journals under consideration should be among the top publications in the field of educational technology research. We have used the Google Scholar metrics to identify the initial list of seven top journals in the educational technology based on their five-year h-index and h-median metrics. The search among the top publications was performed as follows: "Categories: Social Sciences > Subcategories: Educational Technology". We have eliminated the *International Review of Research in Open and Distributed Learning* from the list as the main focus of this journal is on open and distance education. Also, we have considered the *Computers in Human Behavior* journal since it addresses, among other topics, the use of mobile devices in education from a psychological perspective. Therefore, the following journals were identified and used for the current research: British Journal of Educational Technology (BJET), Computers & Education (CAE), Computers in Human Behavior (CHB), Educational Technology Research & Development (ETR&D), Journal of Computer Assisted Learning (JCAL), Journal of Educational Technology and Society (JETS) and The Internet and Higher education (IHEDUC). Table 1 shows the impact factor

(according to the Institute for Scientific Information (ISI) Journal Citation Reports) and the h5-index (according to Google Scholar metrics) for each of the aforementioned journals considered for the review. PhD dissertations were not included in the review as not being peer-reviewed and therefore may be less scientifically rigorous than those that are peer-reviewed and published. The time period selected for the review is from January 2009 to February 2018 since this period provides the most current trends in mobile-based assessment.

(iii) Students used mobile devices (personal digital assistants, tablets or smart phones) for assessment. Studies about computer-based or web-based assessment in general or studies about electronic response systems or specialized polling devices (clickers) were not included in the review. Relative studies have been included in the review only if: (i) mobile devices were used in place of clickers, or (ii) there was a comparative study between mobile assessment and other assessment types.

(iv) Studies should focus on mobile-based assessment procedures or mobile learning activities with extensive integrated mobile-assisted assessment activities. Studies that seamlessly integrate mobile learning and assessment without their focal point to be on mobile assessments were not included in the review.

Table 2 shows the inclusion and exclusion criteria used in this literature review.

3.2 Search strategy

Articles were searched by using the following search terms for the title, keywords and abstract sections: ("*assessment" OR "feedback" OR "micro-learning" OR "microlearning") AND ("mobile" OR "smart phones" OR "Personal Digital Assistants" OR "tablets" OR "m-learning" OR "context-aware" OR "ubiquitous learnin*g"). The term "feedback" has been included since feedback is an integral part of assessment (Chen, Wei, Huang, & Kinshuk, 2013) and assessment is primarily concerned with providing teachers

and/or students with feedback information. The term “microlearning” has been included since mobile-based microlearning also delivers assessment activities (Gu, Gu, & Laffey, 2011). Mobile - based microlearning combines features of mobile learning and microlearning to deliver small learning units and short - term learning activities (Nikou & Economides, 2018a). The mobile devices considered for assessment delivery in this review are PDAs, tablets or smart phones, as being the most commonly used by the students (Crompton, Burke, & Gregory, 2017). The other terms have also been included since they are frequently used in the mobile learning literature.

3.3 *Study selection*

This search resulted in 116 articles (excluding the duplicates). After initial screening, 32 articles have been removed (excluded by examining either the title or the abstract). Furthermore, after full text eligibility checking, 41 articles have been excluded as not being relevant to the scope of our study (according to the aforementioned inclusion and exclusion criteria). This resulted in 43 articles that were finally used in our literature review about MBA. The flow of information through the different phases of the review is presented in the PRISMA flow diagram depicted in Figure 1 (Moher et al., 2009).

3.4 Analysis framework and coding

Based on the research questions, the following features were investigated and coded as appropriate: (i) journal of publication, (ii) year of publication, (iii) education level of the participating subjects (elementary school, secondary school, University, vocational and lifelong learning e.g.in-service teacher training, and mixed subjects), (iv) country context, (v) learning domain (science, humanities, professional education e.g. nursing education, lifelong learning and mixed subjects), (vi) assessment type (formative, summative, mobile-based

classroom polling, self-, peer- assessment or other types e.g. dynamic or performance assessment), (vii) supported technologies (e.g. adaptive, context-aware, augmented reality, learning analytics etc), (viii) research design (quantitative, qualitative or mixed), (ix) research purpose (with the focus to be on the mobile system design or to evaluate mobile-based assessment or serve both purposes). Learning outcome, motivational impact and attitudes/perceptions were coded as being either positive (implying improvement/increase), negative (implying weaken/decrease), neutral (implying neither positive nor negative impact) or not specified respectively. The two authors initially coded independently all the above features and then came to an agreement for all the differences.

4. Results and Discussions

Several findings emerged as a result of the research synthesis of the selected forty-three peer-reviewed articles on mobile based-assessment in terms of the context, design and purpose of the selected studies and also the impact that MBA has on learning performance, motivation and attitudes/perceptions. Table 3 illustrates these findings of our review of the forty-three (43) referred journal articles about MBA, published from January 2009 to February 2018.

A detailed analysis of the outcomes of the review follows, organized into four sections corresponding to the four research questions that have driven our research.

4.1 Research Question one

The classification of the articles considered in our review, based on the selected criteria of: (a) number of articles published by year and journal, (b) subjects (age and education level), (c) country context, (d) learning domain, (e) assessment type and supported technology, (f) research design and (g) research purpose, is presented as follows.

(a) Classification based on number of articles published by year and journal.

Table 4 shows the number of articles about mobile-based assessment published in the selected seven major educational technology journals for the period January 2009 to February 2018. Most reviewed articles (12) were published in the CAE journal followed by the BJET (10 articles) with CHB, ETRD and ETS journals to follow (5 articles each). IHEDUC and JCAL only published 3 MBA-related articles each.

Figure 2 shows the number of mobile assessment articles published from January 2009 to February 2018, presented by the year of publication. The figure shows that there were a relatively higher number of MBA-related publications in the years 2010 and 2011. Afterwards, a period with a moderate count of MBA-related publications (2012-2015) followed. Today there is again an increasing trend in the number publications focusing on mobile assessments. This is in-line with the popularization of BYOD (Bring-Your-Own-Device) policies in schools and Universities (Adams Becker, 2017).

(b) Classification based on subjects.

In the majority of the MBA articles studied, the participants are elementary schools students (30%), followed by University students (28%) and students in secondary education (23%), while 9% of the studies involve a mixed population of both teachers and students (primarily from tertiary education). Previous literature reviews on mobile learning have also shown that elementary and University students are the major samples of mobile learning research (Wu et al., 2012).

According to our review, MBA-related research in vocational and lifelong learning accounts only for 5% of the MBA studies. Research about the use of mobile devices in teacher education and training also accounts only for 5% (Figure 3). Previous studies also have shown that limited mobile learning and assessment research from the teachers' perspective exists (Hwang & Tsai, 2011; Sanchez-Prieto, Olmos-Miguelanez, & Garcia-Penalvo, 2017).

(c) Classification based on country context.

Most of the reviewed articles were conducted in four specific country contexts: Taiwan (28%), China (14%), USA (9%) and Spain (9%). Authors from Taiwan contributed the most publications (12) in the literature about mobile and ubiquitous assessment followed by authors from China (6 publications), USA and Spain with 4 publications each. Other reviews (Chee et al., 2017; Hung & Zhang, 2012) also found that Taiwan is the most contributing country regarding journal publications on mobile learning research. Different European countries (excluding Spain) account in total for 21% of the related publications (9 publications). Minor contributions from other countries (e.g. Hong Kong with 5%, Singapore with 2%) also exist. Also. 5% of the studies come from undisclosed regions.

(d) Classification based on learning domain.

Most of the reviewed articles assess Science (Physics, Information Technology, Environmental education) and Mathematics related subjects (49%). Moreover, a considerable body of research exists about mobile-assisted inquiry-based learning, where assessments (mostly formative) are seamlessly integrated with the inquiry learning procedures (Hung, Hwang, Lin, Wu, & Su, 2013; Looi et al. 2011; Song, Wong, & Looi, 2012). 28% of the reviewed articles refer to Social Sciences, Language, Literature and Culture courses. 16% were conducted in the context of professional education (e.g. medical, teacher training) and lifelong learning. 7% of the articles draw upon mixed courses (Figure 4). These results are in line with previous research about mobile learning (Liu et al., 2014).

(e) Classification based on assessment type and supported technology.

The majority of the reviewed articles refer to formative assessments (44%), followed by self- and peer-assessments (16%) and formative and self-assessments (14%). Researchers agree that due to their ubiquity features and immediate feedback mechanisms, mobile devices are an appropriate medium for delivering formative assessments anywhere and anytime, indoors or outdoors (Chen & Chen, 2009; Hwang & Chang, 2011). Mobile devices are also

an appropriate mean for self- and peer-assessments (Nikou & Economides 2013). Only 7% of the articles refer to a combination of formative and summative assessment practices. Studies about classroom polling with mobile devices (according to the aforementioned inclusion criteria, clickers are not included in this review) represent 7% of the reviewed articles. Also, 12% of the articles refer to other assessment types (dynamic and performance assessments) (Figure 5).

It is interesting to note that 40% of the articles included in our review implemented adaptive and context-aware activities (e.g. with RFID and QR-coding technology) with 15% to incorporate more advanced technologies such as learning analytics (van der Schaaf et al., 2017) and augmented reality (Chao et al., 2016) as well as new pedagogies like game-based assessment (Wang, 2015).

(f) Classification based on research design.

Most reviewed articles are based on a quantitative design (19 articles, 44%) followed by a mixed research design (16 articles, 37%). Only eight articles (4%) in the review are based on a qualitative research design. Chee et al. (2017) also found that in mobile learning research quantitative and mixed methods are favored over qualitative methods.

(g) Classification based on research purpose.

