



SCHOLARS SCITECH RESEARCH ORGANIZATION

International Journal of Progressive Research in Education

www.scischolars.com

Mobile Apps Criteria for Guiding STEM Teachers in Developing Mobile Learning Activities

Khitam Shraim

Educational Technology Department, Palestine Technical University-Kadoorie.

Email: k.shraim@ptuk.edu.ps

Abstract

Smart mobile technologies revolution provides opportunities to improve STEM (Science, Technology, Engineering and Math) education through mobile applications (apps). Mobile apps promise more ubiquitous learning which involves learning in an environment where teachers and learners can collaborate, communicate and learn together as they go. Numerous mobile apps are also available for teaching and learning STEM concepts in more interesting and engaging than traditional face-to-face approaches. However, selecting the appropriate mobile app is an issue that teachers should consider for teaching STEM. The main purpose of the research is, therefore, to formulate a set of criteria to guide teachers in developing mobile learning activities for teaching STEM concepts. For this research, Design-Based Research (DBR) approach is adopted and mixed data methods are collected from fifteen in-service teachers from three public schools in Palestine. The multi-cycle of DBR process provided data for evaluation and refinement of the following nine criteria for guiding STEM teachers in selecting mobile apps for designing effective mobile learning activities: real-world relevance, entertainment, microlearning, learner-generated content, communication, feedback, intuitive user-friendly interface, compatible platform and customization. These criteria encapsulate all the essential elements of authentic learning, social constructivist and usability frameworks.

Keywords: Mobile learning; Mobile apps; Design-based Research; STEM; Usability; Social constructivist; Authentic learning.

1. Introduction

Integrating Science, Technology, Engineering and Mathematics (STEM) subjects has seen to be an effective approach for engaging students, promoting problem-solving and critical thinking skills and helping build real-world connection (Berry et al., 2012.). The specific nature of STEM knowledge (geometry, astronomy, anatomy, chemical elements, interaction, molecules and so on is based on using experiential simulations, modelling, spatial reasoning and problem solving (Engida, 2014). Many challenges are facing both students and teachers in teaching and learning STEM concepts in the traditional teaching approach. For instance, it is difficult for students to understand various geometric solid (e.g find the volumes of cubes, cylinders and spheres, find the total area of the surfaces of 3D shapes, rotate 2D shape to 3D shape) on the chalkboard in a two-dimensional object. Therefore, it is essential to help the learner assimilate abstract STEM concepts in a dynamic visualization way. The smart mobile technologies revolution provides opportunities to improve STEM education through mobile applications (apps). Mobile apps have a great potential for deepening student understanding of complex relationships and concepts (Johnson et al., 2010). Numerous mobile apps are available making learning in more meaningful and engaging way than traditional face-to-face approaches (Walker, 2013). Standalone



mobile learning apps are proliferating at an astonishing rate: as of June 2016¹, the US Apple store offered 171,397 active apps in the education category, accounting for 8.55% of all apps available (2 million), and the total number of education apps for the Google play Android market was 223,170, accounting for 10.14% of all apps available (2.2 million).

Mobile apps possibilities range from a short messaging service to real-time in-class polling and exams administered, to retrieve and engage with digitally-located course materials, such as e-books, courseware, and recordings of lectures (Herrington et al., 2009). Mobile apps can be classified based on the function they serve within educational contexts: Patten, Sánchez, and Tangney (2006) distinguish between administrative (e.g., timetabling), reference (e.g., accessing library or courseware resources) or interactive (e.g., feedback) functions. Alternatively, mobile apps can be categorized by the type of learner engagement they can foster across “collaborative, contextual and constructivist learning environments” (Herrington et al., 2009). This makes it difficult for teachers to access apps database and select the appropriate app that matches the content being taught.

The use of mobile devices for learning has implications as to how learning materials are designed using learning theories and instructional design principles. Therefore, there is a need to develop a set of principles to guide teachers in selecting appropriate apps while designing and applying mobile technologies for their teaching activities (Shraim & Crompton, 2015). Various guidelines for instructional design using mobile technology have been developed over the past several years (Koole, 2009; Herrington et al., 2009; Elias, 2011; Park, 2011; Quinn, 2011; Dillard, 2012). Further, different studies were suggested mobile app evaluation rubrics for educational purposes (Walker, 2013; Green et al., 2014; Baran et al., 2017). However, relatively little has been published about the criteria for guiding in-service teachers for selecting appropriate mobile apps into teaching STEM activities. Therefore, the main purpose of this paper is to formulate a set of mobile apps criteria to guide STEM teachers in selecting mobile apps for developing effective learning activities. The study will contribute to the understanding of the use of mobile technology within teaching STEM at schools. By identification of reusable principles, the study will offer guidance to teachers and practitioners planning to integrate mobile apps to meet students’ needs in STEM contexts.

