EVALUATING MOBILE APPS FOR STEM EDUCATION WITH IN-SERVICE TEACHERS

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ABSTRACT

EVALUATING MOBILE APPS FOR STEM EDUCATION WITH IN-SERVICE TEACHERS

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The purpose of the study was to investigate the perceptions of in-service teachers on mobile app evaluation for STEM (Science, Technology, Engineering, and Mathematics) education. This multi-method research was carried out through interviews with 10 teachers from K-12 schools who were experienced in STEM education and versed in educational mobile app use. Participants included one high school physics teacher, five elementary science teachers, and four information and computer technology teachers from both private and public schools in different cities of Turkey in 2016-2017 Spring semester. Data sources of the study were structured interview questions and mobile app evaluation form included in the interview. The mobile app evaluation criteria of in-service teachers were examined coupled with how they perceived STEM education and how they utilized mobile app integration into STEM context to provide a holistic interpretation. As the results indicated, the in-service teachers most commonly emphasized interdisciplinarity and product development while defining STEM education. They underlined different contributions of STEM education on students such as academic success, positive attitude, skill development, and motivation; contributions on teachers such as job satisfaction and professional development; and contributions on society such as raising individual profile needed, development, finding solutions to society problems and contributions on economy. Within STEM context, teachers reported utilizing mobile apps for assessment, content presentation, scientific measurements, content development, attraction and gamification. According to the in-service teachers, mobile app use positively impacts STEM education practices. They found previously suggested educational mobile app evaluation criteria significant within STEM context and they reported considering further features while selecting mobile apps for STEM education. These results allowed validation and refinement of the mobile app evaluation framework for STEM education and provided recommendations for both mobile learning and STEM education literature.

Keywords: STEM Education, Mobile Learning, Educational Technology, Educational Mobile Apps, Evaluation Criteria, In-service Teachers

ÖZ

STEM EĞİTİMİ KAPSAMINDA KULLANILAN MOBİL UYGULAMALARIN ÖĞRETMENLER İLE DEĞERLENDİRİLMESİ

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Bu araştırmanın amacı, çoklu yöntem araştırma deseniyle öğretmenlerin STEM (Bilim, Teknoloji, Mühendislik ve Matematik) eğitimi için mobil uygulamaların değerlendirilmesi konusundaki görüşlerini incelemektir. Araştırma, STEM eğitiminde ve eğitsel mobil uygulama kullanımında tecrübeli ilk ve orta seviyedeki okullaradan on öğretmen ile yapılan görüşmeler yoluyla gerçekleştirildi. Katılımcılar, 2016-2017 bahar döneminde Türkiye'nin değişik illerindeki hem özel okul hem de devlet okullarında görev yapan bir lise fizik öğretmeni, beş ilköğretim fen bilimleri öğretmeni ve dört bilişim teknolojileri öğretmeninden oluşmaktadır. Durumun bütünsel bir yorumunu sağlamak için, öğretmenlerin mobil uygulama değerlendirme kriterleri, STEM eğitimini nasıl algıladıkları ve STEM bağlamında mobil uygulamaları nasıl faydalı hale getirdikleri ile birlikte incelendi. Çalışmanın veri kaynakları olarak görüşmede yer alan yapılandırılmış mülakat soruları ve mobil uygulama değerlendirme formu kullanıldı. Çalışma sonuçları gösteriyor ki öğretmenler STEM eğitimini

tanımlarken en çok disiplinler arası ve ürün geliştirme ifadelerini vurguladı. Öğretmenler STEM eğitiminin farklı katkılarını, öğrenciler için akademik başarı, olumlu tutum, beceri gelişimi ve motivasyon,öğretmenler için mesleki haz ve profesyonel gelişim, toplum için ihtiyaç duyulan bireyler yetiştirme, gelişme, toplum problemlerine çözüm getirme, ve ekonomiye katkıları olarak açıkladı. Öğretmenler, STEM bağlamında mobil uygulamaları değerlendirme, içerik sunma, bilimsel ölçümler yapma, içerik geliştirme, ilgi çekme ve oyunlaştırma amaçlarıyla kullandıklarını belirtti. Öğretmenlere göre mobil uygulama kullanımının STEM eğitimi süreçlerine olumlu etkilerileri var. Öğretmenler daha önce önerilen eğitsel mobil uygulama değerlendirme ölçütlerini STEM kapsamında önemli buldu ve STEM eğitimi kapsamında mobil uygulamaları değerlendirirken farklı özellikleri de göz önünde bulundurulmasını da belirtti. Bu sonuçlar, mobil uygulama değerlendirme çerçevesinin STEM eğitimi kapsamında geçerliliğinin ortaya konmasına ve düzenlenmesine olanak sağladı ve hem STEM eğitimi hem de mobil öğrenme alanyazını için öneriler sundu.

Anahtar Kelimeler: STEM Eğitimi, Mobil Öğrenme, Eğitim Teknolojisi, Eğitsel Mobil Uygulamalar, Değerlendirme Kriterleri, Öğretmenler

To Labor

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CHAPTER 1

INTRODUCTION

"We cannot solve our problems with the same thinking we used when we created them."

Albert Einstein

1.1. Background of the Study

Technological advancements have provided solutions to various problems in human life especially since late 20^{th} century, on the other hand, they emerged new concerns, too. Educational concerns derived from the developments are mainly about managing how to teach with technology and teaching students how to manage in a world of changing technology (Mishra, Koehler, & Kereluik, 2009). A considerable number of hardware and software have been utilized for educational purposes, their effects on teaching and learning have been investigated. However, technological developments do not seem to slow down in the future. Currently, educators confront with a great challenge of dealing the changes technology brings. It is hard to guarantee educating students in a way they will fit for the inconstant, unpredictable, complicated and undependable future and accordingly, making the decision of which educational methods and organizations should maintain, and which needs to be altered is challenging for educators (Bates, 2015). Thus, alternative ways of teaching should be considered to solve the problem of preparing today's students for a changing future.

A promising education model to teach in today's digital age is STEM education (Science, Technology, Engineering and Mathematics). In 1990s, the disciplines; science, technology, engineering and mathematics were combined with the acronym STEM by National Science Foundation (NSF) (Sanders, 2009). As the term indicates, STEM education is simply defined as teaching and learning progress of these four disciplines. It contains both formal and informal educational activities across all grade levels (Gonzalez & Kuenzi, 2012). In other words, STEM education covers attempts to educate learners from all ages in science, technology, engineering, and mathematics areas. Although the broad character of STEM education causes conflicts about its definition and implementations, it is expected to have significant function for development of next generations.

STEM education is not limited to teaching science, technology, engineering and mathematics disciplines; it represents a further meaning that keeps all disciplines together. On the other hand, linking these disciplines with each other and integrating them into curriculum is a significant issue (Yıldırım & Altun, 2015). During this process, students need to be provided with different construction materials and electronic devices to better understand technology so that they will pay effort to find solutions to real world problems through authentic learning as engineers do (Stohlmann, Moore, & Roehrig, 2012). Thus, introducing effective technological tools is significant for STEM education to help students be familiar with them and discover how to use these technologies most effectively to solve real world problems.

Mobile technologies feature in STEM education as they have immense potential for facilitating more innovative educational methods (Sung, Chang, & Liu, 2016). They extend learning activities such as practice and application out of the classroom for being easily accessed and held (Saran, Seferoglu, & Cagiltay, 2009). Examples for mobile technologies can be mobile phones, handheld computers, or tablets (Kukulska-Hulme & Traxler, 2005). The capabilities of mobile devices have broadened from "portable information" to a more vigorous and credible level promising more educational potential through developments in technology, recently emerged program applications, integrated Web 2.0 technologies and social networking sites (Park, 2011). Considering the current development rate of mobile technologies, it is worth paying their educational potential regard to develop today's teaching and learning environments.

Mobile learning stands for learning within that the learner is not at a constant or previously decided location, and learning through that the learner utilizes mobile technologies for learning (O'Malley, Vavoula, Glew, Taylor, Sharples, & Lefrere, 2003). As these devices are portable, they support accessing educational materials by expanding learning context beyond traditional classroom settings (Mundie & Hooper, 2014). Learning is considered as mobile when learners reach learning materials without time and place constraints (Quinn, 2000). Increasing use of mobile technologies impacts the conception of learning and changes the delivery methods of learning (Traxler, 2007). Notably, teachers play a critical role to use mobile technologies efficiently for educational purposes. If they are given the necessary training and resources to take advantage of mobile technologies for educational purposes, teachers will be more successful to present the intended knowledge and skills to their students (West, 2013). In other words, teachers need to be guided to maximize capabilities of mobile technology so that the potential for mobile learning could be reached.

1.2. Problem Case

Utilizing mobile devices with suitable teaching methods and using special affordances of mobile technologies are necessary to resolve educational challenges and to allow students reach previously defined learning outcomes (Sung, Chang, & Liu, 2016). In this sense, evaluating and selecting the correct mobile applications is an issue that teachers should consider for any target context or purpose. However, evaluating mobile learning has various concerns and most important one is clarifying characteristics of an appropriate evaluation that comes with a clear mobile learning definition and conceptualization (Traxler, 2007). In response to this, different studies were conducted to suggest a common language structure in terms of evaluating mobile apps for educational purposes (Ahmed & Parsons, 2013; Baran, Uygun, & Altan, 2017; Economides & Nikolaou, 2008; Green, Hechter, Tysinger, & Chassereau, 2014; Huang & Chiu, 2015; Vavoula & Sharples, 2009; Walker, 2013). Therein lies the problem that mobile learning gains depth through the time with the emerging features and developing capabilities of mobile technologies. Then, previously suggested tools might no longer be sufficient to evaluate current mobile apps for the specified learning environment of any discipline.

The research base of mobile learning is enriching but there are few studies empirically validating evaluation tools to reveal the quality of the current mobile apps and this calls for research to show good examples of mobile technology integration, combining new knowledge with the existing one about effective pedagogies (Walker, 2013). In this sense, empirical evidence for good examples of utilization and evaluation of mobile apps for STEM education is necessary for further investigation of mobile learning in STEM context. However, there is no study investigating whether today's mobile apps could be evaluated based on the existing tools in STEM context. Furthermore, there is no study guiding in-service teachers for selecting the correct apps considering the specific characteristics of STEM education. Also, mobile learning literature lacks studies focusing on the views of in-service teachers for mobile app evaluation specifically for STEM education. Therefore, there is a need for research on how in-service teachers view existing evaluation frameworks and how they evaluate mobile apps to be used in STEM education.

1.3. Purpose and Research Questions

Based on the abovementioned motives, the primary research aim is to investigate evaluation of mobile apps for STEM education through the lens of in-service science and ICT (Information and Computer Technology) teachers who are competent with mobile technologies and experienced in STEM education. To draw a holistic picture, the specific aim of the study is to provide empirical information on perceptions of in-service teachers on mobile app integration into STEM education.