Regarding the research purpose of the reviewed articles, we categorize the articles as follows: 23 articles (53%) evaluate the effectiveness of mobile-based assessment, 9 articles (21%) design a mobile system for learning and/or assessment and 11 articles (26%) serve both purposes. Previous reviews have also shown that most studies of mobile learning and/or assessment focus on effectiveness, followed by mobile learning system design (Crompton, Burke, & Gregory 2017; Wu et al., 2012).

4.2 Research Question two (Learning performance)

Most (60%) of the reviewed articles reported a significant positive impact on student learning performance. Correspondingly, Nikou and Economides (2016) reported a significant increase in learning achievement for low-achieving students who participated in a seven-week mobile-assisted self-and peer assessment intervention. Negative impact was reported in only 2% of the articles. This reported negative impact is attributed to the high cognitive load imposed by mobile devices (Chu, 2014). Moreover, students may spend more time answering a question on a mobile device compared to answering the same question on a computer (Nedungadi & Raman, 2012). However, 5% of the articles found no impact on student learning performance. The rest 33% of the articles did not investigate the impact that MBA has on student learning performance (Figure 6).

4.3 Research Question three (Learning Motivation)

A large percentage (35%) of the reviewed articles reported a positive impact of MBA on student learning motivation. Nikou and Economides (2017a,b) explained and predicted behavioral intention to use mobile-based assessment from the perspective of Technology Acceptance Model (Davis, 1989) and Self Determination Theory (SDT; Deci & Ryan, 2002) of motivation, providing a more solid background to understand the motivational dimensions that are embedded in mobile-assisted assessments. The SDT motivational constructs of autonomy, competence and relatedness are significant predictors of intention to use mobile-based assessments. Very few of the reviewed articles (2%) found no impact on student motivation. However, it is worth mentioning that from the 16 articles that evaluate the motivational impact of MBA, only six studies (38%) derive their results based on rigorous statistical analysis of students' responses to structured questionnaires. Most researchers simply record students' comments or self-report their own observations through their interactions with the students. More research may need to validate these results. The rest

63% of the articles studied in our review did not investigate the motivational impact (Figure 7).

4.4 Research Question four (Attitudes)

Most of the reviewed articles (72%) reported positive student attitudes and perceptions about mobile-based assessment. 3% of the articles reported negative students' perceptions and 2% reported neutral perceptions. The rest of the articles (23%) investigate neither students' nor teachers' attitudes and /or perceptions about MBA (Figure 8).

Table 5 summarizes the aforementioned results about the impact of mobile-based assessment on student learning outcome, motivation and attitudes/perceptions.

All the aforementioned results about the impact of MBA on learning performance, motivation and attitudes are in line with the findings from comparable literature reviews about mobile learning in general. Previous literature reviews about mobile learning also provide evidence that mobile learning is a promising method in improving students' learning achievements, motivations and interests (Chee, et al., 2017; Crompton, Burke, & Gregory, 2017; Hwang & Wu, 2014; Sung, Chang, & Liu, 2016; Wu et al., 2012).

5. Identified gaps and future research

The following gaps in the mobile-based assessment related research were identified in this review of the selected seven major referred journals.

5.1 Research Question one

(a) Mobile assessment from the lens of the learning domains

In the selected journals, mobile assessment has been mainly used so far with STEM subjects in elementary education and classroom polling in University lecture halls. Therefore, more research is needed in non-STEM disciplines (e.g. Social Sciences or Humanities) and other areas as well (e.g. professional education and lifelong learning).

(b) Mobile assessment from the lens of the participating subjects

More research is needed with participants from secondary education, professional lifelong learning and teacher training. In support of this result, previous research reported that mobile devices are well suited for work-based learning since they can facilitate formative assessments in situ and offer better learning opportunities (Coulby, Hennessey, Davies, & Fuller, 2011). Also, only two of the reviewed studies focus on teachers' perceptions and attitudes about mobile-based assessments (Nikou & Economides, 2018b; Song and Kong, 2017). Therefore, further research on mobile learning and assessment from the teachers' perspective is needed as well.

(c) Mobile assessment from the lens of assessment type

Most of the reviewed articles provide evidence on the effectiveness of mobile devices for formative and self-assessments. According to previous research, technology enhanced formative assessment and feedback enhances student learning supporting critical thinking, inquiry learning and 21st century skills (Spector, et al., 2016). Also, mobile supported self- and peer-assessment activities have been found to promote learning (Chen, 2010). Based on the current review study, mobile-based peer-assessment needs more investigation.

Moreover, only one article (García Laborda, et al., 2014) examined the feasibility (in terms of budget, accessibility, familiarity and quality) of mobile-based assessment in high stakes testing with large number of students. Also, few articles focus on other assessment types e.g. portfolio assessment or even classroom polling with the use of mobile devices. Therefore, in agreement with previous research (Winfred, et al., 2014), more research may be needed in order to investigate issues that arise from the differences on assessments across different devices and types.

(d) Mobile assessment from the lens of the supporting technologies

The utilization of mobile devices for adaptive assessment is not new (Triantafillou, Georgiadou, & Economides, 2008). However, only half of the reviewed articles took full advantage of the adaptivity and context-aware features of the mobile devices. Furthermore, only few recent articles have implemented MBA with embedded learning analytics, augmented reality or game-based learning.

In context-aware and adaptive personalized assessment implementations students can demonstrate their competences in authentic contexts. Researchers agree that mobile devices can facilitate the delivery of embedded assessment, i.e. assessments integrated into the learning flows in authentic environments, and aligned assessments, i.e. assessments aligned with the intended learning outcomes (Hernández-Leo & Safont, 2015). Therefore, next-generation mobile-assisted assessment practices should integrate these new and emerging technologies providing a better alignment of mobile-based assessment with the 21st century learning pedagogical and instructional approaches (e.g. creativity, collaboration, personalization)

5.2 Research Question two: mobile assessment and learners' performance

The majority of the reviewed articles reported a significant positive impact of MBA on student learning performance. However, it is difficult to relate the use of a specific method of student assessment to student performance (Haahr, 2005). Researchers argue that teenagers' familiarity with new technologies increases their motivation and as a result, performance improves (de-Marcos et al., 2010). However, more research is needed to explain how MBA positively relates to higher student achievement.

Researchers agree that learners can benefit from MBA in various aspects including flexible and ubiquitous assessment arrangement, more self-directed learning experiences (Chao, 2016), more opportunities for student self-reflection and more peer-interactions (Chen, 2010), feedback and scaffolding, type and quality of the content, adaptability and

context-awareness (Cayton-Hodges et al., 2015). However, none of the reviewed articles explains or predicts learning performance in terms of specific mobile assessment affordances. It would be interesting to associate mobile assessment affordances, personality characteristics of the learners and positive student outcomes.

5.3 Research Question three: mobile assessment and learners' motivation

A large percentage of the reviewed articles reported a significant positive impact of MBA on student learning motivation. However, in more than half of the articles that investigate the impact of MBA on student motivation, findings are based on students' comments and researchers' personal observations rather than an effect size. For example, researchers argue that students might feel excited or more engaged when using the mobile devices to learn in authentic contexts (Chu, Hwang, Tsai, & Tseng, 2010). Therefore, further research with more rigorous statistical evidence is needed, not only to confirm the validity of the previous results, but also to further investigate the motivational impact of using mobile devices in assessments. There are studies that conceptually investigated motivation in mobile learning. Su and Cheng (2015) explored mobile learning in terms of attention, relevance, confidence and satisfaction. Sha et al. (2012) proposed a mobile learning model based on self-regulation. Nikou and Economides (2017a) proposed a mobile-based assessment adoption model based on the self-determination theory of motivation. However, according to the mobile learning review by Zydney and Warner (2016), a stronger alignment is needed between the general underlying theories and measured outcomes. Therefore, a theoretical background to explain the relation between student motivation and MBA would be valuable to be developed.

Comparing the impact of MBA on performance, motivation and attitudes (Figure 9) the percentages of articles that reported a positive impact of MBA on performance (60%) is greater than the percentages of articles that have not investigated this relation yet (33%). The

same holds for student attitudes, where the percentages of articles that reported a positive impact of MBA on attitudes (72%) is much greater than the percentages of articles that have not investigated this relation yet (23%). This is not the case for motivation, since only 35% of the considered articles reported a positive motivation outcome, while the majority (63%) have not performed such an investigation at all. This may have left some unresolved issues regarding the motivational impact of MBA (e.g. identification of learning domains, mobile assessment types and methods that have different impact on student motivation) that future research may explore.

5.4 Research Question four: mobile assessment and learners' perceptions and attitudes

The majority of the reviewed articles reported positive student attitudes about MBA. Students self-report an increase in satisfaction for using mobile devices during the assessment process. This is true for mobile learning in general as well (Hwang & Wu, 2014). However, more longitudinal studies may needed in order to eliminate any possible novelty effects.

Also, careful consideration is needed to avoid publication bias. Very few studies (Gikas & Grant, 2013; Song & Kong, 2017) reported negative students' attitudes for mobile assessments, e.g. device challenges, devices as destructions, frustration from learning and cognitive load or even teachers' negative perceptions, e.g. technical, social and personal constraints . Therefore, more research is needed to investigate these issues.

6. Limitations

This review is limited by the fact that it examines only articles published in seven top-ranked educational technology journals (based on Google Scholar metrics) during the last eight years (January 2009 – February 2018). The study is not intended to be a comprehensive overview of the status in the research about Mobile-Based Assessment; the study rather provides a snapshot of the MBA-related research published in these journals. Therefore,

generalizations should be made with cautions and further research may include MBA articles from larger databases as well.

7. Conclusions

The current study is a review of forty-three mobile-based assessment related articles published in seven major technology-enhanced learning research journals from January 2009 to February 2018.