2. Literature Review

The literature on leveraging mobile technologies for learning has grown significantly over the past several years, offering a number of perspectives ranging from the techno-centric to the more learner-centric perspective (Sharples et al., 2005; Cronje & El-Hussein, 2010). Pouezevara (2012) categorizes the benefits of mlearning into four main themes: “*accessibility* (access to learning opportunities, experts/mentors, other learners); *immediacy* (on-demand learning, real-time communication and data sharing, situated learning); *individualized* (bite-size learning on familiar devices, which promotes active learning and a more personalized experience); and *intelligence* (advanced features which make learning richer through context-aware features, data capture, and multimedia)”. She further suggests a number of new ways to think about the “m” in mlearning, including microlearning, multimedia learning, and measurement of learning. From this perspective it is clear that mlearning is not just about the use of portable devices but also about learning across contexts (Walker, 2013), and its content should not just be a matter of repackaging existing e-learning content and making it available through mobile devices (Pouezevara, 2012). As Galhotra (2012) points out, the challenges associated with delivering learning content on mobile devices complicate the adoption of mlearning by organizations. Therefore, mlearning requires that traditional instructional design of educational technology must be rethought and strategies for designing effective and engaging mlearning content must go hand in hand with technological attributes and pedagogical affordances of mobile devices, connectivity, user ability, and learning objectives (Park, 2011; Pouezevara, 2012). Gu et al. (2011) further recommend that instructional principles must be identified that are both pedagogically sound and address the context of mobile learning in terms of usability.

Various guidelines for instructional design using mobile technology have been developed over the past several years (Koole, 2009; Herrington et al., 2009; Elias, 2011; Park, 2011; Quinn, 2011). Koole (2009), for instance, proposes a Framework for the Rational Analysis of Mobile Education (FRAME) model, which addresses three aspects of mobile learning: the technical characteristics of mobile devices, the learner, and the social environment. Hypothetically, the intersection of the three aspects is highlighted as the mobile learning process. The usefulness of the FRAME model is that it provides the criteria and examples of each aspect and interaction and the check list for guiding practitioners and educators in the development and assessment of mobile learning environments. Similarly, Vavoula and Sharples (2009) proposed a three-level framework for evaluating mobile learning, comprising a micro level concerning usability, a meso level addressing the learning experience, and a macro level assessing integration within existing educational and organizational contexts.

Similarly, a design-based research study conducted by Herrington et al. (2009) presented a set of design principles for mobile learning in higher education, based on the experiences of teachers and learners in a Faculty of Education.

¹<https://www.statista.com/statistics/276623/number-of-apps-available-in-leading-app-stores/>

<https://www.appbrain.com/stats/number-of-android-apps>



These principles are: Real world relevance (use mobile learning in authentic contexts); Mobile contexts (use mobile learning in contexts where learners are mobile); Explore (provide time for exploration of mobile technologies); Blended (blend mobile and non-mobile technologies); Whenever (use mobile learning spontaneously); Wherever (use mobile learning in non-traditional learning spaces); Whomsoever (use mobile learning both individually and collaboratively); Affordances (exploit the affordances of mobile technologies); Personalize (employ the learners' own mobile devices); Mediation (use mobile learning to mediate knowledge construction and Produce (use mobile learning to produce and consume knowledge). Herrington et al. (2009) recommend that instructors take a design-based approach to mobile learning, with focusing in improving the learning experience and that existing learning theories should be evaluated for their relevance to mobile learning.

Moreover, Elias (2011) extends eight universal instructional design principles for mlearning with particular relevance for distance education which are: equitable use, flexible use, simple and intuitive, perceptible information, tolerance for error, low physical and technical effort, a community of learners and support, and instructional climate. He indicates that, although not specifically developed for mlearning environments, these principles are equally relevant to them. Park (2011) also adopts and adapts transactional distance theory to generate a pedagogical framework for mobile learning in the context of distance education. He categorizes educational applications of mobile technologies into four types based on high versus low transactional distance and individualized versus socialized activity. The value of this framework lies in the contribution it makes to the instructional designers of open and distance learning by reflecting the characteristics of mobile technologies that support both individual and social aspects of learning. Moreover, Dillard (2012) identifies a set of mobile instructional design principles for guiding the creation of effective and efficient mobile learning for adult learners including: a simple and intuitive interface, interactive multi-media, short and modular lessons, engaging and entertaining activities, contextually relevant and meaningful content, and just-in-time delivery.

Previous studies additionally proposed several mobile app evaluation rubrics. For instance, Walker (2013) developed an evaluation rubric "Evaluation Rubric for Mobile Applications: ERMA" to assess the quality of educational mobile apps. The rubric includes five criteria: curriculum connections, authenticity, feedback, differentiation, user-friendliness, and motivation. From the pedagogical perspectives, Green et al. (2014) also suggested a Mobile App Selection for Science (MASS) rubric to examine mobile app selection for 5th through 12th-grade science. The MASS evaluation framework comprises six items: accuracy, relevance of content, sharing findings, feedbacks, scientific inquiry and practices, and navigation. Green et al. (2014) argued that progressing examinations are critical for refining evaluation tools and their role in evaluating technological devices and practices for K-12 science education.