Two main research questions and related four sub-questions are addressed in this study:

1. What are the perceptions of in-service teachers for mobile app use in STEM education?

1.1. How do in-service teachers perceive STEM education?

1.2. How do in-service teachers utilize mobile apps in STEM education?

2. Which criteria do in-service teachers consider while selecting mobile apps for STEM education?

2.1. How do in-service teachers assess PTC3 evaluation criteria in terms of selecting mobile apps for STEM education?

2.2. How do in service teachers assess mobile apps they frequently used based on the PTC3 framework criteria?

1.4. Significance of the Study

According to Sanders (2009), there are sufficient research results showing that STEM education has positive impact on students' achievement, interest, and motivation. This warrants further practice and study of STEM instructional approaches (Sanders, 2009). Considering benefits of these approaches, it is significant to clarify how teachers affectively integrate STEM education. Indeed, examination of teacher support, exemplar practices, efficacy of teachers, and materials to be implemented are vital to take into consideration for STEM education (Stohlmann, Moore, & Roehrig, 2012). Thus, it is significant to understand STEM context and be aware of the affordances of educational technologies before implementing them in educational practices.

Mobile technologies have capabilities to enrich and foster STEM education. While mobile devices are extensively used by almost all segments of the society, teachers are expected to utilize their affordances for educational context and guide learners for productive usage of mobile devices. Therefore, advancements in mobile technologies and emergence of them in educational contexts should be coupled with skill development of K-12 teachers since they are responsible to integrate these technologies into learning environments (Hu & Garimella, 2014). Informed decisions to select mobile apps for specific instructional strategies require experience but more importantly, guidance. It is so possible that a teacher could be lost in the vast amount of existing mobile apps.

Empirical evidence is crucial to demonstrate the affordances of mobile technologies and to effectively use mobile technologies in educational settings (Walker, 2013). Providing mobile app evaluation guidance through experienced teachers' reviews in STEM education will allow reaching more qualified mobile apps and better learning experiences. However, studies on learning practices with mobile tools, impacts of these tools on student learning, and different dimensions how mobile learning promotes lifelong inquiry in students are limited (Sha et al., 2012). This shows the necessity of examining mobile apps including perspectives of teachers and teaching practices for STEM education in specific.

It is significant to show regard to the mobile learning environment as a whole with learning experiences and possible interactions while evaluating mobile technologies including pedagogical views (Traxler, 2007). An evaluation framework called MASS was developed for mobile apps used in science education grounded on the pedagogical concerns given in the study of Kearney et al. (2012) to investigate mobile apps for science education considering lab-based technologies and scientific tools (Green et al., 2014). They argued that progressing examinations are critical for refining evaluation tools and their role in evaluating technological devices and practices for K-12 science education (Green et al., 2014). Followingly, Baran and her colleagues developed an evaluation framework called PTC3 (Pedagogy, technical usability, content, connectivity, and contextuality) to guide teachers for selecting educational mobile apps based on related educational purposes and recommended further studies to refine the existing criteria and specify it for different educational context (Baran et al., 2017). 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.

This study, investigating mobile app evaluation for STEM education through in-service teachers' perspective coupled with their views on mobile app use in STEM context, holds potential for contributing to both STEM education and mobile learning research areas. It attempts to specifically refine and validate PTC3 framework within STEM context as suggested by previous mobile app evaluation studies (Baran et al., 2017; Green et al., 2014). As Kukulska-Hulme (2009) proposed before, this study examines mobile apps together with one of the current learning approaches (STEM education), it includes different data types and present context and impacts of mobile app use.

1.4. Definition of Terms

Educational technology refers to research and principled practice of enhancing learning progress through producing, employing, and dealing with correct technological procedures and resources (Januszewski & Molenda, 2013).

*Mobile App*s are software that are developed to be used through different platforms (Android, IOS, etc.) of mobile devices. Besides their various categories, mobile apps addressed in the study are the ones developed for educational use (Walker, 2013).

Mobile Devices are handheld computing systems that can be easily carried allowing students to access, process and store information, communicate, entertain and organize (Economides & Nicolau, 2008).

Mobile Learning is defined as learning experiences that allow the learners not to be at a constant, prespecified place, or learning experiences that occur taking advantage of means of mobile tools (O'Malley et al., 2003).

STEM Education is the process of teaching or learning in the disciplines of science, technology, engineering, and mathematics across all grade levels in both formal or informal educational settings (Kuenzi, 2012).

CHAPTER 2

LITERATURE REVIEW

To provide a clear information on mobile app evaluation for STEM education, in this section, concepts of "STEM Education" and "Mobile Learning" are explained and related studies are summarized.

2.1. STEM Education

Current education systems aim to provide effective teaching and learning approaches to cope with the economic races, ever-growing technologies, vast amount of information, and other concerns of 21st century. Including science, technology, engineering and mathematics disciplines, STEM education is in the spotlight of several economies (Wells, 2008). These disciplines are significant as STEM jobs have potential to develop nations' innovation and competitiveness capacity originating new concepts, lines of work and branches of industry. Notably, demand for STEM gained acceleration in last decade since they are believed to matter for sustainable economic growth and brighter future (Langdon, Mckittrick, Beede, Khan, & Doms, 2011). K-12 education aims to develop competent individuals to succeed in university education and advance in the career. Coming to the fore in today's competitive global market requires focusing knowledge-based resources especially in science and technology. Rising generation of today will shape the future. Only if given the education to develop literacy in STEM fields and 21st century skills, they will make informed decisions and impact the future of their country (Figliano, 2007).

Bybee (2013) states that STEM education reform process differs from other educational reform attempts in three main aspects: STEM education (a) targets to meet the challenges derived from global economic concerns (b) shows regard to the need for literacy in STEM disciplines for overcoming world's technological and environmental problems and (c) centers upon the knowledge required to develop occupational skills needed in the 21st century (Bybee, 2013).

STEM educational reform has drawn attention of many countries due to the similar reasons, but approaches to implement STEM education has varied in several aspects. The term STEM includes a wide range of knowledge and experience. Thus, some focus on only teaching and learning STEM disciplines while others highlight the different grade levels for STEM implementation. These different points of view caused STEM education concept lack a clear definition. Especially the function of technology and engineering is still uncertain in most of the current STEM education programs (Williams, 2011). According to Bybee (2013), most of the STEM policy discussions focused on teaching specific STEM subjects with advanced methods, especially science and mathematics. On the other hand, STEM is said to embody technology and engineering to indicate how science and mathematics lessons are combined with scientific applications.

2.1.1. History of STEM Education

Even though the STEM education reform has gathered pace in the past few decades, the call for fortifying science and mathematics education was emphasized by different reports since late in twentieth century. The birth of STEM was by virtue of government policy, more particularly of the National Science Foundation (NSF) that combined the areas of science, mathematics, engineering, and technology under the name of SMET in the early 1990s. Later, the acronym SMET was replaced with STEM (Sanders, 2009). Nonetheless, milestones for development of STEM date back to previous decades.

STEM education is said to come in sight when the famous satellite called Sputnik was launched by Russia in 1957, starting space race among industrial countries. This path-breaking event caused west countries to question their science and technology education. Accordingly, in 1962 School Mathematic

Project was started driving forward discovery learning for math education. Similarly, in 1966, Nuffield Science Teaching Project was implemented focusing on experiential learning that accelerated the adoption of student-centered education approach (Banks & Barlex, 2014). The first spaceflight landing to moon in 1969 Apollo-11 turned space race to a cliff-hanger. Assessment of Performance Unit (APU) was established to assess students' understanding of basic science topics as well as scientific thinking. Between years 1980-1989, Children's Learning in Science Project (CLISP) was started by Leeds University promoting constructivist approach to science learning (Banks & Barlex, 2014). This approach gave students the role of natural receiver, interpreter and builder of knowledge. At about the same time, Singapore made a country-wide reform in math education putting forward problem solving skills and heuristic model drawing. The results of TIMMS 2003 revealed that this reform seemed to make sense as the country was rated at the top in 4th and 8th grade mathematics performance. In 1983, Technical and Vocational Education Initiative (TVEI) was funded by the Department of Industry to adopt school curriculum according to the needs of industry and support school leavers. This funding helped emergence of interdisciplinary studies in science and technology (Banks & Barlex, 2014). That means the boundaries between science and technology disciplines were crossed and they were combined creating new branches of study.

In 1985, the Department of Education's statement of policy was announced remarking the importance of active engagement in scientific method for an effective science education. Afterwards, The Great Educational Reform Act was introduced defining core subjects in science, mathematics and technology for national curriculum in science and mathematics from preschool to secondary school in England, 1988. Northern Ireland and Wales. Through 1990-1999, Nuffield Design & Technology Projects placed technology in the national curriculum. Then, Alan Smithers and Pamela Robinson's publication of "Technology in the National Curriculum-Getting It Right" commissioned by the Engineering Council revealed the malfunction of the current technology education and led to remedial (Banks & Barlex, 2014). The lessons learnt from the mistakes of technology education practices revealed new points of views to develop technology competent generations.

In 2000, the Young Foresight was introduced as a curriculum initiative providing 14-year old students with the opportunity of consultancy from mentors in industry to design products and services for the future. In 2002, the changes to the curriculum for England, Wales and Northern Ireland stated design & technology as a must course in all schools. Finally, in 2013 the application of the revised curriculum for all schools was announced (Banks & Barlex, 2014). STEM education may seem a novel approach but a brief look at its history shows that it is an outcome of an evolving educational improvement actions.

Today, an awareness for STEM education is in the burner of many countries and different regulations are made with the intention to promote STEM education. The United States of America and the member states of European Union has initiated various programs and projects to apply related educational approaches that allow students developed required skills, prepare for future taking into consideration fundamentals and required capabilities to survive at modern business environment (Akgündüz, Aydeniz, Çakmakçı, Çavaş, Çorlu, Öner, & Özdemir, 2015). The pioneer actions taken by the developed countries set as a model for the others. The current situation for STEM education in developed countries and Turkey is explained in part 2.1.5.

2.1.2. Definition of STEM Education

Different definitions and approaches emerges as research results and practice outcomes for STEM education develops day by day. STEM education is mainly defined as an educational approach distinguished with its interdisciplinary nature from preschool to college education (Gonzalez & Kuenzi, 2012). Furthermore, STEM education provides quality education utilizing contemporary knowledge, developing life skills and supports advanced thinking (Yıldırım & Altun, 2015).

Although the original acronym includes only science, technology, engineering and mathematics; STEM has been said to represent a further meaning and embody multiple disciplines by different concerned groups. According to the definition of National Science Foundation (NSF), STEM fields further include different disciplines from social, behavioral or political science in addition to the four main disciplines it focuses (Green, 2007). According to another approach, art should be included in STEM education changing the acronym STEM to STEAM. The reason for that is engineering process emphasized by STEM education is claimed to require design and artistic or creative perspectives. This approach has potential to improve art education and active student engagement, creative process and design thinking adding arts to STEM education to make STEAM (Bequette & Bequette, 2012). Also, the acronym E-STEM was formed adding environment discipline to science, technology, engineering and mathematics by the North American Association for Environmental Education (NAAEE). It refers to environmental education as a road to STEM education. E-STEM aims to help students discover STEM subjects around environmental problems trough different project and learning initiatives (Wals, Brody, Dillon, & Stevenson, 2014). Diverse approaches might emerge for STEM education proposing different subjects to take part in it and diverse groups of educators might insist to preserve the main four disciplines by time. Nonetheless, this study refers to science, technology, engineering and mathematics as STEM disciplines.

2.1.3. STEM Education Disciplines

2.1.3.1. Science

Science refers to the study of natural world associated with different disciplines such as physics, chemistry, and biology as well as treatment or application of facts, principals, concepts or conventions related to these disciplines (National Research Council, 2012). Scientific literacy is the comprehension of science-related terms and operations necessary to make individual decisions, contributing culture and society affairs as well as economic development. Utilizing scientific knowledge procedures to make sense of science in life as well as contribution to scientific studies (OECD, 2003).