This study is the first literature review about mobile-based assessment and presents the following new findings that hold for the aforementioned selected journals: (1) In these selected journals, most mobile-based assessment studies have been implemented in STEM subjects, with elementary school pupils and University students, (2) Among the reviewed articles, Taiwan is the most contributing country in the MBA related research, (3) most MBA studies in the selected journals refer to formative assessments, (4) quantitative research design is the preferred research method for most reviewed articles, 5) the primary aim from most reviewed articles in the selected journals is to evaluate the effectiveness of mobile-based assessment, (7) most of the reviewed articles reported a significant positive impact on student learning performance, (8) most of the reviewed articles reported a positive impact of MBA on student learning motivation and (9) most of the reviewed articles reported positive student attitudes and perceptions about mobile-based assessment.

Also, based on the selected journals, the following main research gaps in the mobile-based assessment literature have been identified: (1) more research is needed in non-STEM disciplines, (2) more research is needed with participants from secondary education, professional lifelong learning and teacher training, (3) more research is needed in order to investigate issues that arise from the differences on assessments across different types and devices, (4) next-generation mobile-assisted assessment practices should integrate new and

emerging technologies, (5) more research is needed to explain how and why MBA positively relates to higher student achievement, (6) a stronger alignment is needed between student motivation and different mobile-based assessment practices, (7) more research is needed to investigate issues and concerns related to negative perceptions against mobile assessments.

The study provides a synthesis of the current research and an indicator for future research in the field of mobile-based assessment and therefore it can be a valuable reference for educators and researchers working in this field.

References

(References marked with an asterisk indicate studies included in the review).

Adams Becker, S., Cummins, M., Davis, A., Freeman, A., Hall Giesinger, C., & Ananthanarayanan, V. (2017). NMC Horizon Report: 2017 Higher Education Edition. Austin, Texas: The New Media Consortium.

Alioon, Y. & Delialioğlu, Ö. (2017). The effect of authentic m-learning activities on student engagement and motivation. *British Journal of Educational Technology*. doi:10.1111/bjet.12559 *

Arthur, W., Doverspike, D., Muñoz, G. J., Taylor, J. E., & Carr, A. E. (2014). The Use of mobile devices in high-stakes remotely delivered assessments and testing. *International Journal of Selection and Assessment*, 22, 113–123. doi: 10.1111/ijsa.12062

Binkley, M., Erstad, O., Herman, J., Raizen, S., Ripley, M., & Runmble, M. (2014), *Partnership for 21st century skills*. Retrieved August 20, 2017, from http://www.p21.org/

Black, P. (2008). Formative assessment in the learning and teaching of design and technology. *Design and Technology Education: An International Journal*, 13(3).

Bogdanović, Z., Barać, D., Jovanić, B., Popović, S., & Radenković, B. (2014). Evaluation of mobile assessment in a learning management system. *British Journal Educational Technology*, 45, 231–244. doi:10.1111/bjet.12015*

Campbell, A., & Main, S. J. (2014). Performance, assessment and communication in one app: Mobile tablet assessment is here to stay. *eCULTURE*, *7*(1). Retrieved from http://ro.ecu.edu.au/eculture/vol7/iss1/6

Cayton-Hodges, G. A., Feng, G., & Pan, X. (2015). Tablet-based math assessment: What can we learn from math apps? *Educational Technology & Society*, 18 (2), 3–20.

Chao, K. H., Chang, K. E., Lan, C. H., Kinshuk, & Sung, Y. T. (2016). Integration of mobile AR technology in performance assessment. *Educational Technology & Society*, 19 (4), 239–251. *

Chee, K. N., Yahaya, N., Ibrahim, N. H., & Noor Hassan, M. (2017). Review of mobile learning trends 2010-2015: A Meta-Analysis. *Educational Technology & Society*, 20 (2), 113–126.

Chen, W., Gu, X. and Wong, L. (2017). To click or not to click: Effectiveness of rating classroom behaviors on academic achievement with tablets. *British Journal of Educational Technology*. doi:10.1111/bjet.12593 *

Chen, N., Wei, C., Huang, Y., & Kinshuk. (2013). The integration of print and digital content for providing learners with constructive feedback using smartphones. *British Journal of Educational Technology*, 44, 837-845. doi:10.1111/j.1467-8535.2012.01371.x *

Chen, C.-h. (2010). The implementation and evaluation of a mobile self- and peer-assessment system. *Computers & Education*, 55(1), 229-236. doi:10.1016/j.compedu.2010.01.008 *

Chen, C.-M., & Chen, M.-C. (2009). Mobile formative assessment tool based on data mining techniques for supporting web-based learning. *Computers & Education*, 52(1), 256-273. doi:10.1016/j.compedu.2008.08.005 *

Cheung, W.S., & Hew, K.F. (2009). A review of research methodologies used in studies on mobile handheld devices in K-12 and higher education settings. *Australasian Journal of Educational Technology*, 25(2), 153-183.

Chiang, F.-K., Zhu, G., Wang, Q., Cui, Z., Cai, S. & Yu, S. (2016). Research and trends in mobile learning from 1976 to 2013: A content analysis of patents in selected databases. *British Journal of Educational Technology*, 47, 1006–1019. doi:10.1111/bjet.12311

Chou, P.-N., Chang, C.-C., Lin, C.-H. (2017). BYOD or not: A comparison of two assessment strategies for student learning. *Computers in Human Behavior*, 74, 63-71, doi:10.1016/j.chb.2017.04.024*

Chu, H.-C. (2014). Potential negative effects of mobile learning on students' learning achievement and cognitive load - A format assessment perspective. *Educational Technology & Society*, 17 (1), 332–344. *

Chu, H.-C., Hwang, G.-J., Tsai, C.-C., & Tseng, J.C.R. (2010). A two-tier test approach to developing location-aware mobile learning systems for natural science courses. *Computers & Education*, 55(4), 1618-1627. doi:10.1016/j.compedu.2010.07.004 *

Coulby, C., Hennessey, S., Davies, N., & Fuller, R. (2011). The use of mobile technology for work-based assessment: the student experience. *British Journal of Educational Technology*, 42, 251–265. doi:10.1111/j.1467-8535.2009.01022.x *

Crompton, H., Burke, D., & Gregory, K. H. (2017). The use of mobile learning in PK-12 education: A systematic review. *Computers & Education*, 110, 51-63.

Crompton, H., Burke, D., Gregory, K. H. & Gräbe, C. (2016). The Use of mobile learning in science: A systematic review. *Journal of Science Education and Technology*, 25, (2), 149-160. doi:10.1007/s10956-015-9597-x

Dalby, D., & Swan, M. (2018). Using digital technology to enhance formative assessment in mathematics classrooms. British Journal of Educational Technology. doi:10.1111/bjet.12606 *

Davies, N., Joynes, V., & Walker, T. (2010). Assessment and Learning in Practice Settings (ALPS) - Implementing a large scale mobile learning programme. A report. Retrieved from http://www.alps-cetl.ac.uk/documents/ALPS%20IT%20Report.pdf

Davis, F. D. (1989). Perceived usefulness, perceived ease of use and user acceptance of information technology. *MIS Quarterly*, 13(3), 319–340.

Deci, E. L., & Ryan, R. M. (2002). *Handbook of self-determination research*. Rochester, NY: University of Rochester Press.

de-Marcos, L, Hilera, J. R., Barchino, R., Jiménez, L., Martínez, J. J., Gutiérrez, J.A., Gutiérrez, J.M., & Salvador Otón, S. (2010). An experiment for improving students' performance in secondary and tertiary education by means of m-learning auto-assessment. *Computers & Education*, 55(3), 1069-1079. doi:10.1016/j.compedu.2010.05.003 *

Fuad, M., Deb, D., Etim, J. & Gloster, C. (2018). Mobile response system: a novel approach to interactive and hands-on activity in the classroom. *Educational Technology Research and Development*, 66, 493-514. https://doi.org/10.1007/s11423-018-9570-5 *

Fuller, R., & Joynes, V. (2015). Should mobile learning be compulsory for preparing students for learning in the workplace? *British Journal of Educational Technology*, 46, 153–158. doi:10.1111/bjet.12134

García Laborda, J. G., Magal-Royo, T. M., Litzler, M. F., & Giménez López J. L. G. (2014). Mobile phones for Spain's university entrance examination language test. *Educational Technology & Society*, 17 (2), 17–30. *

Gikas, J., & Grant, M. M. (2013). Mobile computing devices in higher education: Student perspectives on learning with cellphones, smartphones & social media. *The Internet and Higher Education*, 19, 18-26.*

Gu, X. , Gu, F., & Laffey, J. (2011). Designing a mobile system for lifelong learning on the move. *Journal of Computer Assisted Learning*, 27, 204-215. doi:10.1111/j.1365-2729.2010.00391.x *

Haahr, J. H., Nielsen, T.K., Hansen, M. E., & Jakobsen, S.T. (2005). Explaining student performance - evidence from the international PISA, TIMSS and PIRLS surveys. Final Report. *Danish Technological institute*, Retrieved August 10, 2017 from https://www.oecd.org/edu/school/.../35920726.pdf

Hancock, T.M. (2010). Use of audience response systems for summative assessment in large classes. *Australasian Journal of Educational Technology*, 26(2), 226-237.

Harlen, W. (2013). *Assessment & inquiry-based science education: Issues in policy and practice*. Global Network of Science Academies (IAP) Science Education Programme (SEP) Trieste, Italy.

Hernández-Leo, D., & Safont, L.V. (2015). Aligned, embedded and scalable assessment technologies. *Journal of Universal Computer Science*, 21(8) 997-1000.