Baran et al. (2017) conducted a designed based study emphasizing pre-service teacher perceptions on educational mobile app evaluation and proposed an evaluation framework called PTC3 (Pedagogy, technical usability, content, connectivity, and contextuality). In addition, they recommended further studies to refine the existing criteria and specify it for different educational context. According to a study of Tantu (2017) revealed that in-service teachers found PTC3 framework criteria significant within STEM context but their ranking of PTC3 framework criteria in terms of importance follows as content, pedagogy, technical usability, connectivity and contextuality. Besides, Tantu (2017) recommended that as the mobile technologies develop new features each day, the impact of features such as augmented reality should be investigated in the education context. Kukulska-Hulme (2009), suggested four significant points for further research of mobile app evaluation: being congruent with the current approaches about learning; taking into consideration the influence of context; marking diverse types of data and analysis, and allowing learners to participate as co-designers or co-researchers. Further, Cook and Santos (2016) reported three key aspects of mobile learning: the integration with social media for connecting learners and work-based practice, the use of design research to guide mobile learning implementation, and learner-generated content and contexts in learning.

3. Research Questions

The main purpose of this study is to formulate a set of principles to guide STEM teachers in selecting mobile apps for their teaching activities. The main research questions are:

1. What pedagogical aspects should be taken into consideration when STEM teachers design or integrate mobile apps in their instructional practice?
2. Which characteristics make mobile apps effective for STEM learning context?
3. What principles should be developed to guide STEM teachers in selecting mobile apps for learning activities?

4. Methodology

As the field of instructional design for mlearning is still being developed, it is, at this point, necessary to apply a highly flexible methodological blueprint. An emerging approach to research that can be used is Design-Based Research (DBR). DBR "is a systematic but flexible methodology aimed to improve educational practices through *iterative* analysis, design, development, and implementation, based on collaboration among researchers and practitioners in real-world settings, and leading to contextually-sensitive design principles and theories" (Wang & Hannafin, 2005, p. 7).



Herrington et al. (2009) describe their implementation of the DBR to mobile learning through the following phases; in the first phase, a problem is analyzed in depth in consultation with the teachers involved. A solution was then designed according to theoretical principles and with knowledge of mobile technological affordances. The proposed solution was then implemented in two or more iterations, with adjustments and improvements made between implementations, so that the emphasis remains on finding the best way to present the subject in the particular pedagogical context. The last phase is the creation of design principles based on the knowledge gained from the theory, practice and reflection of the previous phases.

For this research, DBR approach was adopted and mixed data collection methods were used for the main successive phases: first, analyzing needs assessment of STEM teachers for integrating mobile apps in their teaching activities. Second, developing a set of criteria based on the relevant literature on evaluation mobile apps criteria and educational instructional design. Finally, implementing and evaluating the proposed criteria in an iterative manner, which provided data for evaluation and refinement of the criteria leading to an improved understanding of what constitutes a satisfactory learning experience within the STEM context.

Participants were 15 female upper elementary STEM teachers in three public schools in Palestine. They were divided into five groups; each group had three teachers with different subject matters: Technology, Math and Science. The DBR enabled participants to work collaboratively into groups to explore the potential of the mobile technologies in meaningful ways, to experiment with multiple apps, gather feedback from peers, and generally pilot these ideas with their students. Participants have weekly team meetings to work on several activities and to discuss the proposed criteria. In addition, the collaboration and communication among participants were encouraged through several mobile apps; for example, each group prepared a document in Dropbox and shared it with each other and created groups in WhatsApp.

4.1. Phase 1: Needs Assessment of STEM Teachers

The importance of the DBR approach in analyzing the needs assessment of teachers is to identify both the technical and pedagogical requirements for teachers within the context of STEM teaching. To address the actual needs of STEM teachers, three workshops were conducted. The first workshop developed an understanding of the technical and pedagogical affordances of mobile apps and their potential when incorporating them into learning and teaching experiences. General mobile apps that are free and cross-platform were downloaded and used for providing participants practical experience on how to integrate mobile apps in various activities such as searching, communication and collaboration, note taking, file sharing, reflection, class management and assessment. Table 1 shows some of the mobile apps that were used in Phase 1 of the DBR. Participants used their own devices which allowed them to experiment and familiarize themselves with their devices as they reflected on their needs and abilities. Participants were also familiar with using several apps in everyday life. However, they do not understand interplay the pedagogical practices with the mobile technologies within the context of the classroom.