2.1.3.2. Technology

Organization for Economic Cooperation and Development defines technology as utilization of knowledge to develop products out of the given resources (2003). Therefore, technological literacy is described as the ability to employ, comprehend and assess technology with its principles and strategies required to solve problems or achieve objectives coupled with the ability to make sense of the way technology is created and influenced by the society in addition to its impacts (International Technology Education Association, 2007).

2.1.3.3. Engineering

Engineering is a profession that use mathematical and scientific knowledge to develop and modify the three fundamental resources that humankind has available for the benefit of mankind: energy, materials, and information (Feisel & Rosa, 2005). According to OECD (2003), engineering literacy is the comprehension of the ways technologies evolve thorugh the engineering design process that needs the skills to apply scientific and mathematical knowledge into related products, processes or systems.

2.1.3.4. Mathematics

Mathematics is a branch of science that requires identification, comprehenion, and implementation of figures, numbers and quantities and making informed judgments about the impacts of mathematics in private, occupation and social life as a productive, aware and active citizen (OECD, 2006). According to definiton of the National Council of Teachers of Mathematics (2000) mathematical literacy is being capable of reading, listenning, creative thinking and communicating based on problems, projections, and solutions with the aim of progressing and having a deep understanding of mathematics.

2.1.4. Integrative STEM Education

Integrative STEM education includes design-based learning approaches that purposefully bind science and mathematics education concepts or practices with technology and engineering education. Furthermore, this integration can be extended including different school subjects related to the other disciplines. (Sanders & Wells, 2006). According to Moore and his associates (2014), integrated STEM education is aims to gather two or more of all of the STEM subjects under a common course, topic, or lesson that is grounded upon links among STEM disciplines and real-world problems (Moore, Stohlmann, Wang, Tank, Glancy, and Roehrig, 2014). Forms of curriculum for integrated STEM education can have learning objectives based on one of the disciplines but contain the context from other STEM subjects (Moore et al., 2014).

Kelley and Knowles (2016), viewed integrated STEM education as an approach for STEM education including content from two or more STEM disciplines, connected with related practices in an authentic learning environment to develop student learning and developed a conceptual framework for integrated STEM education (Kelley & Knowles, 2016, p. 4). The framework was illustrated with an image of a block and tackle of four pulleys lifting a load combining situated learning, engineering design, scientific inquiry, technological literacy, and mathematical thinking as an integrated system. Pulleys represented the four STEM disciplines and are linked to the community of practice rope. Harmony within the system was required to ascertain the integrity of the system as a whole. As the authors indicated, not all four disciplines had to be included in all practices but it was significant to successfully connect STEM disciplines and community of practice (Kelley and Knowles, 2016). The graphic illustrating the integrated STEM education suggested by Kelley and Knowles (2016) is given below (See Figure 1.)

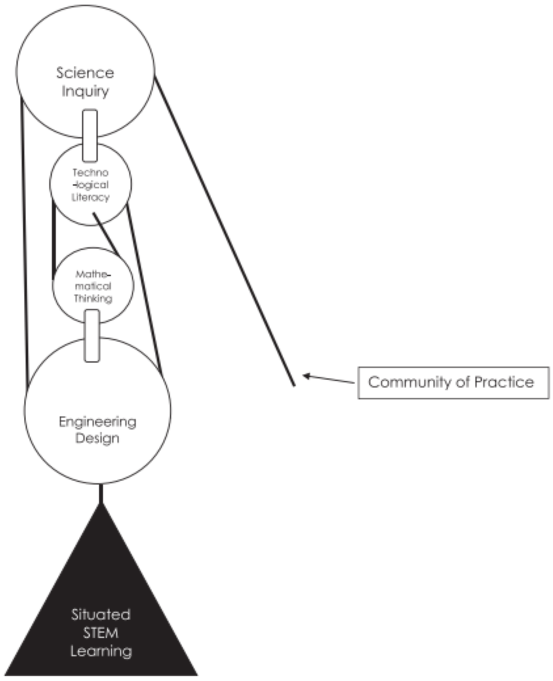

Figure 1. Situated STEM Learning Framework (Kelley & Knowles, 2016, p. 4).

Integrated STEM education, generally carried out through theme-based, problem-based, inquiry-based and design-based pedagogies, is reported to have advantages of increase in student achievement, creating generations for STEM professionals, motivating, exciting and interesting to the students, better preparing students for workplace, and increasing the quality of learning for the students (Heil, Pearson, & Burger, 2013).

2.1.5. STEM Education in the World and Turkey

The United States of America (USA) view STEM education as one of the key factors to preserve the current economic and technological status and place importance to its applications country wide with different actions. A considerable number of schools and universities established STEM Centers in addition to emphasis on project development, inquiry, design, innovative thinking, collaboration, creative thinking in learning and related instructional methods (STEM Akademi, 2013). The USA deliver STEM education in two main paths: implementing engineering skills as cross-curriculum discipline and construct STEM schools for students (Akgündüz et al., 2015).

China believes that science education is the key factor for a developed society. China has focused on STEM education for almost a decade revising high school curriculum in addition to integrating STEM subjects into teacher training programs (Ministry of National Education [MoNE], 2016a). On the other hand, Russia has given priority to higher education and announced three main initiative actions for STEM education: 1) developing the quality of engineering programs, 2) advancing current mathematic education, and 3) enhancing engineering, medicine and science education programs in higher education (Smolentseva, 2014). European countries declared the significance of STEM education for an innovative future and prepared different strategy plans to adopt STEM education. These plans include the students' skill development, increase in STEM workers, curriculum revision in education and teacher training programs. Among all, Finland has prepared the most extensive plan in 2014, forming cultural and educational leader groups to work for developing students' interest and skills in STEM subjects. Furthermore, corresponding educational organizations have their own strategy to promote STEM education (MoNE, 2016a). The given actions taken show that STEM education is attached importance by the world's leading countries.

For Turkey, the recent findings of international assessment studies such as PISA (Program for International Student Assessment), TIMMS (Trends in International Mathematics and Science Study) and PIAAC (The Program for the International Assessment of Adult Competencies) signalize that enhancements in national education is required to provide Turkish students with essential knowledge and skills necessary for the modern era (TEDMEM, 2016). Firstly, PISA 2015 results indicated that performance of Turkish students was below the average in scientific literacy, mathematical literacy and reading skills. On the other hand, they enjoyed science lessons and thought they were competent in science area with a higher frequency compared with the average (MoNE, 2016b). Secondly, the findings for PIAAC 2015 were summarized with the following seven angles; 1. Most of adults in Turkey lacked skills necessary for the time, 2. Educational grades were not effective to upskill the nation, 3. Turkey had the highest difference between the skill levels of men and women, 4. Adults were not able to gain skills after compulsory education, 5. Adults did not use their abilities in workplace or social life, 6. Higher level of skill or education did not have influence on employment situation. 7. Turkey was out of general tendency in terms of non-economic indicators (TEDMEM, 2016). Thirdly, as TIMMS 2015 findings revealed; Turkish students did not have a brilliant success in terms of science and mathematics performance (MoNE, 2016c). These findings call for a systematic country-wide educational reform to support all units of the nation.

Turkey has no specific action plan for STEM education but “2015-2019 Strategic Plan” includes some goals supporting STEM education. To promote STEM education in Turkey, universities such as Hacettepe University, İstanbul University and Middle East Technical University has taken the initial steps building STEM centers that provide training programs and projects for students and teachers. However, the number of universities that have studies or projects on STEM education and teacher training programs are limited. As a national contact point, General Directorate of Innovation and Educational Technologies takes part in the Scientix Project that stands for the community for science education in Europe. This project has the purpose of sharing best practices, projects and tools for STEM education with participation of 30 countries in Europe (MoNE, 2016a).

Ministry of National Education (MoNE) has published “2017 Performance Program” in November 2016, with an approach piecing knowledge and awareness in education together. Parallel to this approach, MoNE aims to develop a libertarian, productive and competitive education system that raise the type of individuals that economy needs. Preparing teachers proper to this system, enhancing curriculum and providing suitable learning environments are main focuses. It is also stated that, being in the core of national education policies, “Teacher Strategy Certificate” will be prepared and put into action (MoNE, 2016d). A “Teacher Academy” system will be started to allow teachers to update their knowledge and skills. A rewarding system will be developed to diagnose and place the selected teachers a premium. Faculties of education will be reconstructed in accordance with the new structure of national education system.

Studies to form national curriculum content in a way that it prepares students from all grades for life, reveal their abilities, provide core competencies, transferring universal values will continue. The curriculum will be shaped to be appropriate for education with information technology support, educational e-contents will be extended and developed. A mechanism that allow parents to participate each step of education process will be formed. Game based learning will be activated. Mobile learning systems will be developed; social media will be used as an effective learning tool. Emphasis will be given to students' learning foreign language to show oral and written communication. Collaborative, problem solving-based, project oriented educational technologies will be generalized. (MoNE, 2016d). The performance program promise hope for enhancement in the national education system but the fundamental point to achieve the abovementioned goals is directly related to wisely applying the program into classroom settings. At this stage, the role of teachers cannot be overlooked, so teachers should be told how to do beyond being told what to do.

Parallel to the given performance program, in February 2017, Ministry of National Educational has published a draft curriculum for K-12 education intended to be applied gradually starting from 1st, 5th and 9th grades in 2017-2018 education year. Development of self-efficacy and skills of individuals called as 21st century skills are the main purposes to support students for innovative and critical thinking, problem solving, communication, collaboration, literacy of information, media, IT technology, entrepreneurism, productivity, responsibility to so that they could show their full potential as citizens. The draft curriculum was open to access for a month for public and expert review. The definitive version of the curriculum is expected to be published considering the reviews. According to Corlu, Capraro, & Capraro (2014), there are variations among teaching practices of STEM subjects in terms of school level, school type and teacher characteristics; indeed, there are discrepancies in STEM disciplines education regarding the facts that there is departmentalization in these subjects after fifth grade education, the level and number of instructional hours for mathematics and science courses varies according to the school type, and the age and experience of the STEM teachers changes with the school level and school type. Additionally, as the study of Yıldırım and Selvi (2016) indicates, pre-service teachers are not knowlegdable and skillful enough at STEM education and it is difficult for them to relate STEM knowledge into daily life practices, also they have some misconceptions about STEM education such as it should be given with special educational tools or it is appropriate just for gifted students.

In summary, Turkey has taken some initial steps to promote STEM education but more extensive implementations are necessary to disseminate teaching strategies, studies and practices for STEM education all around the country.

2.1.6. Impacts of STEM Education

The reasons that the countries gave importance to STEM education are listed as: 1. leading in technology and economy, 2. having success in science and mathematics, 3. raising qualified individuals, 4. developing a sustainable economy, 5. providing skill development in scientific process, inquiry, critical thinking, 6. solving real world problems and be productive 6. increasing the number of individuals needed in twenty first century workface (Toulmin & Groome, 2007). The learning experiences of students in primary and secondary education levels provides basis to feel competent and interested in science and mathematics areas (Ainley, Kos & Nicholas, 2008). In this sense, results derived from different STEM practices in K-12 education context are significant for further investigations. According to Morrison (2006) the STEM educated students are expected to be problem solvers, innovators, inventor, self-reliant, logical thinkers, technologically literate, STEM lexicon participants and able to relate cultural and historical background to their education (Morrison, 2006). The studies examining the effect of STEM education in K-12 students are mentioned followingly.

