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Mobile Learning Technology in STEM Education: A Systematic Review from 2010 to 2019

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Abstract: Mobile technology could support students' learning in anytime and anywhere. It led to mobile learning principle, which has been recognized as pedagogy to support the learning of Science, Technology, Engineering, and Mathematics (STEM). Recently, there is less systematic analysis to reveal trend of mobile learning in STEM education. This paper conducted a meta-review of the studies published in academic journals, indexed by Scopus, from 2010 to 2019 to analyze years, nationalities, and subject areas emphasizing the pedagogy and technology of mobile learning in STEM education. The results revealed that the application of mobile learning technology in STEM disciplines have been increased in the past decade. In addition, the review articles reported subject areas in social science has the highest number of using mobile technology in STEM learning. The findings of this study encourage more educational research in the area of mobile learning technology in STEM education.

Keywords: Mobile technology, ubiquitous technology, mobile learning, ubiquitous learning, STEM

1. Introduction

According to the growth of mobile technologies and expanded usage of mobile devices in education, there has been an increasing adoption of mobile learning in both formal and informal education. Mobile technologies provide new learning opportunity and enhance teaching and learning process, such as context awareness and ubiquity, personalization and adaptively, communication and collaboration among learners, interactivity and seamless bridging between contexts in both formal and informal learning. The learning tools of mobile technologies (i.e., tablets, personal digital assistants, and smartphones) are utilization of consumers, process, and store information everywhere, anytime, by anyone. Mobile learning technology is a promising in improving students' learning outcomes, motivations and interests. Furthermore, mobile learning technology can be extended to Science, Technology, Engineering and Mathematics disciplines, which need further understanding regarding student generated multimedia activities (Yao et al. 2016; Hwang & Wu, 2014).

STEM approach derived from Science, Technology, Engineering, and Mathematics, has been the focus of educational reform in United States and the approach has been popular across the world (Susan et al., 2018). STEM approach, which has been as integrated teaching approaches, provides students with integration of science, technology, engineering, mathematics and problem-based learning. The fundamental goal of this approach is to create a leader for future that can bring a positive change on the community (Sri et al. 2019). The 21st century education has been driven by teaching and learning process regarding STEM approaches. It directly provides students with direct practice in integrating all aspects of learning, leading them to easily learn knowledge of concepts in authentic problems. Furthermore, the students use technology through science learning to operate the scientific experiment

and prove scientific law or concepts. All findings support the data management by mathematical reasoning (Bybee, 2010).

Besides, technology competency is an important skill that should be developed as one of 21st century skills. All technology tools are involved, namely computers, MP3 player, notebooks, mobile telephone, and tablets. Focuses of this mobile learning are on students with their interaction with portable technology. The use of technology motivates active learning of student, exploration, inquiry based learning, collaborative work among learners and teachers, and creativity (Robert, 2008). This study conducted a literature search of mobile learning in STEM research journals and the articles published from 2010 to 2019. The review study is operated as following aspects. First, the literature reviews were used to present the rationale for a mobile learning for STEM. Then, the research methodology section follows with the inclusion and exclusion criteria, search years, nationalities, and subject areas. Study results with limitations come afterwards. Finally, there is the conclusions section that summarizes the information of the study.

2. Review Literature

2.1 Mobile Learning

The rapid development of mobile technologies offered more chances to design and develop innovative learning approach with mobile devices in preparing schools and students for a future (Panjaburee & Srisawasdi, 2018). Mobile learning has been recognized as the approach to access education and enables learners to pursue their studies according to their own scheduled time. Mobile Learning is also free from fixed class times, which enables learning at all times and in all places, during breaks, before or after shifts, at home, or on the go because of the portability of mobile devices (Robert, 2008). Based on previous research, a broad discussion of studies on mobile and ubiquitous learning was published in six journals between 2001 and 2010. In their review of 154 articles, they discovered that the use of mobile and ubiquitous learning accelerated markedly during 2008; researchers mostly studied students in higher education, and the fields were most often researched in language arts, engineering, and computer technology (Hwang et al. 2011). Mobile learning projects revealed that most mobile learning activities occurred across the different settings, and took place within a physical context and an official environment, such as a classroom or workplace. Regarding the pedagogical roles, mobile devices play important role in education. Most researchers have used mobile devices by primarily as a sort of reinforcement tool to stimulate motivation and strengthen engagement, and secondarily as a content delivery tool. The educational projects have used mobile devices to assist with constructive thinking or reflection. Furthermore, most learning activities using mobile devices have been controlled by the teachers as well as a handful of learner center projects in existence. Concerning the communication functions, very few studies have made any use of cooperative or team communication. Moreover, the majority of studies have made the use of participants, and little research has involved experienced participants. Regarding educational goals, it was found that the majority of research has focused on lower-level knowledge and skills, and ignored higher-level tasks, such as analysis and evaluation (Dirk et al., 2009). Mobile learning facilitates the design of authentic learning, meaningful learning, where targets real world problems to make attractive learning environment to the students. Also, theoretically, the use of mobile phones in learning activities could enable students to customize the transfer of, and access to information in order to building their skills and knowledge and to meet their own educational goals. Obviously, mobile learning approach could make the student-centered learning environment and empower students to learn (Helen & Rhona, 2007).