Table 1: General mobile apps downloaded during the first workshop

Mobile Apps	Description
Safari	a built-in mobile app for web browser and searching information.
Doceri	an interactive whiteboard for iPad, live presentation, create hand-written lessons and screencast videos.
WhatsApp	a cross-platform for communication, sharing personal insight, having discussions with peers, and collaborating with others.
Evernote	a cross-platform for note taking, create text, audio or image notes, and access them anytime, anywhere.
Dropbox	a cross-platform for file sharing, keep all files, photos, and videos in a secure place accessible from any computers and Dropbox website.
VoiceThread	an easy voice recorder for reflection and comments using multiple types of input (text, audio, video).
Socrative	a cross-platform for formative assessments through quizzes and quick question polls. Socrative also instantly grade, aggregate and provide visuals of results.

TeacherKit	a cross-platform app for class management. It helps teachers in taking attendance, recording a grade book, analyzing and sharing information.
Khanacademy	a cross-platform app providing short lectures in the form of YouTube videos. It also provides supplementary practice exercises and materials for different subjects; math, science, computing, art, and economics.
Edmodo	a cross-platform app for communication that allows students to access their homework, grades, school notices, share useful information and send reminders.

The second workshop included hands-on activities and brainstorming on how to evaluate and assess the potential of apps for teaching STEM activities. Participants were given two weeks to develop five activities around the selected topics and they were asked to evaluate the mobile apps in terms of the aspects taken into account when selecting apps for the specific STEM context. Table 2 shows the alignment of the groups' topics, pedagogy and mobile apps used during the workshop.

Table 2: Groups' topics, pedagogy and mobile apps.

Group #	Topics Content	Teaching strategy Pedagogy	Mobile Apps Technology
Group1	Lightreflection and refraction	Simulation	Specific apps: Khan Academy, Phet General apps: Padlet
Group2	Fraction Formula	Manipulative and visualization	Specific apps: Graphing Calculator General apps: Edmodo
Group3	Periodic Table Reaction	Presentation	Specific apps: The Chemical Touch General apps: ASANA
Group4	Geometry	Inquiry-based approach	Specific apps: Sketchpad General apps: Skype
Group 5	Coding	Problem-solving	Specific apps: MIT App Inventor, Scratch General apps: QR, VoiceThread

The third workshop focused on reviewing specific activities to be conducted in the implementation phase. Participants were also encouraged to search the database of the Apple Store and Google Play to select the best mobile apps (general apps and specific apps) that support teaching the planned activities.

By the end of these workshops, participants have built a framework for understanding how mobile technology can be used in meaningful ways to support reform-based STEM teaching and learning and able to maximize the effectiveness of apps used in the mobile learning environment.

4.2. Phase 2: Develop a Checklist of Evaluation Mobile Apps Criteria

The identifying and understanding the mobile apps criteria should not only rely on theoretical framework, but also should develop context appropriate solutions informed by STEM teacher's needs. The theoretical framework served to identify the main principles and then to stimulate debates which helped in developing mobile apps criteria for STEM context. The actual classroom experience enhanced understanding of the theory and connected it to the practice observed during instruction (Yang, 2009). So, a checklist was created to provide participants a useful reference on evaluation criteria. The checklist was developed based on two input sources: theoretical frameworks came from reviewing relevant literature on mlearning and instructional design and actual practices came from reflecting and sharing ideas and experiences of participants. The checklist domains encapsulate the essential authentic learning, social constructivist and usability aspects of an app. The proposed criteria were modified based on a regular reflection and feedback from the participants.



4.3. Phase 3: Implementation and Evaluation

The DBR process is iterative, which means that it is applied repeatedly and improved according to actual learning conditions and learners' needs (Nouri et al., 2016). In this study, four iterations of the learning activities were implemented and evaluated with Science Students Clubs in three Palestinian public schools conducted over two semesters in the academic year 2017/2018. Collaboration with teachers leads better ideas in making a connection between theories and practices in using mobile apps for teaching STEM activities. Participants designed various activities integrating a range of general and specific mobile apps, from drill and practice to creative endeavors, while emphasizing on the purpose for using the app and students' needs. Selecting the apps was through pilots and trial and error. Through experimentation, teachers worked collaboratively in analyzing 47 apps in terms of meeting the criteria provided in the checklist selecting one of "Yes" (the app meets the criteria), "No" (the app does not meet the criteria) and "N/A" (the criteria is not applicable for the app) options. Participants were also invited to provide comments explaining their considerations while selecting mobile apps for teaching the STEM activities and giving any further information. In practical use, there was not an app that received all checks on the list, but in general, the more checks, the better the app is for STEM teaching. Consequently, an app's checklist score is very dependent on the intended purpose and student needs and apps that score low may still be good apps for other purposes.

5. Discussion

The three phases of the research produced contextually-grounded knowledge of mobile apps criteria for guiding STEM teachers in selecting appropriate mobile apps for developing mobile learning activities. The DBR affords participants the opportunity to learn how to integrate specific mobile apps situated to the learner needs in the STEM context (O'Hara et al., 2013). In addition, teachers worked collaboratively, reflecting and sharing ideas and experiences on a regular basis helping in developing the proposed principles (Herrington et al., 2009). Analysis revealed that in-service teachers' evaluations of mobile apps ranked nine criteria according to their prominence to STEM context. These criteria listed below based on the main components of authentic learning, social constructivist and usability frameworks.