A pilot study was performed to examine the application of a science and technology curriculum based on robotics to increase the achievement scores of student ages 9-11 in an after-school program. The results retrieved from the comparison of students in the robotics intervention with the control group showed that the mean scores of robotics intervention participants significantly increased in on the post-test while the scores of the control group did not significantly change from the pre-test to the post-test (Barker & Ansorge, 2007).

A similar study was conducted by Sullivan (2008) examining the relationship between robotics experience with the application of scientific literacy skills and the development of systems understanding for 11–12-year-old middle school students. The students attended an intensive robotics course offered at a summer camp. According to the results of pre/post-tests, the students increased their systems understanding coupled with science literacy-based thinking and science process skills.

In another study conducted by Apedoe and her associates, engineering design was used to teach students central and difficult concept of Heating/Cooling System unit. The study results revealed that students showed significant development on concept knowledge of the unit. On the other hand, the post-test results were low and that indicated the need for further improvement (Apedoe, Reynolds, Ellefson, & Schunn, 2008).

Riskowski et al. conducted a study implementing an engineering design project that focused on water resources in 8th grade science classes. The treatment group students were exposed to an engineering project while the control group took a more traditional education. A pre-post assessment tool was applied to measure students' knowledge of water resource issues. According to the results of the study, students who attended the engineering project showed statistically significant higher levels of thinking on open-ended questions and deeper content knowledge. This study pointed the positive effect of engineering in promoting student learning in the middle school science curriculum (Riskowski, Todd, Wee, Dark, & Harbor, 2009).

Olivarez (2012) investigated the impact of STEM education on 8th grade students' academic success in her doctorate dissertation. The study focused on the outcome measures of mathematics, science, and reading. The study followed an ex-post facto, causal-comparative research design in which experimental group students were provided with STEM education as the control group did not. The results of the study showed that participation in a STEM academic program, where teachers use Project-Based Learning (PBL), collaborative learning, and hands-on strategies, has positive influence on eighth grade students' academic achievement in mathematics, science, and reading (Olivarez, 2012).

Another study was undertaken to assess students' science process skills, content and concept of knowledge after attaining an elementary STEM program for one year. As the study results indicated, the experimental group students showed statistically significant improvement in terms of science process skills, content and concept knowledge of science compared with the control group (Cotabish, Dailey, Robinson, & Hughes, 2013).

As can be seen in the abovementioned studies, STEM education has a positive impact on student performance at related disciplines. Participating in robotics courses allowed students to increase achievement grades of middle school students (Barker & Ansorge, 2007; Sullivan, 2008), integrating of engineering design process in or out of the classroom helped middle school students develop content knowledge and scientific literacy (Apedoe et al., 2008, Rikowski et al., 2009), receiving STEM programs developed academic achievement in disciplines such as science, mathematics and reading (Cotabis et al., 2013; Olivarez, 2012).

2.2. Mobile Learning

Mobile learning, utilizing handheld technologies for educational purposes, is still in progress with regard to related technologies and pedagogies, yet it progresses rapidly (Traxler, 2007). This emerges the various descriptions of mobile learning but all of them takes the link between mobile device use and learning practices, in other words, the process of learning facilitated with handheld devices (Kearney et al., 2011).

Integrating mobile technologies into educational context coincide with the educational purposes of broadening learning opportunities, developing student performance, enhancing learning with diverse needs, aims and styles, and providing learners with authentic learning practices when an alternative way of access to related material is impractical (Kukulska-Hulme, 2009). Mobile learning facilitates personalized learning taking individual learner profile into consideration and provide learning experiences where the learner want, support situated learning through context-sensitive and instant learning, provide authentic learning that is based on real-world problems and projects in relevance with interest of the learner, enable spontaneous reflection and self-evaluation, thus allow students to use less time and space, to collaborate with other students and to receive more teacher support (Traxler, 2007). According to Chiong and Shuler (2010), the unique affordances of mobile learning to improve education are listed as fostering learning regardless of time and place, reaching underserved students, improving communication and collaboration needed in 21st century, suiting different learning environments and allowing for personalized learning.

Koole (2009), proposed a model for framing mobile learning. The model was developed regarding to technical characteristics of mobile devices coupled with social and personal aspects of learning and it described learning, participating and interacting with others as well as knowledge and systems through various physical and virtual locations anytime and anywhere (Koole, 2009). The model is presented in Figure 2.

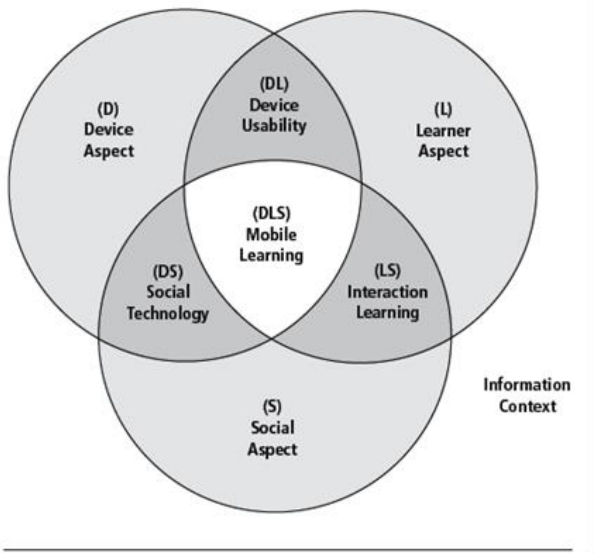

Figure 2. The Frame Model for Mobile Learning (Koole, 2009, p. 27).

The Frame model for mobile learning has three main aspects: device, learner and social. In device aspect, physical characteristics such as input and output capabilities, file storage and retrieval, processor speed and error rates of the device were suggested; in learner aspect, prior knowledge, memory, context and transfer, discovery learning in addition to emotions and motivations were included; in social aspect, on the other hand, conversation-cooperation and social interaction was included (Koole, 2009). Each aspect and their details were described with related examples, concepts and comments.

For intersections, Koole (2009) included portability, information availability, psychological comfort and satisfaction in device usability; device networking, system connectivity and collaboration in social technology; interaction, situated cognition and learning communities in learning interaction learning intersections. Furthermore, distinct advantages of mobile learning were listed as time and place free learning, access to various materials promoting comprehension and retention, authentic learning experiences and reduced cognitive load for learners in the study (Koole, 2009). The Frame model for mobile learning was a guiding light for the following studies in mobile learning area.

Inspired by the Frame model, Kearney et al. developed framework to emphasize the pedagogy of mobile learning suggesting three main constructs of authenticity, collaboration and personalization. Authenticity stands for contextualized, participatory, situated learning; collaboration, on the other hand, refers to conversational, connected aspects of mobile learning and personalization includes ownership, agency and autonomous learning (Kearney, Schuck, Burden, & Aubusson, 2012, p. 8). The pedagogy of mobile learning was described through three main constructs: authenticity, collaboration and personalization. Authenticity focused on the opportunities for contextualized, participatory, situated learning; collaboration emphasized the conversational, connected aspects of mobile learning and personalization foregrounded ownership, agency and autonomous learning (See Figure 3.)

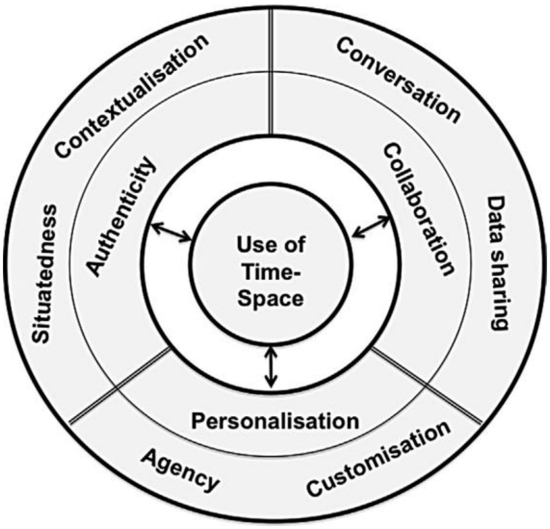

Figure 3. Pedagogical Framework for Mobile Learning Developed by Kearney et al. (2012, p. 8)

In their study, Kearney et al. (2012) explained how mobile learning coincide with the theories suggested in the framework. Firstly, personalized learning focuses on learning choice, active engagement and self-discipline in addition to customization (McLoughlin & Lee, 2008). The learners can control the place, pace and time for learning in addition to autonomy over the given content. Additionally, the context-aware capabilities of devices provide acquizition of information related to the learner or learning environment fostering personalized learning (Kearney et al., 2012). Similarly, augmented reality apps and customised interactions hold potential for learning, selecting, manipulating and applying information to individual needs and "pervasive learning environment" (Laine et al., 2009). Authenticity is described as the perceptions of learners about relations between their practices and the use value of them (Barab, Squire, and Dueber, 2000). Learning mobile includes integration of high degrees of task and process authenticity through engaging in rich and contextual tasks as well as real life practices (Kearney et al., 2012). In socio-cultural theory, collaboration is focused regarding interactions with more capable peers or adults during learning and scaffolding (Trudge, 1990). Through mobile learning, a high degree of collaboration is possible with high degree of connections to others and resources using a mobile device (Kearney et al., 2012).

2.3. STEM Education and Mobile Technology

Teaching technology is one of the concerns of STEM education reform. As Bybee indicates (2013), technology may be taught diffused in science, mathematics and engineering disciplines to provide solutions to real world problems (Bybee, 2013). To integrate STEM subjects and technology, teachers need to know foundations of each subject and the correct way when STEM and technology overlap during planning and applying STEM activities (Banks & Barlex, 2014). Teachers should follow and apply technological developments to be successful in their profession in 21st century.

According to the International Society for Technology in Education (ISTE) (2008), the teachers of todays connected global world should plan, build and evaluate learning activities to maintain student engagement, to continue professional development, to act as a model for students, working partner, and the society to meet the National Educational Technology Standards for Teachers (International Society for Technology in Education [ISTE], 2008).

Considering the affordances and extensive use of mobile technologies, it is significant for a STEM teacher to utilize mobile devices for any educational intention. Despite its varying definitions, mobile learning mostly refers to learning, mobile tools and their interrelation (Kearney et al., 2012). To be more specific, mobile learning is any kind of support or opportunity that provides technological information or subject content to support learning without time and space constraints (Lehner & Nosekabel, 2002). Indeed, it is learning of individuals or groups through explorations and conversations interactive technologies (Sharples et al., 2007).

The presence of mobile technologies in learning environments provides mastery in learning as suggests ubiquitous learning (learn anytime and anywhere), bringing together formal learning with informal learning, and followingly facilitating continuous development and experiencing its impact (Diaz, Moro, & Carrión, 2015). According to Low (2006), mobile tools support students while creating and comprehending their own knowledge, attaining information, working on learning stimuli, communicating with others through building functional relationships.

The abovementioned features and affordances of mobile devices constitute a significant potential for STEM education. Initially, considerable steps need to be taken for mobile learning instead of allowing mobile technologies affect the way people learn (Kukulska-Hulme, 2009). Thus, mobile technologies should be used by STEM teachers to broaden the opportunities provided by mobile applications in STEM learning experiences. This reveals the need for evaluation of mobile for valid and reliable rubrics to apply while deciding which mobile apps to integrate in STEM education.