Huang, Y.-M., & Chiu, P.-S. (2015). The effectiveness of a meaningful learning-based evaluation model for context-aware mobile learning. *British Journal of Educational Technology*, 46, 437–447. doi:10.1111/bjet.12147

Huang, Y.-M., Lin, Y.-T., & Cheng, S.-C. (2009). An adaptive testing system for supporting versatile educational assessment. *Computers & Education*, 52(1), 53-67. doi:10.1016/j.compedu.2008.06.007 *

Hung, P.-H., Hwang, G.-J., Lin, Y.-F., Wu, T.-H., & Su, I.-H. (2013). Seamless connection between learning and assessment-applying progressive learning tasks in mobile ecology inquiry. *Educational Technology & Society*, 16 (1), 194–205. *

Hung, P.-H., Lin, Y.-F., & Hwang, G.-J. (2010). Formative assessment design for PDA integrated ecology observation. *Educational Technology & Society*, 13 (3), 33–42. *

Hwang, G.-J., & Wu, P.-H. (2014). Applications, impacts and trends of mobile technology-enhanced learning: a review of 2008–2012 publications in selected SSCI journals. *International Journal Mobile Learning and Organization*, 8(2). doi:10.1504/IJMLO.2014.062346

Hwang, G.-J., & Chang, H.-F. (2011). A formative assessment-based mobile learning approach to improving the learning attitudes and achievements of students. *Computers & Education*, 56(4), 1023-1031. doi:10.1016/j.compedu.2010.12.002 *

Hwang, G.-J., & Tsai, C.-C. (2011). Research trends in mobile and ubiquitous learning: a review of publications in selected journals from 2001 to 2010. *British Journal of Educational Technology*, 42, 65–70. doi:10.1111/j.1467-8535.2011.01183.x

Lai, C. L., Hwang, G. J., & Tu, Y. H. (2018). The effects of computer-supported self-regulation in science inquiry on learning outcomes, learning processes, and self-efficacy. *Educational Technology Research and Development*, pp. 1-30. https://doi.org/10.1007/s11423-018-9585-y *

Lai, C.-L., & Hwang, G.-J. (2015). An interactive peer-assessment criteria development approach to improving students' art design performance using handheld devices. *Computers & Education*, 85, 149-159. doi:10.1016/j.compedu.2015.02.011 *

Liu, M., Scordino, R., Geurtz, R., Navarrete, C., Ko, Y., & Lim, M. (2014). A Look at research on mobile learning in K–12 education from 2007 to the present. *Journal of Research on Technology in Education*, 46(4), 325-372. doi:10.1080/15391523.2014.925681

Looi, C. K., Zhang, B., Chen, W., Seow, P., Chia, G., Norris, C., et al. (2011). 1:1 mobile inquiry learning experience for primary science students: A study of learning effectiveness. *Journal of Computer Assisted Learning*, 27, 269-287. doi:10.1111/j.1365-2729.2010.00390.x *

Moher, D., Liberati, A., Tetzlaff, J., Altman, D. G., & The PRISMA Group. (2009). Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement (Reprinted from Annals of Internal Medicine). *Physical Therapy*, 89(9), 873-880. doi:10.1371/journal.pmed.1000097

National Research Council. (2001). *Knowing what students know: The science and design of educational assessment.* Committee on the Foundations of Assessment. Pelligrino, J., Chudowsky, N., & Glaser, R., (Eds.). Board on Testing and Assessment, Center for Education. Division of Behavioral and Social Sciences and Education. Washington, DC: National Academy Press

Nedungadi, P., & Raman, R. (2012). A new approach to personalization: integrating e-learning and m-learning. *Educational Technology Research and Development*, 60(4), 659-678. doi:10.1007/s11423-012-9250-9 *

Nikou, S.A., & Economides, A.A. (2018a). Mobile-Based micro-Learning and Assessment: Impact on learning performance and motivation of high-school students, *Journal of Computer Assisted Learning*, 1–10, https://doi.org/10.1111/jcal.12240 *

Nikou, S.A. & Economides, A.A. (2018b). Factors that influence Behavioral Intention to Use Mobile-Based Assessment: a STEM teachers' perspective, *British Journal of Educational Technology*, doi:10.1111/bjet.12609 *

Nikou, S.A., & Economides, A.A. (2017a). Mobile-Based Assessment: Integrating acceptance and motivational factors into a combined model of Self-Determination Theory and Technology Acceptance. *Computers in Human Behavior*, 68, 83-95. doi:10.1016/j.chb.2016.11.020 *

Nikou, S.A., & Economides, A.A. (2017b). Mobile-based assessment: Investigating the factors that influence behavioral intention to use. *Computers & Education*, 109, 56-73. doi:10.1016/j.compedu.2017.02.005 *

Nikou, S.A., & Economides, A.A. (2016). The impact of paper-based, computer-based and mobile-based self-assessment on students' science motivation and achievement, *Computers in Human Behavior*, 55, 1241-1248. doi:10.1016/j.chb.2015.09.025 *

Nikou S. A., & Economides A.A. (2013). Mobile Assessment: State of the art. In Z.L. Berg, and L. Y. Muilenburg (Eds.), *Handbook of mobile learning*, (pp. 346-355). New York, NY : Routledge Taylor & Francis group.

Nusche, D. et al (2012) *OECD Reviews of Evaluation and Assessment in Education: New Zealand 2011*. OECD Publishing.

Oakley, A. (2012). Foreword. In D. Gough, S. Oliver, & J. Thomas (Eds.), *An introduction to systematic reviews*, (pp. 7-10). London: SAGE Publications.

P21 Partnership for 21st Century Learning (2018). Framework for 21st Century Learning. Retrieved from http://www.p21.org/our-work/p21-framework

Pimmer, C., Mateescu, M., & Gröhbiel, U. (2016). Mobile and ubiquitous learning in higher education settings. A systematic review of empirical studies. *Computers in Human Behavior*, 63, 490-501. doi:10.1016/j.chb.2016.05.057

Pu, Y., Wu, T., Chiu, P., & Huang, Y. (2016). The design and implementation of authentic learning with mobile technology in vocational nursing practice course. *British Journal Educational Technology*, 47, 494-509. doi:10.1111/bjet.12443 *

Roschelle, J., Rafanan, K., Bhanot, R., Estrella, G., Penuel, B., Nussbaum, M., & Claro S. (2010). Scaffolding group explanation and feedback with handheld technology: impact on students' mathematics learning. *Educational Technology Research and Development*, 58, 4, 399–419. https://doi.org/10.1007/s11423-009-9142-9. *

Samaie, M., Mansouri Nejad, A., & Qaracholloo, M. (2018). An inquiry into the efficiency of WhatsApp for self- and peer-assessments of oral language proficiency. British Journal of Educational Technology, 49, 111-126. doi:10.1111/bjet.12519 *

Sanchez-Prieto, J. C., Olmos-Miguelanez, S., & Garcia-Penalvo, F. J. (2017). MLearning and pre-service teachers: an assessment of the behavioral intention using an expanded TAM model. Computers in Human Behavior, 72, 644–654.

Santos, P., Cook, J., & Hernández-Leo, D. (2015). M-AssIST: Interaction and scaffolding matters in authentic assessment. *Educational Technology & Society*, 18 (2), 33–45.

Santos, P., Hernández-Leo, D., Pérez-Sanagustín, M., & Blat, J. (2012). Modeling the computing based testing domain extending IMS QTI: Framework, models and exemplary implementations. *Computers in Human Behavior*, 28(5), 1648-1662. doi:10.1016/j.chb.2012.04.003 *

Santos, P., Pérez-Sanagustín, M., Hernández-Leo, D., Blat, J. (2011). QuesTInSitu: From tests to routes for assessment activities. *Computers & Education*, 57(4) 2517-2534. doi:10.1016/j.compedu.2011.06.020 *

Sha, L., Looi, C.-K., Chen, W., & Zhang, B.H. (2012). Understanding mobile learning from the perspective of self-regulated learning. *Journal of Computer Assisted Learning*, 28, 366–378. doi: 10.1111/j.1365-2729.2011.00461.x

So, S. (2016). Mobile instant messaging support for teaching and learning in higher education. *The Internet and Higher Education*, 31, 32-42, https://doi.org/10.1016/j.iheduc.2016.06.001 *

Song, Y. & Kong, S.C. (2017). Affordances and constraints of BYOD (Bring Your Own Device) for learning and teaching in higher education: Teachers' perspectives. *The Internet and Higher Education, 32, 39-46*. https://doi.org/10.1016/j.iheduc.2016.08.004 *

Song, Y., Wong , L.-H., & Looi, C.-K. (2012). Fostering personalized learning in science inquiry supported by mobile technologies. *Educational Technology Research Development*., 60, 679–701, doi:10.1007/s11423-012-9245-6

Spector, J. M., Ifenthaler, D., Samspon, D., Yang, L., Mukama, E., Warusavitarana, A., Lokuge Dona, K., Eichhorn, K., Fluck, A., Huang, R., Bridges, S., Lu, J., Ren, Y., Gui, X., Deneen, C. C., San Diego, J., & Gibson, D. C. (2016). Technology enhanced formative assessment for 21st century learning. *Educational Technology & Society*, 19 (3), 58–71.

Stowell, J.R. (2015). Use of clickers vs. mobile devices for classroom polling. *Computers & Education*, 82, 329-334. doi:10.1016/j.compedu.2014.12.008 *

Su, C.-H., & Cheng, C.-H. (2015), A mobile gamification learning system for improving the learning motivation and achievements. *Journal of Computer Assisted Learning*, 31, 268–286. doi:10.1111/jcal.12088

Sung, Y.-T., Chang, K.-E., & Liu, T.-C. (2016). The effects of integrating mobile devices with teaching and learning on students' learning performance: A meta-analysis and research synthesis. *Computers & Education*, 94, 252-275. doi:10.1016/j.compedu.2015.11.008

Sun, J. C.-Y. (2014). Influence of polling technologies on student engagement: An analysis of student motivation, academic performance, and brainwave data. *Computers & Education*, 72, 80-89. doi:10.1016/j.compedu.2013.10.010 *

van der Schaaf, M., Donkers, J., Slof, B., van Lon, J.M., van Tartwijk, J., Driessesn, E., Badii, A., Serban, O., & Cate, O.T. (2017). Improving workplace-based assessment and

feedback by an E-portfolio enhanced with learning analytics. *Educational Technology Research and Development*, 65(2), 359–380. doi:10.1007/s11423-016-9496-8 *

Tarighat, S. & Khodabakhsh, S. (2016). Mobile-Assisted Language Assessment: Assessing speaking. Computers in Human Behavior, 64, 409-413. https://doi.org/10.1016/j.chb.2016.07.014. *

Triantafillou, E., Georgiadou, E. & Economides, A. A. (2008). The design and evaluation of a computerized adaptive test on mobile devices. *Computers & Education*, 50(4), 1319-1330. doi:10.1016/j.compedu.2006.12.005

UNESCO (2015). Education Research and Foresight Working Papers - The futures of learning3: What kind of pedagogies for the 21st century? Retrieved 20 August, 2017, from http://unesdoc.unesco.org/images/0024/002431/243126e.pdf

Wang, A.I. (2015). The wear out effect of a game-based student response system. *Computers & Education*, 82, 217-227. doi:10.1016/j.compedu.2014.11.004 *

West, M. & Vosloo, S.E. (2013). UNESCO policy guidelines for mobile learning. Paris: UNESCO.