5.1. Authentic Learning

Mobile apps revolutionize learning through providing authentic learning experiences to students in terms of real-world relevance, entertainment and microlearning.

5.1.1. Real-World Relevance

A major part of meaningful learning is engaging students by connecting them with the real world (Herrington et al., 2009). In-service teachers highly perceived the usefulness of mobile apps with features that connecting learning with students' everyday life experiences. Many participants commented that real-world relevance made students more highly engaged and enthusiastic in learning STEM subjects. To further enhance student learning with real-world relevance, more recent mobile Augmented Reality(AR) and Virtual Reality(VR) offer a new form of interactivity between the real-world and virtual experiments and create a highly engaging environment and transform the learning experience of students (Kesim & Ozarslan, 2012). Participants noted the importance of using apps with AR and VR features. For instance, using SkyView app, learners can learn new knowledge about astronomy, which can be difficult to understand, and they might better understand the solar system when using AR and being able to see it in 3D. For teaching human body, teachers could visualize bones and organs and bring the human body to life using Anatomy 4D app. goREACT and Elements 4D apps allow learners to conduct virtual chemistry experiments on a smartphone or tablet by combining elements from the Periodic Table to create different compounds. Likewise, teaching Elements and Atoms topics in ChemistryAR can aid students in understanding chemistry by allowing them to visualize the spatial structure of a molecule and interact with a virtual model of it that appears, in a camera image, positioned at a marker held in their hand. A chemistry teacher remarked: "real-world applications such as goREACT stimulate students' curiosity and interest in STEM.... engage students in problem-based learning experiences in a safe environment".

5.1.2. Entertainment

Integrating interactive multimedia elements such as videos, animations or games in the teaching activities motivates learners to take an active role in the teaching and learning process and therefore enhances their learning experiences (Traxler, 2007). Multimedia elements have paramount importance in teaching STEM subjects in which different phenomena and processes are presented vividly, simulate complex content, and present different levels of abstraction. This helps in meaningful and authentic learning (Shah & Khan, 2015). In-service teachers considered educational entertainment was a critical criterion for selecting mobile apps in teaching STEM. A math teacher expressed that "mobile apps are invaluable tools in providing educational entertainment and promoting fun, enjoyment and challenge". The student is highly motivated and engaged in mobile learning if the apps include elements of educational games (e.g. competition, awards, visualization, dynamic animation and interactivity) (Walker, 2013, Baran et al., 2017). Many apps for analyzing and visualizing complex datasets are becoming more readily available. For instance, the geometry apps (e.g., Geometer's Sketchpad) are interactive apps use visualization, spatial reasoning, and geometric modeling to solve problems. Visualization gives a better representation of data that enables learners to better understand and interpret information than inputs in figures and words; this can improve both attention and comprehension. Gamification apps such



as Class Dojo can greatly enhance students experience, promotes student active learning through the engagement of social and interactive experiences. The findings of this study supported Walker (2013) and Baran et al. (2017) researches that have examined the importance of representing material in multiple multimedia forms (e.g., pictures, videos, text, and sounds) to keep students motivated.

5.1.3. Microlearning

Mobile learning should be micro, that is, a bite-size content that promotes active learning and a more personalized experience (Pouzevara, 2012). The bite-sized learning modules are appropriate for mobile devices and more relevant to learners who prefer on-demand learning anytime and anywhere. Participants perceived great mobile apps that aim to engage the learner through concise and short activities (not more than 3-7 minutes). Participants frequently commented that “delivering large information makes it difficult for learners to retain any information and feel boring in navigating it”. Participants considered an app with a microlearning feature is a supplement solution and the full learning materials could be upload and download via linking to cloud storage apps such as Microsoft One Drive, Drop box and Google Drive. Mobile apps design should also make microlearning lesson interactive by adding short YouTube videos and other game widgets, this will help learners to be more focused and they can study or watch the content as many times as they want at whatever speed. For example, Info graphic contains a bunch of information in one large and appealing image. The information is limited to only the most important facts and this helps to be highly memorable.

5.2. Social Constructivism Framework

From a learning design perspective, mobile apps can encourage social learning through user-generated content, communication and collaboration and real-time feedback.