2.2 Mobile Learning Technology in STEM Disciplines

To date, pedagogy of mobile and ubiquitous learning has become more important in context of science education (Srisawasdi, Pondee, & Bunterm, 2018). Mobile learning by using technology tools, such as mobile devices, mobile phones, tablet, laptops, or personal computers is a fairly new approach to the

educational paradigm in terms of supporting learning performance, promoting motivations to learn, and learning perceptions. Mobile learning is the process involving conversations across multiple contexts among people and personal interactive technologies (Helen & John, 2016). The implementation of STEM education can benefit the students in the fields of science, technology, engineering, and mathematics. Integrative STEM education is about the teaching and learning of one or more subject areas in schools or any other educational institution. Integrative STEM education is defined as general education focusing on preparing citizens to function in a science and technology society (Scott, 2008). STEM is the purposeful integration of various disciplines to solve real world problems involving forming all four disciplines, such as science, technology, engineering, and mathematics to one unit. Furthermore, STEM could be enhanced through the use of mobile devices (Jay et al., 2010).

3. Research Methodology

This paper started with searching publications indexed by SCOPUS database from 2010 to 2019, which have titles, abstracts, or keywords met the logical condition STEM and mobile and learning. In this study, there are 278 publications related to mobile learning and STEM. Afterward, 209 non-article papers were excluded and 69 papers were included by deleting 40 papers were not related STEM approach and mobile learning. Totally, 29 publications are the target items in this paper. The flow of information through the different phases of the review is presented in Figure 1.

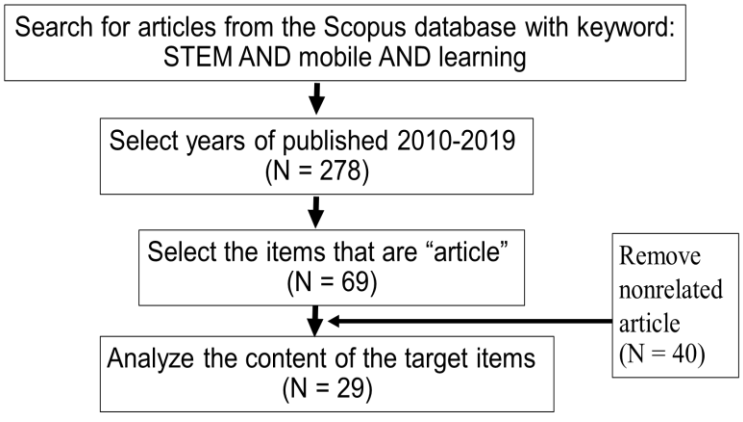

Figure 1. Scopus database searching steps.

4. Research Results

4.1 Classification based on Number of Articles published by Year

There were 29 papers in this study. The articles were classified and reviewed by two authors based on the coding scheme. If there were inconsistent coding results and then the authors came to an agreement for all the differences.

Figure 2 shows the number of mobile learning for STEM articles published from 2010 to 2019, presented by the year of publication. Considering Figure 2, there were no literature reviews mobile learning for STEM articles in the years 2010 to 2012 and a period with a moderate count of mobile learning for STEM publications in the years 2012 to 2016. Afterwards, a relatively high number of mobile learning for STEM publications in the years 2017 to 2019.

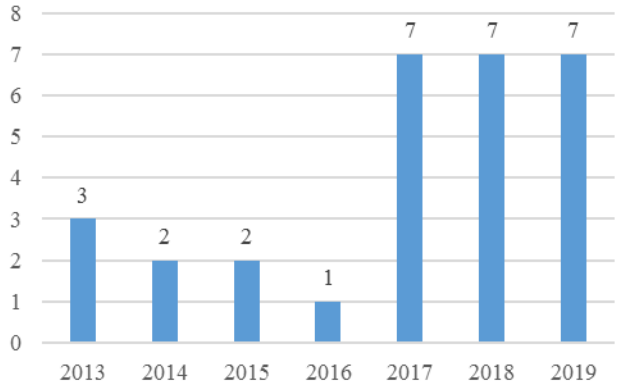

Figure 2. Published paper using mobile learning in STEM education during 2010 – 2019