Winfred, A. Jr., Doverspike, D., Munoz, G.J., Taylor, J. E., & Carr, A.E. (2014). The use of mobile devices in high-stakes remotely delivered assessments and testing. *International Journal of Selection and Assessment*, 22(2), 113–123.

Wu, W.-H., Wu, Y.-C.J., Chen, C.-Y., Kao, H.-Y., Lin, C.-H., & Huang, S.-H. (2012). Review of trends from mobile learning studies: A meta-analysis. C*omputers & Education*, 59(2), 817-827. doi:10.1016/j.compedu.2012.03.016

Zhai, X., Zhang, M., & Li, M. (2016). One-to-one mobile technology in high school physics classrooms: Understanding its use and outcome. *British Journal of Educational Technology*. doi:10.1111/bjet.12539 *

TABLE 3

*MBA studies with samples characteristics, learning domain, technologies used, assessment type, research design and research purpose (*N = 43*)*

No	Study	Academic Journal	Subjects	Country	Learning domain	Technologies used	Assessment type	Research design	Research purpose
1	Alioon and Delialioğlu, (2017)	BJET	30 3rd grade undergraduate students	Turkey	Computer networking course	Authentic m-learning activities	Formative	Mixed	Investigates the effect of authentic collaborative m-learning activities on students' engagement and motivation
2	Bogdanović, et al. (2014)	BJET	40 University students (20-28 years old)	Serbia	Information systems	Mobile quiz application integrated into Moodle	Summative	Quantitative	Investigation of students' attitudes and motivation regarding mobile-learning activities integrated in the e-learning process.
3	Chao et al. (2016)	ETS	50 sophomore students	Taiwan	Culinary course	Augmented Reality context-awareness	Performance assessment	Mixed	Development and evaluation of a mobile Augmented Reality performance assessment system (MARPAS).
4	Chen, Gu and Wong, (2017)	BJET	124 low-grade elementary school students	China	Student behavior monitoring in Chinese courses	Tablet-based classroom behavior management system (Class-Dojo like)	Formative assessment of pupils' classroom behaviors	Quantitative	Shows the feasibility and potential of handheld computer-based assessment strategies in classroom organization practices.
5	Chen, et al. (2013)	BJET	80 University students	China	Computers Networks	QR Codes and hyper linking, integrated in printed materials	Formative and self-assessment	Quantitative	Implements and evaluates a pedagogical strategy that provides learners with real-time and personalized suggestions according to the results of electronic assessment.
6	Chen (2010)	CAE	37undergraduate and graduate students	China	Teacher education course	PHP and MySQL	Self- and peer-assessment	Quantitative	Development of a Mobile Assessment Participation System (MAPS) to facilitate the effectiveness of self- and peer-assessment in classrooms.

TABLE 3 (Continued)

No	Study	Academic Journal	Subjects	Country	Learning domain	Technologies used	Assessment type	Research design	Research purpose
7	Chen and Chen (2009)	CAE	69 students (9-11 years old)	China	Mathematics	Adaptive, Data-mining	Formative, web-based portfolios	Quantitative	Development and evaluation of a mobile formative assessment system with e-portfolios environment.
8	Chou et al. (2017)	CHB	46 high school students	Taiwan	Language course	Socrative app (web-based assessment tool)	Formative, Summative	Mixed	Investigation of the effects of the BYOD (Bring Your Own Device) assessment approach on student language learning.
9	Chu (2014)	ETS	64 elementary school students	Taiwan	Culture course	MSSQL, ASP.NET, and IIS	Formative assessment	Quantitative	Development and evaluation of a formative assessment mobile learning system**.**
10	Chu, et al. (2010)	CAE	57 fifth-grade elementary students (11 years old)	Taiwan	Natural science course	Radio Frequency Identification (RFID), Adaptivity	Formative	Quantitative	Proposes a personalized learning guidance approach by detecting real-world learning behaviors of students.
11	Coulby, et al. (2011)	BJET	13 medical students	UK	Medical education	Personal Digital Assistants	Formative	Qualitative	Examination of the impact of delivering work-based competency based formative assessments via personal digital assistants.
12	Dalby and Swan, (2018)	BJET	Secondary students	England	Mathematics	iPad technology	Formative	Qualitative	Explores how mobile devices are used within formative assessment processes to improve learning.
13	Fuad et al. (2018)	ETRD	University students	USA	Computer Science	Mobile Response System Software (Java, Android)	Formative (interactive problem-solving activities)	Qualitative: focus group interviews	Design, implementation and evaluation of a mobile-based learning environment with interactive problem-solving activities
14	García Laborda, et al. (2014)	ETS	Experts and high school students (17 years old)	Spain	Language course	Ubiquitous technologies	Dynamic assessment	Mixed	Provides a powerful and low cost system for the foreign language paper of the Spanish College Entrance Exam (PAU).

TABLE 3 (Continued)

No	Study	Academic Journal	Subjects	Country	Learning domain	Technologies used	Assessment type	Research design	Research purpose
15	Gikas and Grant (2013)	IHEDUC	University students	USA	History, Social work, communication	Social media and Web 2.0 tools	Formative	Qualitative: focus group interviews	Presents students' perceptions of learning with mobiles and receiving feedback and formative guidance through social media.
16	Gu, Gu and Laffey, (2011)	JCAL	Adults (lifelong learning)	China	"World Expo English" and "Six-Step Change Tire"	FlashLite 2.*x* and Actionscript 2.0	Micro - formative and self assessment	Qualitative: focus group interviews	The study identifies a set of pedagogical and usability design issues for lifelong micro- learning on the move.
17	Huang, Lin and Cheng (2009)	CAE	University students and teachers	Taiwan	Computer Science	ASP.NET 2.0 (C#) and MSQL Server, Adaptive	Formative, summative and self-assessments	Mixed	Development and implementation of an adaptive assessment system based on Item Response Theory (IRT).
18	Hung et al. (2013)	ETS	49 elementary students (11-12 years old)	Taiwan	Ecology course	Automated scoring feedback mechanism	Formative, Authentic	Mixed	Development of a series of worksheets as scaffolding to support inquiry-based ecology observations in a mobile learning environment.
19	Hung et al. (2010)	ETS	27 elementary school students	Taiwan	Ecology course	Automated scaffolding and feedback mechanism	Formative, Adaptive	Mixed	Proposes a formative assessment design for integrating PDAs into ecology observations.
20	Hwang and Chang (2011)	CAE	61 elementary school students	Taiwan	Local culture course	MSSQL, ASP.NET and IIS	Formative	Quantitative	Proposes a formative assessment-based approach for improving the learning achievements of students in a mobile learning environment.
21	Lai, Hwang, and Tu (2018)	ETRD	56 elementary school students	Taiwan	Natural science course	Nearpod Interactive Classroom Tool	Formative and self-assessments	Quantitative	Evaluates the effectiveness of a self-regulated science inquiry learning approach on students' performance of science inquiry and their self-regulation.

TABLE 3 (Continued)

No	Study	Academic Journal	Subjects	Country	Learning domain	Technologies used	Assessment type	Research design	Research purpose
22	Lai and Hwang (2015)	CAE	103 elementary school students	Taiwan	Art course	web server, peer assessment system, criteria database	Peer-assessment	Quantitative	Proposes an interactive peer-assessment to help students develop assessment criteria and reflect in artwork design activities.
23	Looi, et al. (2011)	JCAL	elementary (grade 3) students	Singapore	Science	GoKnow® MLE environment	Formative and Self-assessment	Mixed	The study examines the learning effectiveness of a mobilized science curriculum
24	de-Marcos, et al. (2010)	CAE	98 high-school and 28 university students (14 to 21 years old)	Spain	Technology and Physics (secondary), nursery course (tertiary)	Java technology and XSLT	Self-assessment	Quantitative	Design and implementation of a web based system to support mobile self-assessment in traditional class-based learning.
25	Nedungadi and Raman (2012)	ETRD	61elementary students	not specified	Mathematics, Science	Context-adaptation	Formative	Mixed	Development of an Adaptive Learning and Assessment System (ALAS) and evaluation of its effectiveness aiming to compare e-learning with m-learning.
26	Nikou and Economides (2018a)	JCAL	108 senior-level high school students	Europe	Physics	jQuery with PHP and MySQL backend	Formative and Self-assessment (micro-content)	Quantitative	The proposed mobile-based micro-learning and assessment homework intervention enhances students' motivation and improves students' exam performance in terms of factual knowledge.
27	Nikou and Economides (2018b)	BJET	161 STEM teachers	32 European countries	STEM	not specified	not specified	Quantitative	The study explores STEM teachers' intention to use mobile-based assessments in their teaching practice.