5.2.1. Learner-Generated Content

Shifting from content consumption to content creation stimulates students to employ a range of higher-order thinking skills. Therefore, one significant criterion for selecting mobile apps was learner-generated content. Mobile apps that link to mobile device built-in tools (voice recorder, camera, note-taking, GPS, contact address), give students the opportunities to write, record, film, build, design, and code. For example, students can use their mobile camera to take photos or videos in real life world, tag them with the geo-location, annotate them, and share them digitally with classmates using iMovie app. Content creation could also involve making a multimedia research report using apps such as Book Creator and RQ apps and students could then share the iBook with their classmates. Padlet app is a multimedia friendly and real-time wiki that allows students to express their thoughts on a common topic easily and upload their content (e.g. images, videos, documents and text). In mathematical formulas, math teachers also acknowledged Sketchpad and Geometry apps that provide construct functions for generating an alternative solution for formula (e.g. graphs, numeric, symbols, table, image, photo, video and audio).

5.2.2. Communication and Collaboration

Communication among students and with teachers are essential for effective learning. Interaction tendency in students is enhanced by mobile apps. For STEM teachers, an app that integrates a communication platform to support effective collaboration including blogs, social networks and emails was useful. For example, Asana and Classdojo apps have high valued in the checklist. These apps allow teachers to create teams and assign them tasks. Throughout the process, team members can communicate through email and chat. Asana can also be linked to Google for additional features and it sends notifications and reminders of upcoming due dates. So, mobile apps should facilitate on going collaboration and allow for quick and seamless interactions through direct link access to Twitter, LinkedIn, Facebook, Skype, Calendar and equivalents. Different modes of communication include text, voice video are also offering value to students' needs and help them to stay connected with their teachers. The app should offer alert message, phone, text, email to keep students motivated.

5.2.3. Feedback

Effective feedback is essential to improve learning performance, where teachers give it an important consideration in judging the quality of educational mobile app (Walker, 2013). STEM teachers are always looking for mobile apps that help them to provide timely feedback to the students. When feedback is given immediately, the student responds positively and remembers the experience of what is being learned in a confident manner. For example, Edmodo app makes it possible for a teacher to give students constructive feedback and it is easy for students to respond. Assessing learning via different tests was key affordances of mobile apps (Baran et al., 2017). Kahoot, Socrative and Poll Everywhere apps significantly facilitate the use of formative assessment – that is, frequent, interactive assessment of student progress and understanding. A technology teacher commented “we prefer mobile apps that support self-evaluation of the learner through audio, video recordings”. Many mobile apps can be used to provide drill and practice exercises, provide instant feedback report learner progress. These exercises give users repetitive practice to increase skill levels and lead to more meaningful learning.



5.3. Usability Framework

The usefulness of an app is based on its usability. The main usability criteria that have influenced the selection of educational mobile apps included intuitive, user-friendly interface, compatible platform and customization.

5.3.1 Intuitive, User-Friendly Interface

One of the most important criteria for mobile apps is the simple interface that enables learners to quickly and easily learn how to use it (Gu et al, 2011; Dillard, 2012, Baran et al., 2017). STEM teachers in this study were also appreciated the intuitive, user-friendly mobile apps that help learners to navigate its functions smoothly and not get lost. Participants also valued apps that provide a tutorial as one participant remarked: “we need some tips on how to use the app effectively and smoothly... a short video can help”. They need to clearly understand how to interact with the interface of an app in order to complete their work successfully and efficiently, and to feel competent and satisfied. Interaction with the interface of an app and its features is also an important requirements for enhancing the usability and efficiency of apps (Nouri et al., 2016). Therefore, the navigation of content around the app should support through a mix of modes such as screen-based touch, zooms, swipes, flicks, pulls and pinching.

5.3.2. Compatible Platform

The app should adaptable to any device and not restricted to a particular device (Khaddage, 2013). Participants considered compatible platform criterion was essential in selecting mobile apps. Mobile apps should offer very reasonable options for delivering content in different platforms such as iPhone, iPad and Android because the bring-your-own-device (BYOD) model represent a viable strategy for effective implementation of mobile learning in schools. Wi-Fi is not always available at schools, so the Internet connection is a critical element in the Palestinian schools as that also should be considered. Therefore, the app should provide alternative ways to access include mobile-based and web-based and the app work on off-line and on-line access.

5.3.3. Customization

Another important criterion in selecting mobile apps was customization. The customization features of mobile apps provide a personalized learning experience and provide multiple learning opportunities for students to master the content such as self-paced learning (Walker, 2013; Pouzevara, 2012). Many participants reported that the mobile app should offer complete flexibility to modify tasks and settings to meet student needs. While app technologies have a great potential to address various equity needs in regards to learners needs, from participants' perspective, the focus should be put on configurable settings including multiple language support, screen size adjustment, customize fonts, and use interactive color pickers. Providing different interaction modes such as text, voice video are offering value to students' needs. Text to speech feature can also be included as a significant feature of an app.