STEM education that utilizes content of technology education has been applied in some pilot projects but curriculum plans for entire levels are limited (Becker & Kyungsuk 2011). According to the meta-analysis study of Becker and Kyungsuk (2011), among different project on integrative STEM education, the ones that include technology education integrated in all other STEM subjects showed the greatest effect size on student learning. The fact that technology education allows hands-on activities and helps students conceptualize knowledge and bring it into real world uses. Thus, it holds an immense potential to contribute STEM education reform. On the other hand, open-discussions are required to justify the reasons behind applying reforms or changes made in education coupled with professional development program and resource delivery. Furthermore, the positive effects of STEM education for both student learning and teaching practices should be presented with data collecting mechanisms (OECD, 2013). In the reverse case, the reforms would be made only for sake of change.

An exploratory case study was conducted to investigate teacher readiness for mobile learning on iPads in the STEM fields through a summer professional development based on cultivating and its results indicated that participants found iPads useful and effective for STEM education using related knowledge and skills in lesson planning, engaging student actively in learning activities and assessment (Hu & Garimella, 2014).

In another study, fifth grade students' interaction with nature with mobile technology was examined. The participants of the study were 55 students from two low-income schools. The results of this study showed that participants made use of mobile technology to discover nature and stay engaged. Students used the mobile devices to refer, collect data, and engage. The desire of the students to stay in nature and positive response toward interacting with nature were recorded in the study and mobile devices were stated to be useful tools to maintain student interest in Science (Boyce, Mishra, Halverson, & Thomas, 2014).

Reforms promoting STEM education should be planned carefully for the emergence of positive effects. The ones who work in technology education should take action with curriculum development and application sooner than the focus of the countries was directed to a different point than science, technology, engineering and mathematics education (Ritz & Fan, 2014).

2.4. Mobile App Evaluation

As a basis for technology evaluation in education, Meek (2006) conducted a study investigating computer and information technology evaluation and exploring the academics' evaluation practices adopting lifecycle approach that placed evaluation at the center from initial stages of development through the presentation of the teaching material using an Evaluation Lifecycle Toolkit. The study examined both academics using the Toolkit independently and evaluation consultant. The results of this study indicated that evaluation of computer and information technology is predominantly a summative process, academics developing these technologies should be aware of the evaluation methods used in software engineering and the area of usability and they should have access to evaluation techniques to make sure the technology developed meets usability standards (Meek, 2006).

Economides and Nicolaou (2008), conducted a study to investigate the status of mobile devices and their suitability for mobile learning. This study provided framework to evaluate mobile devices in in terms of mobile learning. Also, it evaluated present mobile devices based on the proposed evaluation criteria to identify the strengths and weaknesses of them and suggested technical features suitable for mobile learning. The framework suggested three main evaluation areas: usability, technical and functional. The mobile devices were analysed in terms of the details suggested by these evaluation areas.

Vavoula and Sharples (2009) developed a 3-level evaluation framework "M3" based on the lifecycle evaluation approach proposed by Meek (2006), to be used in educational technology evaluation (p. 7). According to this framework, evaluation takes places under three main levels: micro, meso and macro. Micro level evaluation deals with personal use of technological tools and measures the usability and utility. Meso level, on the other hand, deals with learning experiences as a whole to review learning progress and analysis. In macro level evaluation, the impact of the current educational technology on the present educational practices and institutions are examined (Vavoula & Sharples, 2009, p. 9).

Similarly, Walker (2011) developed an evaluation rubric called ERMA (Evaluation Rubric for IPod Apps) to construct a common method to assess educational mobile apps as a part of dissertation research. This rubric had five main domains: curriculum connections, authenticity, feedback, differentiation, user friendliness, and motivation. Walker conducted a further study to establish content validity for the rubric and declared that the validated rubric provided a system to evaluate educational mobile apps to identify those of the highest quality.

Based on the pedagogical perspectives suggested by the framework of Kearney et al. (2012) and mobile app evaluation rubric developed by Walker (2011), Green et al. (2014) designed a rubric called MASS to particularly examine mobile app selection for 5th through 12th grade science. This rubric had 6 main criteria: accuracy, relevance of content, sharing findings, feedbacks, scientific inquiry and practices, and navigation. Each criterion was asked to be assessed in terms of being applicable and to what extend met by any selected educational mobile app for science education.

Another evaluation framework was developed based on mobile science inquiry that had six main focuses of interest; three of them were about mobile application including technological usability, learners' perceptions and cognitive load; two of them were based on inquiry-based learning skills: learners' performance and inquiry and reasoning skills the other focuses were in terms of long-term effect of application-related and inquiry-based learning and reasoning skills at organizational context (Ahmed & Parsons, 2013,)

Also, a framework to assess context-aware mobile learning grounded upon meaningful learning was developed through literature review followed by expert assessment. In this framework, the main aim is realization of meaningful learning through mobile learning practices. Thus, meaningful learning key points that are active, authentic, constructive, cooperative and interactive learning and the characteristics of context aware mobile learning constituted the criteria for evaluation. (Huang & Chiu, 2015).

Baran et al. (2017) conducted a designed based study emphasizing pre-service teacher perceptions on educational mobile app evaluation and suggested another framework called PTC3 to be referred selecting educational mobile apps. The initial categories were determined based on the MASS rubric developed by Green et al. (2014). These categories were defined as contextuality, pedagogy, technical usability, content, and connectivity. Each category was enlarged on related sub categories (See Figure 4.)

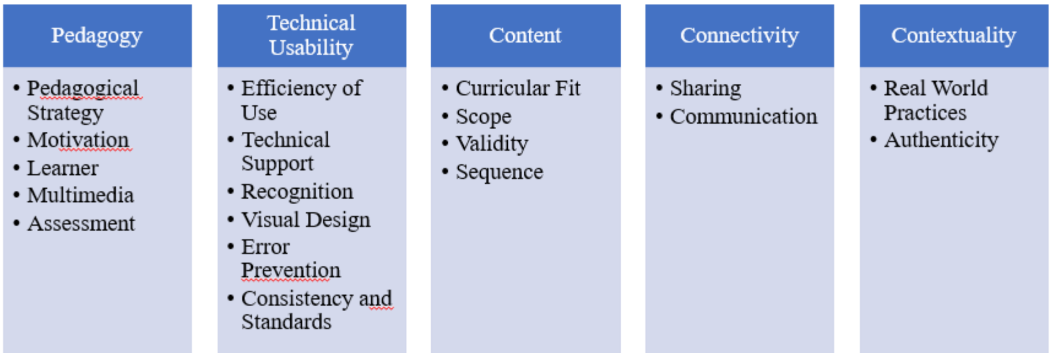

Figure 4. Figure 4. PTC3 Evaluation Framework Categories. Adopted from Baran et al. (2017, p. 2117—1131).

The evaluation criteria included sixteen items for pedagogy category, sixteen items for technical usability category, six items for content category, two items for connectivity and two items for contextuality. Items for pedagogy focused on pedagogical strategy, motivation, learner, multimedia and assessment.

Technical usability items were related to efficiency of use, technical support, recognition, visual design, error prevention, and consistency and standards features of the apps. For content, curricular fit, scope, validity and sequence were emphasized. Connectivity category focused on sharing and communication. Contextuality items were related to real world practices and authenticity of the selected educational mobile apps (Baran et al., 2017).

2.5. Summary of Literature Review

STEM education reform process is different from others in three ways: (a) targeting to deal with challenges of global economic concerns (b) focusing on the call for literacy in STEM disciplines to overcome the global technological and environmental issues and (c) centering upon the knowledge needed for occupational skills development in the 21st century (Bybee, 2013). STEM was firstly used by NSF combining science, technology, engineering and mathematics disciplines (Sanders, 2009). However, it is a result of evolving education since the launch of Sputnik in 1957 as it promoted focusing on science and technology education (Banks & Barlex, 2014). Definition of STEM education is varying as it is viewed from different perspectives but in general, it is described as an education approach focusing on interdisciplinarity and including teaching and learning processes of science, technology, engineering and mathematics disciplines (Gonzalez & Kuenzi, 2012).

Students that received STEM education are supposed to be successful at problem solving, innovation, invention, self-reliance, logical thinking, technological literacy, and relating cultural and historical background to their education (Morrison, 2006). The study findings that investigated the impacts of STEM education in K-12 students showed that (Barker & Ansorge, 2007; Sullivan, 2007; Apedoe et al., 2008; Rikowski et al., 2009; Olivarez, 2012; Cotabish et.al., 2013) STEM education positively affected student performance at related disciplines. A global awareness for STEM education is observed from the studies and practices. The USA, China, Russia, European countries took a sort of actions to promote countrywide STEM education.

In Turkey, there has not been a specific action plan for STEM education but related regulations are being implemented to support STEM education. A group of universities constructed STEM centers to provide learners and teachers with different training programs and projects and General Directorate of Innovation and Educational Technologies takes part in the Scientix Project as an initial contact point for STEM education (MoNE, 2017). Yet, further country-wide implementations are needed to extend teaching strategies, studies and practices for STEM education (MoNE, 2016).

One of the focuses of STEM education reform is effective technology education. As the capabilities of mobile technologies are considered, its informed integration into STEM context is significant. Mobile learning is generally defined uniting learning, mobile tools and their interceptions (Kearney et al., 2012). The Frame model of mobile learning includes device, learner and social aspects of mobile learning coupled with their interceptions (Koole, 2009). The pedagogy of mobile learning is explained under three main constructs of authenticity, collaboration and personalization in pedagogical framework for mobile learning (Kearney et al., 2012).

Mobile learning has promising contributions to teaching and learning (Kukulska-Hulme, 2009) but also mobile learning has potential to meet unique needs and demands of STEM education (Krishnamurthi & Richter, 2013). STEM education and mobile learning share similar pedagogies such as problem-based learning, authenticity, student-directed learning, collaborative learning. Utilization of mobile technologies in STEM context were studied in some pilot projects but curriculum plans for all levels are limited (Becker & Kyungsuk, 2011).

A group of researchers conducted studies to provide frameworks, and rubrics for mobile learning evaluation purposes (Ahmed & Parsons, 2013; Baran, Uygun, & Altan, 2017; Economides & Nikolaou, 2008; Green, Hechter, Tysinger, & Chassereau, 2014; Huang & Chiu, 2015; Vavoula & Sharples, 2009; Walker, 2013). Referred in this study, the PTC3 evaluation framework, developed by

Baran et al. (2017), for educational mobile apps has five main categories: pedagogy, technical usability, content, connectivity and contextuality.

CHAPTER 3

METHODOLOGY

This chapter includes the research design employed in the study, detailed information on context and participants, description of data collection instruments, procedures and data analysis, explanations on strategies to construct trustworthiness and finally background and role of the researcher.

3.1. Research Design

This study followed "multimethod QUAL" research design through interviews to investigate evaluation of mobile apps for STEM education from in-service teachers' perspective in-depth (Tashakkori & Teddlie, 2010). The abbreviation QUAL indicates that the study is qualitatively driven in which qualitative and quantitative data was collected at the same time (Byrne & Humble, 2007). Multimethod studies employ multiple methods considering complementary strengths and weaknesses of each regarding to a defined set of research questions. The questions of the study can be better addressed through the combination of quantitative and qualitative methods (Brewer & Hunter, 2006). In this study, qualitatively, structured interview questions and quantitatively evaluation form responses were analyzed. The combination of the results for perceptions of teachers in terms of mobile app use in STEM education and evaluation criteria suggestions, PTC3 framework criteria ratings, rankings and opinions of the in-service teachers were interpreted.