TABLE 3 (Continued)

No	Study	Academic Journal	Subjects	Country	Learning domain	Technologies used	Assessment type	Research design	Research purpose
28	Nikou and Economides (2017a)	CHB	140 secondary school students	Europe	Environmental course	QR- coding technology	Self-assessment	Quantitative	Explains and predicts behavioral Intention to Use Mobile-based Assessment based on TAM and Self Determination Theory of Motivation.
29	Nikou and Economides (2017b)	CAE	145 secondary school students	Europe	Science	QR- coding technology	Formative, Summative, Authentic	Quantitative	Explains and predicts behavioral Intention to Use Mobile-based Assessment based on Technology Acceptance Model.
30	Nikou and Economides (2016)	CHB	66 secondary school students	Europe	Physics	Web-based and mobile quiz application	Self-assessment	Quantitative	Paper-, computer- and mobile-based self assessment in a high school Physic class.
31	Pu, et al. (2016)	BJET	60 nursing students	Taiwan	clinical practice of vocational nursing education	m-Learning System for authentic Health Education	Formative and self-assessment	Mixed	Proposes an authentic learning model for vocational nursing education.
32	Roschelle et al. (2010)	ETRD	173 4th grade elementary students	USA	Mathematics	Technology-mediated, Peer-Assisted Learning (TechPALS)	Formative	Quantitative	Compares small-group and individual feedback, using respectively wireless handheld technology and a popular desktop product .
33	Samaie et al. (2018)	BJET	30 English learners (12-18 years old)	Iran	English (oral language proficiency)	Whats App mobile application	Self- and peer-assessment	Qualitative	Explores the efficiency of Whats App for assessment purposes.
34	Santos et al. (2012)	CHB	secondary students	Spain	Geography, Botany, Literature	Contextual awareness	Assessment in situ	Mixed	Presents a conceptual model that defines and evaluates a Computing Based formative assessment framework extending IMS QTI activities.

No	Study	Academic Journal	Subjects	Country	Learning domain	Technologies used	Assessment type	Research design	Research purpose
35	Santos, et al. (2011)	CAE	34 students (17 years old)	Spain	Geography and History courses	GPS and geolocation	Location-aware formative assessment	Mixed	Development of a system that enables the creation of geolocated questions so as students to answer them in front of a real space/location (in situ).
36	van der Schaaf et. al. (2017)	ETRD	202 students and 141 supervisors	not specified	Professional education	Learning analytics	Formative	Mixed	Presents a design for personalized feedback in a learning analytics driven e-portfolio system.
37	So (2016)	IHEDUC	61 undergraduate students	Hong Kong	Teacher training	Instant messaging application	Formative	Quantitative	Evaluates the use of mobile instant messaging tools to support teaching and learning in higher education.
38	Song and Kong (2017)	IHEDUC	17 teachers	Hong Kong	Different subjects	Different apps and platforms	Different assessment activities	Qualitative	Examines the affordances and constraints of BYOD for varied pedagogical practices from teachers' perspectives in higher education
39	Stowell (2015)	CAE	University students	USA	Psychology	Polling application	Classroom polling	Mixed	Compares clickers vs. mobile devices for classroom polling.
40	Sun (2014)	CAE	69 University students (23 years old)	Taiwan	Educational research courses	Polling application	Classroom polling	Mixed	Assesses the differences between the effects of clickers and mobile polling.
41	Tarighat & Khodabakhsh (2016)	CHB	17 female adults learners of English	Iran	English as a foreign language	WhatsApp mobile application	Dynamic and peer assessments	Qualitative	Investigates the feasibility of Mobile-Assisted Language Assessment (speaking) as well as the learners' proficiency and attitudes.
42	Wang (2015)	CAE	University students	Norway	Software architecture course	Kahoot! (web-based assessment tool)	Game-based polling	Mixed	Investigation of the effect of frequent use of a game-based student response system over a period of time.
43	Zhai, Zhang, & Li, (2016)	BJET	831 high school students	China	Computer Science	Tablet-based Interactive Learning System	Formative	Quantitative	Examines the impact of in-class and after-school mobile technology use on their physics learning performance.

TABLE 1

Educational technology journals included in the literature review study

Academic Journal	Impact Factor JCR (2016)	h5-index Google Scholar (2012 - 2016)
British Journal of Educational Technology	2.410	53
Computers and Education	3.819	94
Computers in Human Behavior	3.435	95
Education Technology Research and Development	0.725	34
Journal of Computer Assisted Learning	1.253	37
Journal of Educational Technology & Society	1.584	49
The Internet and Higher Education	4.238	46

TABLE 2

Inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
Article was published in one of the BJET, CAE, CHB ,ETRD, JCAL, ETS, IHEDUC	Conference papers, book chapters or Ph.D. dissertations are excluded.
Article was peer-reviewed.	Studies must not be about clicker devices.
Must be published between January 2009 and February 2018.	Studies must not be exclusively about computer-based or web-based assessment.
Must involve mobile assessment as a primary condition.	Non-English.
Students used mobile devices (smart phones, personal digital assistants, tablets).	

TABLE 4

Articles about Mobile-Based Assessment by academic journal

Academic Journal	Articles	%
Computers and Education	12	28
British Journal of Educational Technology	10	23
Computers in Human Behavior	5	12
Journal of Educational Technology & Society	5	12
Education Technology Research and Development	5	12
The Internet and Higher Education	3	7
Journal of Computer Assisted Learning	3	7

TABLE 5

Impact of MBA on student learning performance, motivation and attitudes

No	Study	Impact on learning performance	Impact on learning motivation	Impact on learning attitudes and perceptions
1	Alioon and Delialioğlu, (2017)	not specified	positive	positive
2	Bogdanović, et al. (2014)	positive	positive	positive
3	Chao et al. (2016)	positive	not specified	positive
4	Chen, Gu and Wong, (2017)	positive	not specified	not specified
5	Chen, et al. (2013)	positive	not specified	not specified
6	Chen (2010)	positive	not specified	positive
7	Chen and Chen (2009)	positive	positive	positive
8	Chou et al. (2017)	positive	positive	positive
9	Chu (2014)	negative	not specified	not specified
10	Chu, et al. (2010)	positive	positive	positive
11	Coulby, et al. (2011)	positive	not specified	positive
12	Dalby and Swan, (2018)	positive	not specified	not specified
13	Fuad et al. (2018)	positive	not specified	positive
14	García Laborda et al. (2014)	not specified	not specified	positive
15	Gikas and Grant (2013)	not specified	not specified	positive
16	Gu, Gu and Laffey, (2011)	not specified	not specified	positive
17	Huang, Lin and Cheng (2009)	not specified	not specified	positive
18	Hung et al. (2013)	positive	positive	positive
19	Hung et al. (2010)	positive	positive	positive
20	Hwang and Chang (2011)	positive	not specified	positive
21	Lai, Hwang, and Tu (2018)	positive	positive	positive
22	Lai and Hwang (2015)	positive	positive	not specified
23	Looi et al. (2011)	positive	not specified	positive
24	de-Marcos, et al. (2010)	positive	neutral	positive
25	Nedungadi and Raman (2012)	neutral	not specified	positive
26	Nikou and Economides (2018a)	positive	positive	not specified
27	Nikou and Economides (2018b)	not specified	not specified	positive
28	Nikou and Economides (2017a)	not specified	positive	not specified
29	Nikou and Economides (2017b)	not specified	not specified	positive
30	Nikou and Economides (2016)	positive	positive	not specified
31	Pu, et al. (2016)	not specified	not specified	positive
32	Roschelle et al. (2010)	positive	not specified	not specified
33	Samaie et al. (2018)	positive	not specified	negative
34	Santos, et al. (2012)	not specified	positive	not specified

No	Study	Impact on learning performance	Impact on learning motivation	Impact on learning attitudes and perceptions
35	Santos, et al. (2011)	positive	positive	positive
36	van der Schaaf, et al. (2017)	not specified	not specified	positive
37	So (2016)	positive	not specified	positive
38	Song and Kong (2017)	not specified	not specified	positive
39	Stowell (2015)	neutral	not specified	positive
40	Sun (2014)	positive	not specified	positive
41	Tarighat, et al. (2016)	not specified	not specified	mixed
42	Wang (2015)	not specified	positive	positive
43	Zhai, Zhang, & Li, (2016)	positive	not specified	positive