In summary, no single app meets all the criteria and a multi-purpose app with several functions is a challenge to design. So, single-purpose apps promise a better user experience due to their simpler, clearer and leaner designs (Abraham, 2014; Bratton, 2014). Financial and technical support are necessary to integrate appropriate apps in teaching STEM activities. However, schools have no budget or financial support for purchasing costly apps and improving internet accessibility, so teachers prefer free apps while selecting mobile apps for teaching STEM activities (Walker, 2013). Selecting any mobile app is also dependent on the intended purpose and student needs. Teachers and even students, therefore, should be able to design and create their own mobile apps especially with the recent availability of resources and references guiding and inspiring them in coding mobile apps with less technical knowledge. When STEM teachers and students learn to code, it enables them to learn how to take complex ideas and break them down into simpler parts in collaborative and creative ways that will be applicable to and integrated with the needs of the real world.

6. Conclusion

The research goal is to propose a set of mobile apps criteria that may help educators to address the unique aspects of the STEM mobile learning context. The iterative process of DRB based on collaboration among STEM teachers in real-world settings was used in this study. The first phase is completed by conducting a series of workshops identifying the technical and pedagogical needs of STEM teachers and training participants for designing collaborative and creative mobile learning activities for their students. During the second phase the preliminary criteria were developed for STEM mobile apps based on a literature review of mobile learning and instructional design. The last phase is the creation of a set of criteria based on the knowledge gained from the theory, practice and reflection of the previous phases.

The conclusion includes a set of nine criteria: real-world relevance, entertainment, microlearning, learner-generated content, communication, feedback, intuitive user-friendly interface, compatible platform and customization. These criteria encapsulate all the essential elements of usability, social constructivist and authentic learning framework. No single app meets all the criteria and a multi-purpose app with several functions is a challenge to design. Teachers and even students, therefore, should be able to design and create their own mobile apps especially with the recent availability of resources and references guiding and inspiring them in coding mobile apps with less technical knowledge.



The limitations of this study include the small and limited sample of teachers from Palestinian public schools. So, the proposed criteria for mobile app selection in STEM context requires more examination from students' perspectives.

References

- [1] Ally, M. (2009). *Mobile learning: Transforming the delivery of education and training*. Edmonton, AB: Athabasca University Press.
- [2] Baran, E., Uygun, E., & Altan, T. (2017). Examining pre service teachers' criteria for evaluating educational mobile apps. *Journal of Educational Computing Research*, 54(8), 1117–1141.
- [3] Berry, M., Chalmers, C., & Chandra, V. (2012). STEM futures and practice: Can we teach STEM in a more meaningful and integrated way? *Instructional innovations and interdisciplinary research in STEM education*. 2nd International STEM in Education Conference, Beijing, November 24-27.
- [4] Brown, T. H. (2005). "Towards a model form-learning in Africa". *International Journal of E- Learning*, 4(3), 299-315.
- [5] Buckner, E. & Kim, P. (2011). "Mobile innovations, executive functions, and educational developments in conflict zones: A Case Study from Palestine". Retrieved from <http://elizabethbuckner.files.wordpress.com/2012/01/mobiles-in-palestine.pdf>.
- [6] Cameron, L. & Tanti, M. (2011). "Students as learning designers: Using social media to scaffold the experience". *elearning Paper*, No. 27.
- [7] Cook, J., & Santos, P. (2016). Three phases of mobile learning state of the art and case of mobile help seeking tool for the health care sector. In D. Churchill, J. Lu, T. K. F. Chiu, & B. Fox (Eds.), *Mobile learning design* (pp. 315-333). Singapore: Springer.
- [8] Cronje, J., & El-Hussein, M. (2010). Defining mobile learning in the higher education landscape. *Journal of Educational Technology & Society*, 13(3), 12–21.
- [9] Dillard, A. (2012). *Mobile instructional design principles for adult learners*. Capstone report, Applied Information Management Program, University of Oregon, Eugene, OR.
- [10] Elias, T. (2011). Universal instructional design principles for mobile learning. *The International Review Of Research In Open And Distance Learning*, 12(2), 143-156. Retrieved from <http://www.irrodl.org/index.php/irrodl/article/view/965/1675>
- [11] Foley, A. & Luo H. (2012). "Developing Web Prototypes for Mobile-Learning Design Research". *International Journal of Mobile and Blended Learning*, 4(1), 31-44.
- [12] Galhotra, A. (2012). *How To Develop Your Own Mobile Learning Tools*. Edudemic Retrived from <http://edudemic.com/2012/05/how-to-develop-your-own-mobile-learning-tools/>
- [13] Green, L. S., Hechter, R. P., Tysinger, P. D., & Chassereau, K. D. (2014). Mobile app selection for 5th through 12th grade science: The development of the MASS rubric. *Computers & Education*, 75, 65–71.
- [14] Gu, X., Gu, F. & Laffey, J. (2011). Designing a mobile system for lifelong learning on the move. *Journal of Computer Assisted Learning*, 27(3), 204–215.
- [15] Herrington, A., Herrington, J. & Mantei, J. (2009). Design principles for mobile learning. In J. Herrington, A. Herrington, J. Mantei, I. Olney, & B. Ferry (Eds.), *New technologies, new pedagogies: Mobile learning in higher education* (pp. 129-138). Wollongong: University of Wollongong. Retrieved from <http://ro.uow.edu.au/>
- [16] Jonassen, D. (2000). Revisiting activity theory as a framework for designing student-centered learning environments. In D. H. Jonassen & S. M. Land (Eds.), *Theoretical foundations of learning environments* (pp.89-121). Mahwah, NJ: Lawrence Erlbaum Associates, Publishers.
- [17] Kearney, M., Schuck, S., Burden, K. & Aubusson, P. (2012). Viewing mobile learning from a pedagogical perspective". *Research in Learning Technology*, 20(1), 1-17.
- [18] Kim, P., Miranda, T. & Olaciregui, C. (2008). Pocket School: Exploring mobile technology as a sustainable literacy education option for underserved indigenous children in Latin America. *International Journal of Educational Development*, 28(4), 435-445.
- [19] Kim, P. (2009). Action research approach on mobile learning design for the underserved. *Educational Technology Research and Development*, 57(3), 415-435.
- [20] Koole, M. L. (2009). A model for framing mobile learning. In M. Ally (Ed.), *Mobile learning: Transforming the delivery of education and training* (pp.25-47). Edmonton, AB: AU Press, Athabasca University.