Multimethod research differs from the mixed method design in the way that it includes more than one method or data collection procedure under a common approach. In multimethod design, two or more research methods are employed and the results of both are triangulated to suggest a comprehensive whole (Morse, 2003). In this sense, through a qualitative approach, this multimethod study examined the evaluation criteria of in-service teachers on mobile app selection for STEM education. The primary concern of the study was to reveal in-service teachers' perceptions on mobile app evaluation for STEM education based on PTC3 evaluation framework (Baran et al., 2017). To holistically interpret teachers' mobile app selection criteria, perception of STEM education, description of mobile learning practices, and analysis of frequently used mobile apps were also investigated additionally for validation and refinement of PTC3 framework in STEM education context. Through interviews, both qualitative and quantitative data was utilized for in-depth investigation of mobile app evaluation for STEM education through in-service teachers' perspective.

3.2. Research Questions

The purpose of the study was to investigate evaluating mobile apps for STEM education through in-service teachers' perspective. The study focused on the following research question and related sub questions:

1. What are the perceptions of in-service teachers for mobile app use in STEM education?

    1.1. How do in-service teachers perceive STEM education?

    1.2. How do in-service teachers utilize mobile apps in STEM education?

2. Which criteria do in-service teachers consider while selecting mobile apps for STEM education?

    2.1. How do in-service teachers assess PTC3 Evaluation Criteria in terms of selecting mobile apps for STEM education?

    2.2. How do in service teachers assess mobile apps they frequently used based on the PTC3 framework criteria?

3.3. Context and Participants

In this study, snowball sampling was employed. Snowball sampling is a technique to find research participants, initially selecting a small number of respondents that match the criteria for inclusion in the study, and then they are asked to recommend others they know who also meet the selection criteria (Vogt, 1999). The inclusion criteria for the study is as follows:

- Working as a teacher in K-12 level,
- Attending at least one training about STEM education,
- Implementing at least one STEM activity as a teacher,
- Having experience in using educational mobile apps in STEM contexts,

Considering the inclusion criteria above, firstly, one science teacher and two ICT teachers that meet the criteria were included in the study as participants. Followingly, the other participants were reached through suggestions of the previous teachers and a combination of ten in service teachers were reached to be referred in the study.

The participants of the study included ten in-service K-12 teachers (3 male and 7 female) teaching elementary science (*n=4*), high school physics (*n=1*) and information and computer technology (*n=4*) subjects. The participants' ages ranged between 25 and 44. The teachers graduated from education faculty (5 bachelor and 5 master's degree) and they had teaching experience from 3 to 21 years. The participants of the study included teachers from both public (*n=5*) and private (*n=5*) schools from Kayseri (*n=1*), Urfa (*n=2*), Konya (*n=1*), Manisa (*n=1*), Ankara (*n=3*), Adana (*n=1*) and İstanbul (*n=1*). The teachers worked in schools located in village (*n=1*), county town (*n=2*) and city center (*n=7*). All the teachers indicated that they attended a STEM-related training, they applied at least one STEM activity and they used mobile apps in their lessons. Demographic information of the participants is summarized in Table 1.

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Table 1.

Demographic Information of the Participants

Participant	*Gender*	*Subject*	*Age*	*Teaching Experience*	*Graduation Degree*	*Current Workplace*
Adam	Male	Science	28	5	Master	Public School City Center/Kayseri
Beth	Female	Science	25	3	Master	Public School Village/Urfa
Cedric	Male	Science	34	13	Bachelor	Public School City Center/Konya
Dalton	Male	Science	32	5	Bachelor	Public School County Town/Manisa
Eda	Female	ICT	44	21	Bachelor	Private School City Center/Ankara
Farida	Female	ICT	30	5	Master	Private School City Center/Adana
Gabi	Female	ICT	30	6	Master	Private School City Center/Ankara
Hanna	Female	Science	28	5	Bachelor	Public School City Center/Urfa
Ilona	Female	Physics	44	19	Bachelor	Private School County Town/İstanbul
Jenny	Female	ICT	36	14	Master	Private School City Center/Ankara

The time spent using mobile tools or internet changes from approximately 1 hour to 8 hours per day for the teachers. The in-service teachers owned or used different technological devices such as laptop (*n=10*), tablet (*n=7*), smart phone (*n=10*) and smart watch (*n=1*). The participants generally used mobile devices for the purposes of communication, gaming, listening to music, searching, storing and sharing information in addition to educational purposes. The most commonly used mobile applications among the participants were Whastapp, Facebook, Instagram, Twitter and Google Apps (e.g., e-mail, drive,hangouts).

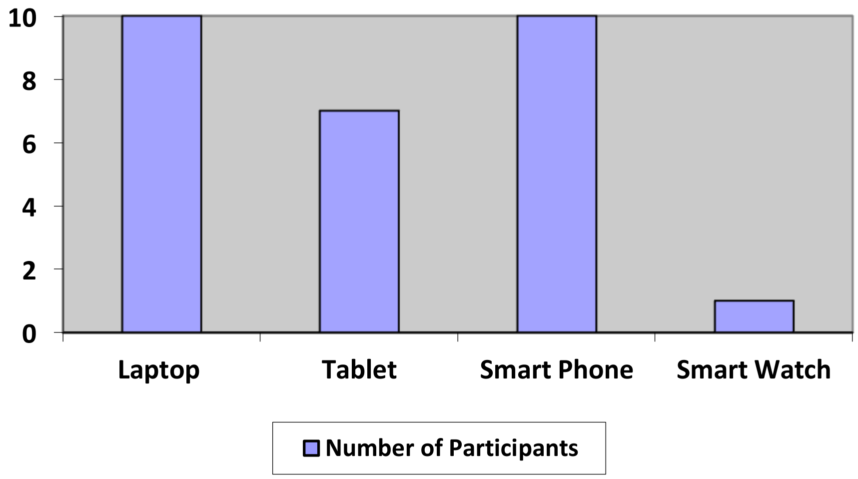

Figure 5. Technological Devices Participants Use

3.3.1. Participant 1: Adam

Adam is working at a public school in the city center of Kayseri as an elementary science teacher. He has five years of teaching experience and master's degree from education faculty. He has attended one-day theoretical STEM program organized by the STEM center in their city, he also attended one-week program in which STEM activity practices were presented. Adam practices STEM education through activities related to course content such as pressure in his lessons. He prepares semi-structured instruction sheets and allow students to complete it using their creativity. In his STEM activities, assessment is generally formative based on discussions. He exchanges ideas with technology and design teacher and ask for helping students in terms of visual design or technics in students' models developed within STEM activities. Adam integrates mobile apps using his individual mobile phone in the class. He states that he can reach mobile apps related to matter (chemistry), human body systems (biology), sound (physics) but he has difficulty to reach apps for assessment and planning. He stays informed about current educational mobile apps through social media, colleagues, friends and instructors from graduate course in university.

3.3.2. Participant 2: Beth

Beth is an elementary science teachers working at a public school in a village of Urfa. She has master's degree from education faculty. He has attended many training programs related to STEM education some of which are two-day training in a private school, four-day training in a STEM center, nine-day teacher training in a university, two-day training in another university. She practices STEM education through STEM activities she designs based on the course content. She only collaborates with the mathematics teacher conducting STEM activities since there is no technology teacher in her school. Beth explains how her school's principle supports STEM activities as he gives permission for any STEM activity in which students are asked to develop a model or a design product. She employs both formative and summative assessment in STEM activities. She generally integrates group discussions as a part of design process and asks exam questions from the STEM activities in the exam as summative assessment. She indicates that there is no computer lab in their school, neither the students; therefore, mobile phones are the only technological devices they used during STEM activities. Beth stresses the lack of apps related to chemistry and physics. She indicates that she learns about new mobile apps through social media, especially Facebook groups and people she meets in the teacher training programs.

3.3.3. Participant 3: Cedric

Cedric is working as an elementary science teacher at a public school in Konya. He has attended one-day teacher training program that is supported by Ministry of National Education. He practices STEM education integrating STEM activities in his science lessons. He does not collaborative any teachers in his school in terms of developing STEM activities. He presents STEM challenges to his students that could be achieved through design process with materials that can easily be found in school. He focuses on following design process based on a given problem. He states that there are apps for biology, chemistry, physics and astronomy disciplines and he does not have difficulty reaching apps to be used in science. Cedric uses his individual mobile devices in the classroom to integrate mobile app in his lessons. He checks foreign websites, forums and Facebook groups to keep up with the current mobile apps.

3.3.4. Participant 4: Dalton

Dalton is an elementary science teacher from Manisa and he is working at a public school in county town. He attended one-week teacher training program of a university related to problem-based STEM education. He practices STEM education as long term design processes that aim to find solutions to society problems with 7^{th} grade students. He collaborates with technology and design teacher both in planning and product development stages of the process, he also collaborates with cleaning personnel of the school during design process in case of a need. Dalton and his students use and develop mobile apps during their long-term design process. Dalton touches to the lack of an app covering all STEM disciplines. Dalton is informed about the current educational mobile apps through individual search, teacher training programs, sharing experiences with other teachers and Facebook groups.

3.3.5. Participant 5: Eda

Eda is an information and computer technology teacher working at a private school in city center of Ankara. She attended one-day teacher training program abut STEM education organized by educational specialist of her school. She conducts STEM activities in coordination with science lessons. In the STEM activities they conduct, students are given a real-life problem and asked to design a product to solve it following design process and initially defined criteria. In information and computer technology lessons, students make search, create draft models, prepare presentations, or develop 3D models for the product. She plans STEM activities with education specialists and science teachers, as well. Eda uses her mobile phone in the classroom while conducting STEM activities. According to Eda, there are sufficient number of apps for mathematics and English subjects while there are no apps for developing computer skills and integrating technology with other disciplines. She stays informed about the educational mobile apps using the Internet and social media.

3.3.6. Participant 6: Farida

Farida is an information and computer technology teacher that works in a private school at the city center of Adana. She attended two-day teacher training organized by a university, also different sessions in organizations related to STEM education and she individually made research to be informed. She integrates activity-based STEM education in her lessons. She plans activities based on the objectives of ICT lesson and science and mathematics. The activities are generally semester or year-long ones following planning, product development. Assessment is generally formative and through observations. Farida integrates mobile apps in the classroom in addition to computer-based tools. Farida states that she can easily find apps related to coding and she has difficulty finding interactive apps that provide feedback and also apps including basic computer skills. She stays informed about mobile apps by internet search, conference and congress as well as teacher trainings.

3.3.7. Participant 7: Gabi

Gabi is working as an information and computer technology teacher at a private school located in the center of Ankara. She has attended different seminars and congresses related to STEM education and follow STEM education developments through magazines, as well. In her school, STEM activities are integrated as a semester project that all students should complete and they take the first exam grade in terms of their performance in the activity. Furthermore, a school wide competition is made and volunteer students have chance to apply for this competition, assessing is conducted through different teachers of the disciplines integrated in the activity. In her school, there is a group of teachers to conduct STEM activities and each grade has a different theme for STEM projects. Not only integration of science, technology and mathematics but also integration with subjects such as music or arts are designed for the projects. Therefore, collaboration with teachers from other disciplines starts at the beginning of the semester by sharing lesson objectives for planning and continues through the project. Gabi generally uses mobile apps in computer as both the teacher and the students are provided with computers in her class. She has no difficulty finding any apps related to her subject. She is informed about the current mobile apps through the technology team in their school, weekly sharing with colleagues, blogs, Edmodo teacher groups, related foundations, Whatsapp groups, and symposiums.