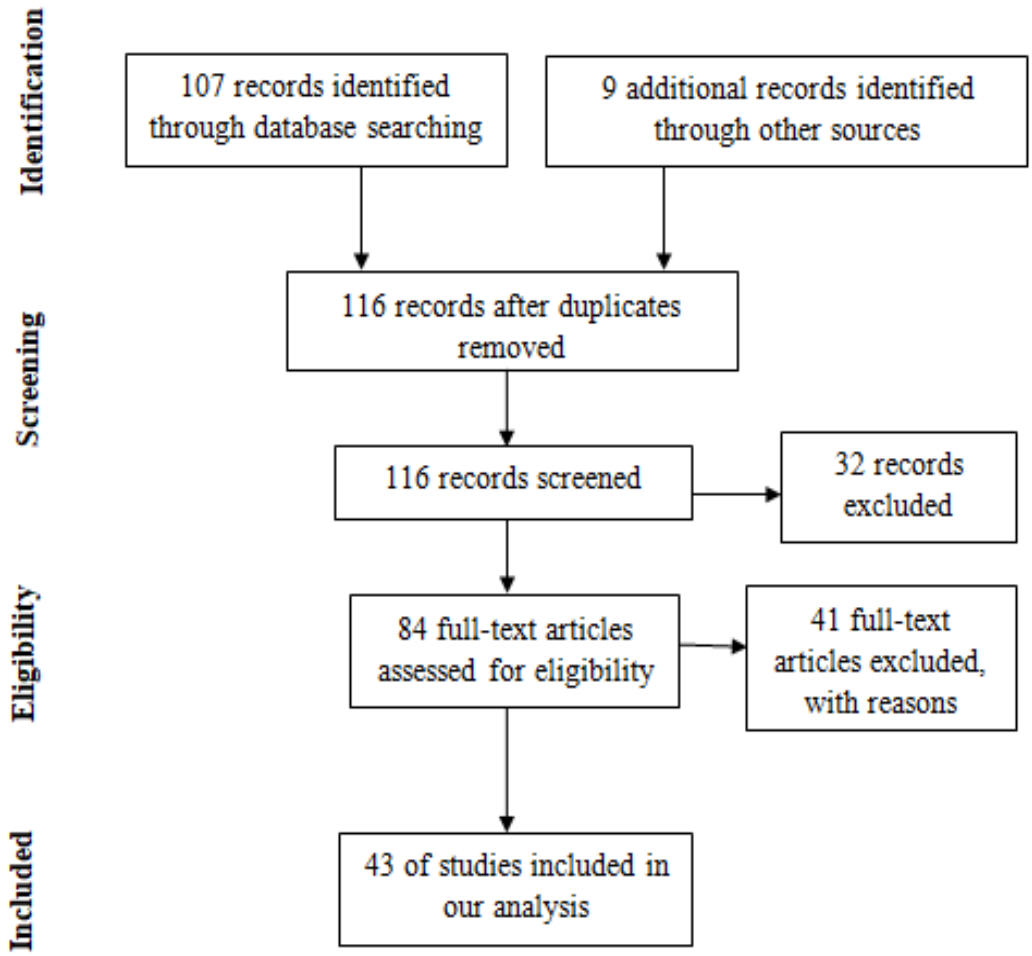

Figure 1. PRISMA flow diagram (From Moher et al., 2009).