- [21] Nouri, J., Spikol, D., & Cerratto-Pargman, T. (2016). A Learning Activity Design Framework for Supporting Mobile Learning. *Designs for Learning*, 8(1), 1–12.
- [22] O'Hara, S., Pritchard, R., Huang, C. & Pella, S. (2013). Learning to integrate new technologies into teaching and learning through a design-based model of professional development. *Journal of Technology and Teacher Education*, 21(2), 203-223.
- [23] Park, Y. (2011). A Pedagogical Framework for Mobile Learning: Categorizing Educational Applications of Mobile Technologies into Four Types. *The International Review of Research in Open and Distance Learning*, 12(2), 78-102. <http://www.irrodl.org/index.php/irrodl/article/view/791/1699>
- [24] Pechenkina, E. (2017). Developing a typology of mobile apps in higher education: A national case-study. *Australasian Journal of Educational Technology*, 33(4), 134-146. DOI: <http://dx.doi.org/10.14742/ajet.3228>
- [25] Peters, K. (2007). “m-Learning: Positioning educators for a mobile, connected future”. *International Journal Of Research in Open and Distance Learning*, 8(2), 1-17.
- [26] Pouezevara, S. (2012). “Mobiles For Teaching and Learning: Translating Theory into Practice”. *mLearn 2012 conference*, Helsinki, 15-18 October 2012.
- [27] Quinn, C. (2011). *Designing mlearning: Tapping into the Mobile Revolution for Organizational Performance*. Pfeiffer.
- [28] Shah, I. & Khan, M. (2015). Impact of Multimedia-aided Teaching on Students' Academic Achievement and Attitude at Elementary Level. *US-China Education Review A*, 5(5), 349-360.
- [29] Sharples, M., Taylor, J. & Vavoula, G. (2005). “Towards a theory of mobile learning”. Retrieved from <http://www.lsri.nottingham.ac.uk/msh/Papers/Theory%20of%20Mobile%20Learning.pdf>
- [30] Shraim, K. & Crompton, H. (2015). Perceptions of Using Smart Mobile Devices in Higher Education Teaching: Case Study from Palestine. *Contemporary Educational Technology*, 6(4), 301-318.
- [31] Tantu, Ö. (2017). *Evaluating mobile apps for STEM education with in-service teachers*. (Master thesis). Middle East Technical University, Turkey.
- [32] Tiffany, A. Koszalka, T.A. & Ganesan, R. (2004). “Designing Online Courses: A taxonomy to guide strategic use of features available in course management systems (CMS) in distance education”. *Distance Education*, 25(2), 243-256.
- [33] Traxler, J. (2007). Defining, discussing, and evaluating mobile learning: The moving finger writes and having write. *International Review of Research in Open and Distance Learning*, 8(2), 1-12.
- [34] Uden, L. (2007). Activity theory for designing mobile learning. *International Journal of Mobile Learning and Organization*, 1(1), 81-102.
- [35] Vavoula, G., & Sharples, M. (2009). Meeting the challenges in evaluating mobile learning: a 3-level evaluation framework. *International Journal of Mobile and Blended Learning*, 1(2), 54–75.
- [36] Walker, H. (2013). *Establishing content validity of an evaluation rubric for mobile technology applications utilizing the delphi method* (Doctoral dissertation). John Hopkins University, Baltimore, Maryland.
- [37] Wang, F. & Hannafin, M. J. (2005). Design-based research and technology-enhanced learning environments. *Educational Technology Research and Development*, 53(4), 5-23.
- [38] Zurita, G. & Nussbaum, M. (2007). “A conceptual framework based on activity theory for mobile CSCL”. *British Journal of Educational Technology*, 38(2), 211-235.