3.3.8. Participant 8: Hanna

Hanna is an elementary science teacher working at a public school in the city center of Urfa for five years. She attended one-week STEM training organized by NASA in the USA, she also attended introduction to STEM education training for one week organized by the STEM and science center in Urfa, another training program she attended was project-based STEM education training given by the same center. She practices STEM education through activities based on designing a product for the problem and criteria defined before. The students are delivered activity sheets and asked to make calculations about the materials they used. After the products are developed, group discussions are made to evaluate students' works. In terms of collaboration with school personnel, she just shares and exchanges ideas with her colleagues. She generally uses apps through classroom computer or individual mobile phone. Hanna indicates that there are many apps for sharing, biology content, she can reach but there are only two mobile apps specific for STEM education. Also, she highlights Algodoo for physics and mathematics but adds that there should be more apps for physics and chemistry. Hanna uses Facebook primarily to stay informed about mobile apps, also teacher trainings, Internet search and social media is beneficial for her to learn about educational mobile apps.

3.3.9. Participant 9: Ilona

Ilona is working as a high school physics teacher in a private school in the county town of İstanbul. This is the 19^{th} year of her as a teacher. She has attended different half-day teacher training programs twice that were given by a university. She has also attended a conference as and STEM is her research area for graduate studies. She integrates STEM activities as a part of her physics lessons and for now, she has made no collaboration with other teachers or school personnel in her school in terms of conducting STEM education. She integrates mobile apps in the classroom through her individual mobile devices. According to Ilona, mobile apps that present content with simulations are easily reached but apps for all topics in physics discipline are rare need to increase in number. She is informed about the current mobile apps through searching.

3.3.10. Participant 10: Jenny

Jenny is an ICT teacher working in the city center of Ankara in a private school. She has a master's degree in educational studies and has a 14-year experience in teaching. She conducts long term STEM activities as a part of her lesson based on themes from science education. She takes engineering design process into consideration for the activities and communicates with her students through online platforms during the activities. She receives advice from science teachers while planning STEM activities. She also collaborates with technology experts for technical supports using the high-tech technologies provided in the school. She also collaborates with curriculum development specialists and measurement and assessment specialists in her school designing and developing STEM activities. Jenny develops mobile apps with her students in computer lab and they utilize mobile apps for research for survey development, data collection, etc. She stresses that there are many apps for language learning and sports disciplines while apps for information technologies and robotic coding are rare. Additionally, there are apps for each disciplines of STEM but no apps specifically developed for STEM education integrating disciplines.

3.4. Data Collection Instruments

In this study, data was collected through demographic information form, structured interview questions and evaluation form integrated in the interviews (See Appendix A). Interview content, based on the PTC3 evaluation framework criteria, and considering the aim of the study, were developed through literature survey, discussions conducted between the researcher and the thesis supervisor and recommendations provided by the experts. Thereafter, data collection instruments were piloted and put into the final form with the guidance of the supervisor. The structure of the interview and related instruments are summarized in Figure 6.

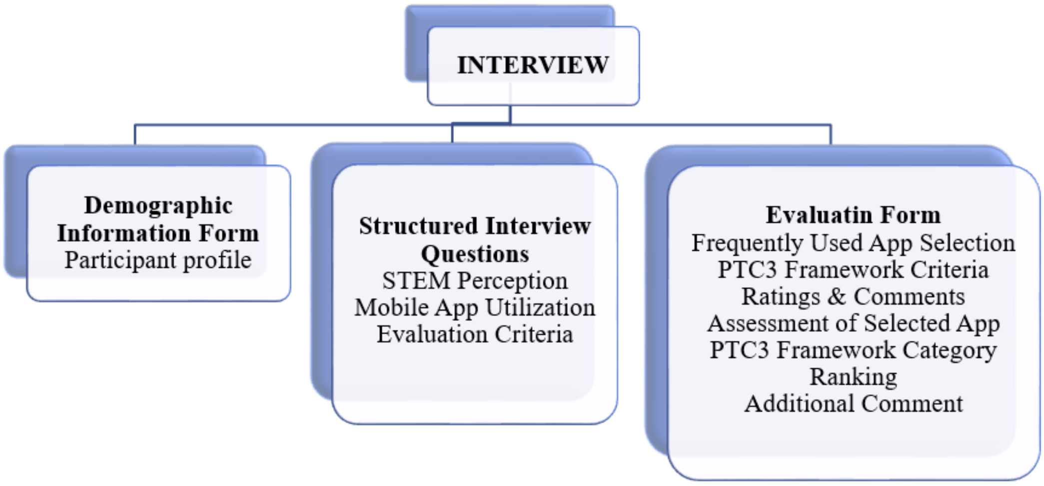

Figure 6. Summary of the Interview Content

3.4.1. Demographic Information Form

Demographic information form was included to provide information on the participant profile. Correspondingly, each participant was asked to fill in the form before starting the interview. Demographic information form included 12 questions in total. Questions related to teachers' gender, age, subject they taught, graduation degree, the city, site and type of the school they worked at, and their teaching experience in years. Also, questions seeking which technological tools the teachers used, for which purposes they used mobile devices, which apps they used frequently and how much time they spent using mobile devices were also asked in demographic information form (See Appendix A).

3.4.2. Structured Interview Questions

Twelve structured interview questions were included to provide information on the teachers' perceptions of mobile app use in STEM education. Indeed, six of the questions sought which training programs they attended related to STEM education (duration, organization and content of the training), how they practiced STEM education in their schools (collaboration with other teachers or school personnel, planning, implementing and assessment phases of STEM practices), which mobile apps they used in STEM context (for which purposes), to which apps they could easily reach and to which they could not and how they stayed informed about current mobile apps. Data gathered from these questions were explained in detail for each participant to draw a picture of the context of mobile app use in STEM practices they conducted. There were four questions seeking what were the STEM education definitions of teachers (characteristics, distinguishing features and essentials), what were their opinions how STEM education contributes to students, teachers, and society, how they utilized mobile apps for STEM context, what were their opinions on impacts of mobile app use in STEM education. Data gathered from these questions were referred to answer the first research question and related sub questions of the study. Also, two structured interview questions were included to reveal which criteria the teachers consider while selecting mobile apps for STEM education (See Appendix A).

3.4.3. Evaluation Form

Evaluation form was included to reveal how in-service teachers assessed the evaluation criteria suggested in PTC3 framework and how they assessed specific apps based on the evaluation criteria. Before starting with the evaluation form, each teacher was asked to select a mobile app they frequently used. The evaluation form had three parts for each of 49 PTC3 evaluation framework criterion; firstly, the teachers were asked to read the criterion, indicate whether the selected app met the criterion, rate to what extent the criteria would be important while selecting apps for STEM education, and made comments or give opinions related to criteria if any. At the end of the evaluation form, the teachers were also asked to rank PTC3 evaluation categories (pedagogy, technical usability, content, connectivity and contextuality) in terms of importance for selecting mobile apps for STEM education. Data gathered from the evaluation form was referred to answer the second research question and related sub questions in the study. At the end of the interview, participants were also asked to indicate if they had further explanation or comment related to the interview. Information on data distribution for each research question is given in Table 2.

Table 2.

Data Distribution for Research Questions

Research Question	Data Type	Data Source
1. What are the perceptions of in-service teachers for mobile app use in STEM education?	Qualitative	Interviews
1.1. How do in-service teachers perceive STEM education?	Qualitative	Interviews
1.2. How do in-service teachers utilize mobile apps in STEM education?	Qualitative	Interviews
2. Which criteria do in-service teachers consider while selecting mobile apps for STEM education?	Qualitative	Interviews
2.1. How do in-service teachers assess PTC3 Evaluation Criteria in terms of selecting mobile apps for STEM education?	Quantitative & Qualitative	Evaluation Form & Interviews
2.2. How do in service teachers assess mobile apps they frequently used based on the PTC3 framework criteria?	Quantitative	Evaluation Form

3.5. Data Collection Procedures

Data collection process of the study included translating PTC3 Framework criteria into Turkish from English, development of data gathering instruments, expert review, pilot study, contacting the participants and conducting interviews.

Table 3.

Data Collection Timeline

Date	Scope
09.02.2017	Ethics Committee Approval
25.01.2017 – 07.02.2017	Expert Opinion
15.02.2017	Pilot Study
06.03.2017 – 28.03.2017	Interviews

3.5.1. Before Implementation

Through the instrument of in-depth literature survey and discussions conducted between the researcher and thesis supervisor, the initial version of structured interview questions and evaluation form were prepared and interview structure was set up. The initial version of the interview coupled with application including the summary of the study and consent forms were submitted to Human Subject Ethics Committee of the university to ascertain that the study followed the related ethical concerns. As the approval of the study was provided (See Appendix C), expert opinion was received and pilot study was conducted before the implementation.

3.5.1.1. Expert Opinion

In this study, 14 experts from different occupations and expertise areas were consulted before the pilot study. Expert opinion process had two main phases: language check and interview revision. After the PTC3 Framework criteria was translated into Turkish from English, two language experts were asked to review the framework. One of the experts was an English language instructor in a private university and asked to review the criteria in both language and correct if any mistranslation or semantic change existed. The other expert was a research assistant at computer and information technology education department at a university and asked to review if the technological terms included in the criteria was translated to Turkish correctly. As the translation corrections proposed by the experts were made, the interview was sent to other educational specialists stating the purpose and a summary of the study and their opinions for interview questions' accuracy, completeness, clarity and relevance were asked.

Expert 1, a professor at Informatics department of a public university, suggested providing the purpose of the interview in a detailed way, including STEM-specific interview questions for mobile app evaluation, asking questions related to instruction and assessment processes of STEM education practices. Also, dividing the evaluation criterions that has multiple concerns. Expert 2, an associated professor at Computer Education and Instructional Technologies department of a public university, suggested that interview questions should have been given details in terms mobile apps used. Expert 3, an assistant professor at Elementary Science Education department at a public university, advised that evaluation criterions that has multiple concerns should be divided into separate items and criterions that included complex sentences should be simplified. Expert 4, a research assistant at Educational Science department of a public university, advised that interview form should have been divided into three main parts: demographic information form, interview questions and evaluation form, purpose of the study should have been detailed, structured probe questions should have been added to the interview questions, and asking the evaluation criteria of the teachers before implementing evaluation form. Expert 5, a research assistant at Computer Education and Instructional Technology department at a public university, suggested appropriate words for the technical terms in evaluation criteria. Expert 6, reviewed Turkish and English versions of the interview in terms of correct translation and she suggested slight changes in the items to preserve the meaning of the evaluation. Expert 7, 8, 9, 10, and 11, working as curriculum development specialists in a private school, suggested division of the evaluation criteria items that had multiple dimensions, additional interview questions to reveal context that teachers worked in, clarifying criteria items without changing the meaning. Experts 12 and 13, working as measurement and assessment specialists at a private school, suggested division of the items that included more than one dimensions and clarifying the sentences for teachers to better comprehend. Finally, Expert 14, one of the authors of the study that suggested the PTC3 Framework was consulted to examine definitive version of the interview and receive peer feedback for the current version of PTC3 framework. All the recommendations from the experts were examined and combined by the researcher and the interview was updated. The original version of the PTC3 framework included 16 criterions for pedagogy criteria, 16 for technical usability, 6 content, 2 connectivity and 2 contextuality criteria. Dividing the items that included multiple dimensions into different items, final version of the evaluation framework included 20 items for pedagogy, 18 items for technical usability, 7 items for content, 2 items for connectivity and 2 items for contextuality.