4.2 Classification based on Nationalities

In this study, the articles were examined by using the nationality of the authors on mobile learning in the field of STEM area, as shown in Figure 3. There are 15 countries of nationality of authors using mobile learning to support STEM education; those are Greece, Austria, Israel, Canada, Croatia, Ireland, Italy, United Kingdom, Thailand, Indonesia, Brazil, Chile, Malaysia, Spain and United States. The results reveal that many countries have attempted to apply mobile technology in STEM teaching. Authors from United States contributed the most publications (34) relating mobile learning in STEM followed by authors from Spain (12) and Malaysia (7), Brazil and Chile with 6 authors each. Other reviews found that United States is the most contributing country regarding journal publications on mobile learning in STEM research in which STEM education has been reformed in United States (Sri et al., 2019). In addition, there are the different European countries (exception Spain), South America countries and Asia countries.

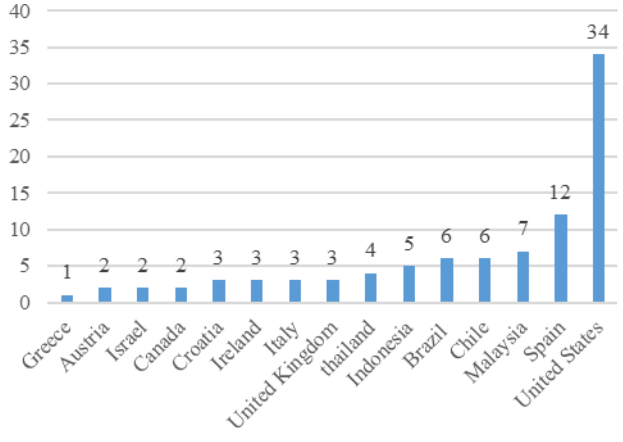

Figure 3. Nationality of the authors on mobile learning in STEM during 2010 to 2019.

4.3 Classification based on Subject Area

The subject area were investigated in the mobile learning for STEM education, including the aspects of social sciences, computer science, engineering, biochemistry genetics and molecular biology, business management and accounting, chemistry, earth and planetary sciences, agricultural and biological sciences, immunology and microbiology, mathematics, neuroscience and physics and astronomy. Figure 4 shows the number of each subject area in the literatures. It could be seen that the studies on social sciences (18 articles), computer science (8 articles), and engineering (8 articles) constituting the majority of the research. In contrast, 13 pure science publications were related to mobile learning in STEM. It is interesting to note that the subject area related social science was the main

concern of most of the mobile learning in STEM studies among STEM education research. Many researchers intended to integrate mobile technology into STEM area because it was a motivated way to bring students' learning with mobile devices as a learning tool.

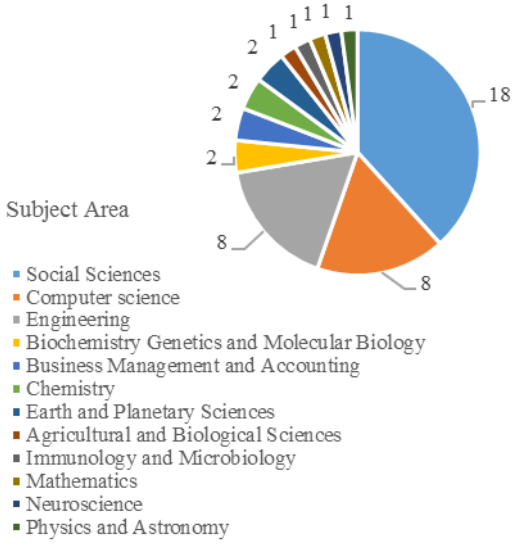

Figure 4. Subject area on mobile learning in STEM from 2010 to 2019.

5. Conclusion and Discussion

The current study presents a review result of 29 articles related mobile learning technology in STEM education published in SCOPUS database from 2010 to 2019. This study is kind of systematic review about mobile learning for STEM area and presents the new findings that hold for the aforementioned selected journals. This result indicated that the quantity of studies increased over many years. Moreover, it was found that the number of publications which integrated the mobile technology for STEM education has been greatly increasing over the decades. It was also found that many studies used system development in the methodology. This implied that numerous researchers have considered to develop the application of mobile devices in STEM subject. In addition, United States is the most contributing country regarding journal publications on mobile learning in STEM research because STEM reform in United States. Furthermore, the issues related to social science was the majority of the mobile learning in STEM studies among STEM education research. This reveals that more studies are required to develop students' learning performance through the process for science learning.

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

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