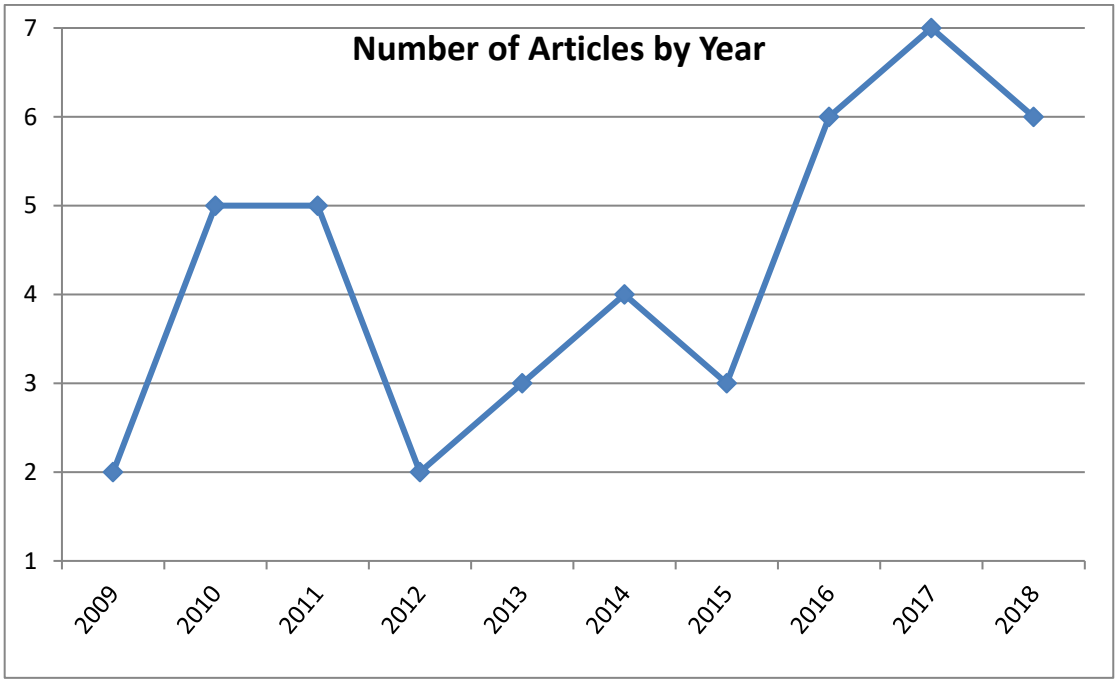

Figure 2. Number of published articles by year

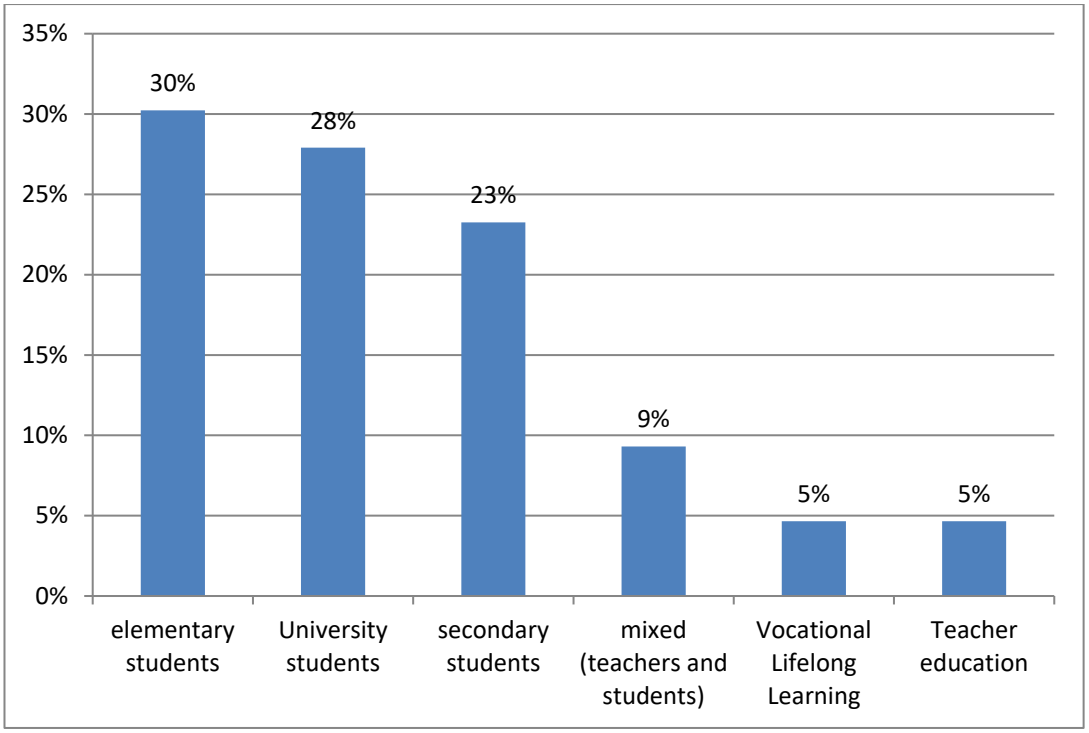

Figure 3. Classification of subjects by education level

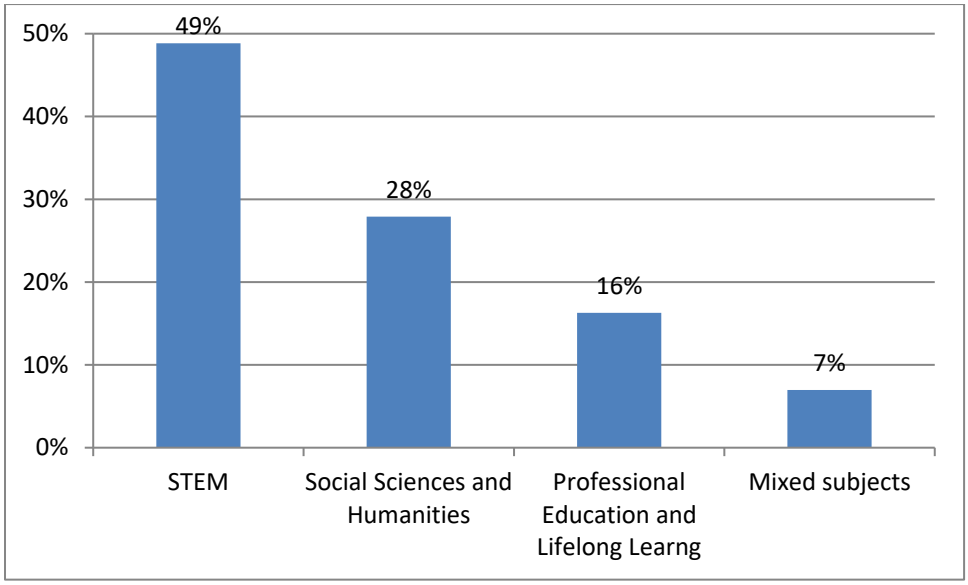

Figure 4. Classification of articles by learning domain

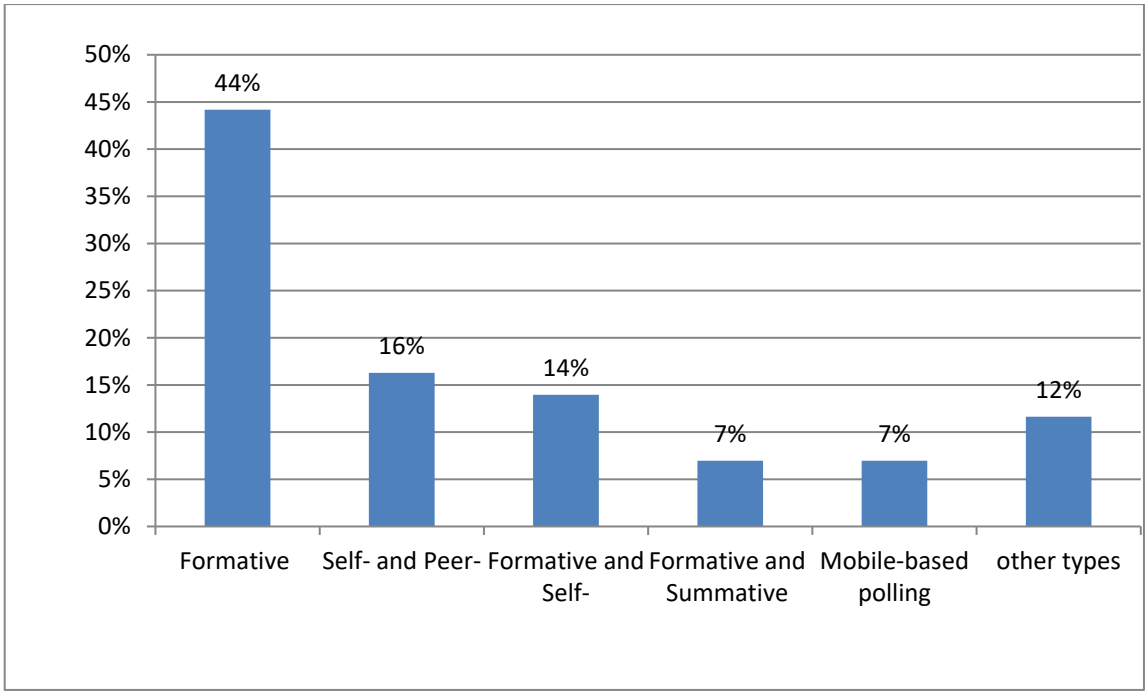

Figure 5. Classification of articles based on assessment type

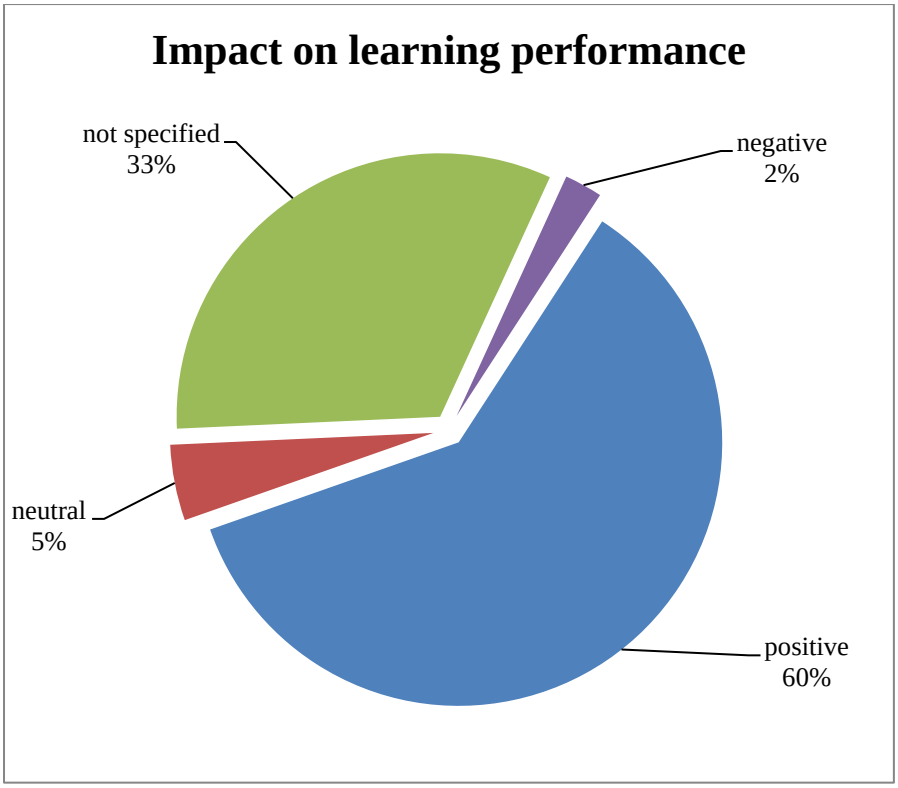

Figure 6. Impact of MBA on students' learning performance

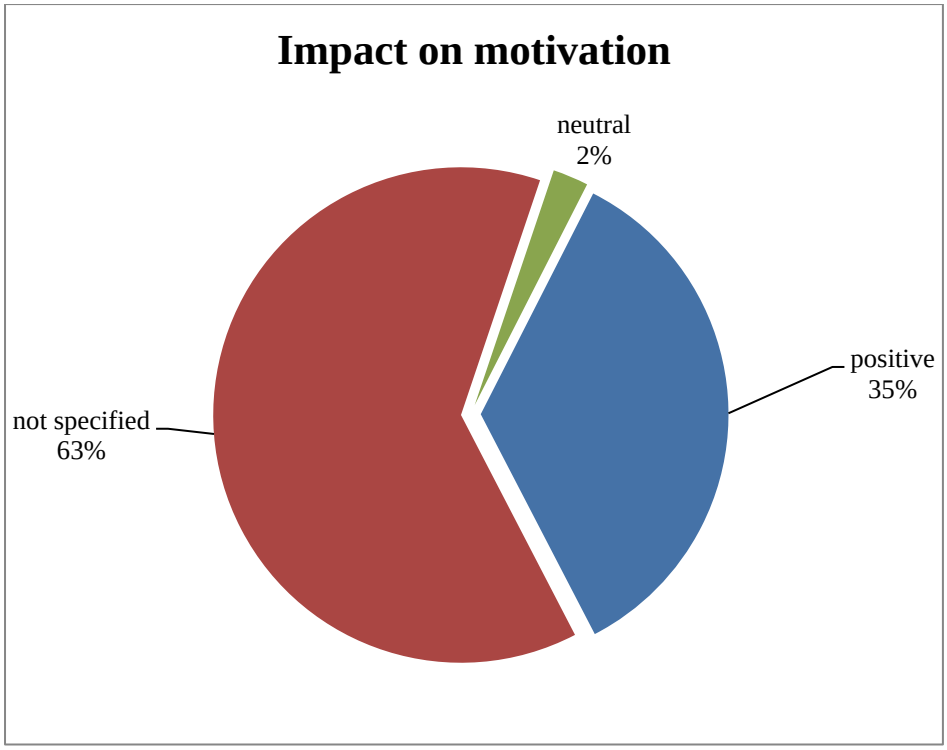

Figure 7. Impact of MBA on students' learning motivation

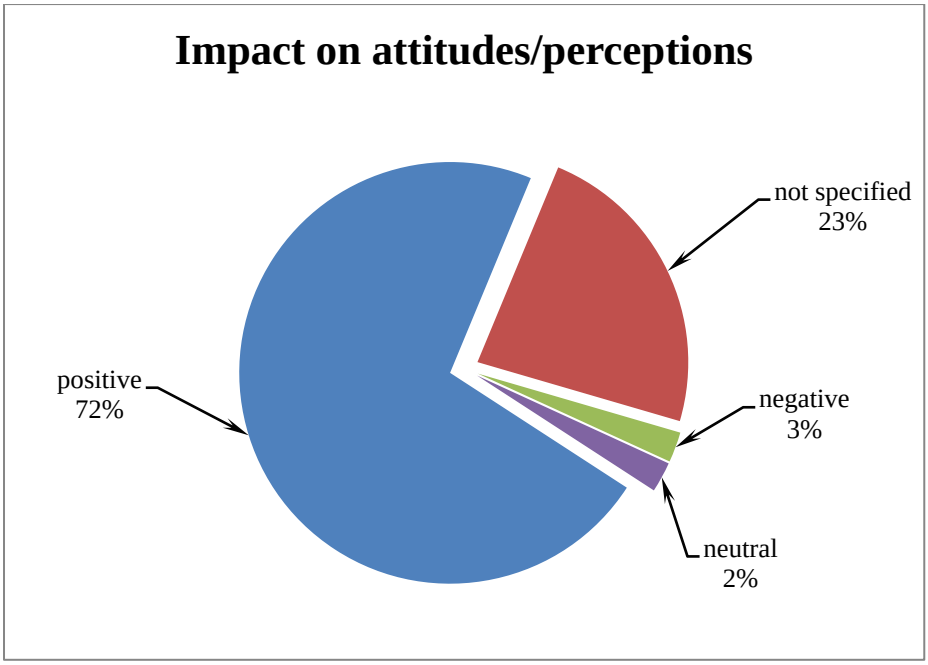

Figure 8. Impact of MBA on students' attitudes/perceptions

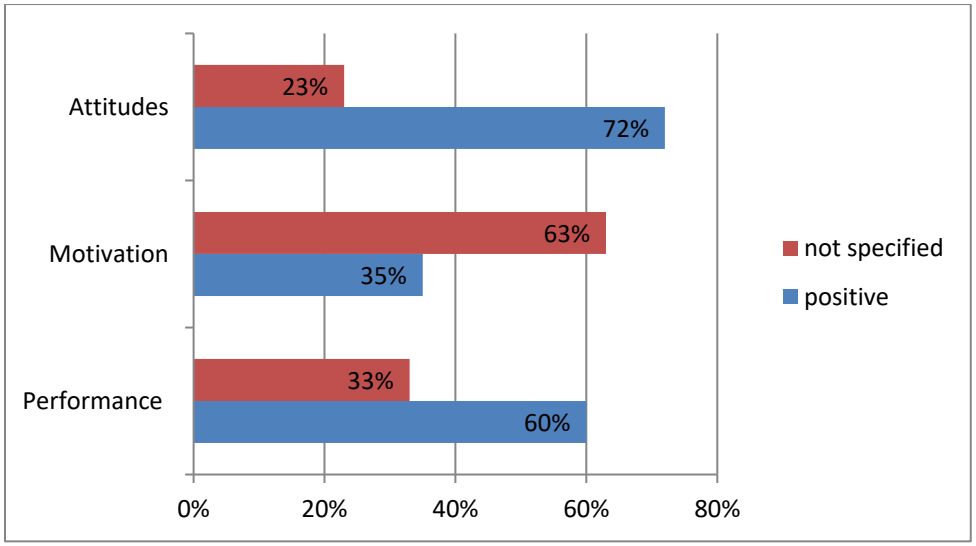

Figure 9. MBA positive impact vs. not investigated on performance, motivation and attitudes