Table 4.

Summary of Expert Recommendations and Related Changes

Expert/s	Suggestion	Change
1	• Explain purpose clearly • Add STEM-specific interview questions • Include questions for instruction and assessment • Divide multiple dimensional items	• The purpose clearly explained • Questions for STEM education definition and practices were added • Related items were separated
2	• Detail interview questions for mobile app use	• Questions for mobile app use, impact and access were included
3	• Divide multiple dimensional items • Simplify item sentences	• Related items were separated • Related sentences were simplified
3	• Divide multiple dimensional items • Simplify item sentences	• Related items were separated • Related sentences were simplified
4	• Divide interview form into three parts • Detail purpose of the study • Include probe questions • Ask evaluation criteria before evaluation form	• The current structure of the interview form was designed • The purpose clearly explained • Structured interview questions were added for evaluation criteria
5	• Correct technical terms	• Related corrections were made
6	• Correct mistranslations	• Related corrections were made
7, 8 ,9, 10, & 11	• Divide multiple dimensional items • Ask about STEM context	• Related items were separated • Questions for STEM practice context were added

Table 4 (continued)

Expert/s	Suggestion	Change
12 & 13	• Divide multiple dimensional items • Clarify item sentences	• Related items were separated • Related items were clarified
14	• Correct mistranslation	• Mistranslations were corrected

3.5.1.1. Pilot Study

Pilot study was conducted to refine the interview with two participants. One of the participants was a research assistant at a university and had a background in STEM education. The other participant was an ICT teacher working at a private school in the city center of Ankara, Turkey, who had a STEM teacher certificate and experienced in STEM education as well as mobile learning.

Before conducting the interview, both participants were contacted to inform about the details of the study, a copy of the interview form was sent to them allowing to review the questions. Both interviews were conducted face to face; noted down and recorded by the researchers. Analyzing the data gathered from the pilot study, the questions were examined in terms of clarity (The participants understood the questions in the same way with the researcher), repetition (There were no repeating questions directing to the same response), efficiency (The questions were efficient to unveil the target phenomena with intended perspectives). Followingly, appropriate corrections were made editing problematic questions, unifying questions with the same meaning and deleting irrelevant questions. In this way, the definite version of the interview was ready to be used with the target participants of the study.

3.5.2. Implementation

Implementation process included announcement, contacting participants, phone talk, e-mailing interview form and conducting the interview. Target teachers were informed about the study through Facebook group posts, face-to-face communication, e-mail, phone calls or with the suggestion of the previous participant. As the teachers accepted to take part in the study, they were initially asked about their STEM and educational mobile app experiences to ensure they met the inclusion criteria of the study. If so, the cover page of the interview and teacher copy of the interview questions were shared with the participants including the purpose and summary of the study. If they examined the related documents and were willing to join the interview, appointments were made to conduct the interview through the communication channel they preferred. Eight of the interviews were conducted through video calls and they preferred to make the video calls when they were at home that would be a comfortable and silent place for them. Two face to face interviews, on the other hand, were preferred to be conducted in office room of the teachers in their schools for the same reasons.

Figure 7. Data Collection Process

Eight of the interviews were conducted through video interviews and two of them were conducted face to face. All the interviews were recorded with the permission of the participants and their responses were noted down by the researcher. For each interview, participants were supplied with the copy of interview questions and PTC3 framework criteria list to allow interviewees stay focused on the questions and prevent confusion during the process. The interview durations changed from 26.02 minutes to 58.45 minutes. As can be seen from Table 5, face-to-face interviews took less time than the video interviews.

Table 5.

Information on Interview Settings

Interview Number	Participant	Date	Duration (minutes)	Technique
1	Adam	06.03.2017	49.54	Video call
2	Beth	07.03.2017	43.03	Video call
3	Cedric	08.03.2017	48.19	Video call
4	Dalton	08.03.2017	58.45	Video call
5	Eda	09.03.2017	26.02	Face to face
6	Farida	13.03.2017	37.53	Video call
7	Gabi	15.03.2017	46.23	Video call
8	Hanna	26.03.2017	39.33	Video call
9	Ilona	26.03.2017	42.47	Video call
10	Jenny	28.03.2017	29.27	Face to face

3.6. Data Analysis

In this study, mobile app evaluation criteria of in service teachers for STEM education was examined including both qualitative and quantitative data gathered through structured interview questions and evaluation form. Qualitative data was collected and analyzed to reveal STEM perception and mobile app utilization of in-service teachers. Also, data from mobile app selection criteria of the participants and PTC3 framework assessment were parts of qualitative data. Quantitative data, on the other hand, included numeric data retrieved from assessment of PTC3 framework in addition to assessment of the selected mobile apps.

To analyze qualitative data gathered through the interviews, firstly, voice records of the interview were re-listened, transcribed and interview notes were refined and given details accordingly to be prepared for coding phase. Additionally, to facilitate the coding process, a first order analysis was conducted generating memorable codes for each different point addressed within the questions. According to Punch (2009), first order analysis is significant to summarize data by generating initial codes on the way to higher levels analysis. In this sense, the first order analysis provided the researcher with a holistic view of the case before the coding phase. At the end of the first order analysis, two categories emerged for perceiving mobile apps use for STEM education: STEM perception and mobile app utilization, and five categories previously defined in PTC3 framework for mobile app selection criteria: pedagogy, technical usability, content, connectivity, and contextuality.

After all the data related to the generated categories were designated and examined through constant comparison that allow for checking and comparing of each item with the rest of the data to create analytical categories (Pope, Ziebland, & Mays, 2000). For further analysis, all the responses of the participants for the interview was imported to MAXQDA qualitative data analysis software. The utilization of a qualitative data analysis tool allowed for easily storing, organizing and analyzing data. This process provided a database for the study that could be reached easily and demonstrated data as a whole enhancing the trustworthiness of the study (Baxter & Jack, 2008).

Further analysis of the categories revealed sub categories for each theme. For STEM perception; definition of STEM education, contributions of STEM on students, teachers and society. For mobile app utilization in STEM context, mobile app use and affordances were generated. For affordances, the sub categories of authenticity, personalization and collaboration were determined based on the study that emphasized the pedagogical perspectives of mobile learning (Kearney, Schuck, Burden, & Aubusson, 2012). For mobile app selection criteria of STEM teachers, PTC3 framework domains were primarily included as sub categories coupled with the other category. The themes, categories and sub categories generated after data analysis are summarized in Table 6.

Table 6.

Main Themes Emerged from the Analysis

Themes
A. Perceptions: Mobile Apps in STEM
1. STEM Education
1.1. Definition
1.2. Contribution
1.2.1. For Students
1.2.2. For Teachers
1.2.3 For Society
2. Mobile App Utilization
2.1. Mobile App Use in STEM Context
2.2. Affordances of Mobile Apps
B. Mobile App Evaluation Criteria
1. Pedagogy
2. Technical Usability
3. Content
4. Connectivity
5. Contextually
6. Other

In addition to the data analysis of qualitative data, quantitative data gathered from the evaluation form was also included into analysis process to obtain results as a whole. In-service teachers' ranking of the PTC3 framework categories in terms of importance for mobile app selection in STEM context, ratings for each evaluation criterion, and assessment of currently used mobile apps were revealed through quantitative data analysis. Quantitative data gathered in the study was imported, organized and analyzed through Microsoft Excel.

Descriptive statistics such as frequency, percentage and mean value were reached after the data analysis feature of the program was applied to the relevant data.

3.7. Trustworthiness

Trustworthiness is the set of procedures followed to validate study findings. Indeed, it is employing different strategies to strengthen accuracy or credibility of the findings (Creswell, 2012). Guba (1981) suggested four main constructs to ensure the trustworthiness of the qualitative studies: credibility, transferability, dependability, and confirmability.

Credibility stands for the extent to that the qualitative study is congruent with reality (Merriam, 1985). To promote credibility in this study, provisions such as triangulation, honesty for participants, background of the researcher, thick description of the phenomenon were employed. For triangulation, to investigate the research phenomena in depth, both qualitative data from interview questions and quantitative data from evaluation form were collected and examined (Baxter & Jack, 2008). As Patton (2005) indicates, being the main instrument for data collection and analysis, credibility of the researcher has great significance in qualitative studies. For this reason, the background of the researcher, including experiences as a teacher and curriculum developer, special study areas, and related qualifications were presented in the study. Honesty for the participants means giving them right to refuse contributing the study to ensure data is collected by the ones who are willing and prepared to offer data freely. In this sense, teachers were informed about the purpose of the study, approximate duration and content of the interview before conducting interviews. Also, they were given opportunity to stop or give up the interview in case they would like to. Another strategy to promote credibility in the study was thick description meaning that the studies in related study area were explained in detail to help comprehending the study within its context more easily (Shenton, 2004).

Transferability measures to what extent the findings emerged from the study is possible to be applied in other studies (Merriam, 1985). To construct transferability, this study included information on the number and profile of the participants in detail, highlighted the inclusion criteria to present the restrictions of the participants, data collections methods, number and duration of the interviews, the time period within that data was collected as suggested by Shenton in 2004.

Dependability questions whether comparable results would be generated applying the same study through the same methods and participants (Merriam, 1985). To conduct dependability in the study, the research processes of the study should thoroughly be reported to allow the other researchers design the study again in the same way again, including the research design and its implementations, detailed description of data gathering and reflections on the study (Shenton, 2004). For this reason, this study provided extensive information on the research process, implementation, data gathering instruments and data gathering process adding related tables and figures for clarification.

Confirmability stands for the objectivity of the researcher in qualitative studies (Shenton, 2004). Miles and Huberman (1994), stress that confirmability is mostly related to the researchers' declaring his or her individual predispositions (Miles & Huberman,). As Shenton indicates detailed description of methodology is to allow the readers measure whether the data and the procedures generated the data overlap (Shenton, 2004). As mentioned before, methodology was thoroughly explained including data collection instruments and procedures, timeline of the study, participants and other contributors of the study such as experts and pilot study participants.

All in all, this study employed various strategies: triangulation, honesty for participants, background of the researcher and thick description for credibility; information on context and participants, data collection methods, interview numbers and durations, and data collection period for transferability; thorough description of the research process for dependability; and detailed report on methodology for confirmability in order to construct trustworthiness.

3.8. The Role of the Researcher

I am a graduate student at Curriculum and Instruction Program in the department of Educational Sciences. I was graduated from Elementary Science Education department. I worked as a science teacher for three years and I have been working as a curriculum development specialist more than one year. My special interest in educational technology started when I was working as a science teacher, after receiving a teacher training about technology integration into classroom settings; observing, as a teacher, how positively students' attitudes and performance were affected when technological applications took part in the science classroom. As a part of my current job, I contribute to preparing information and computer technologies lessons utilizing technologies such as augmented reality, 3D modelling, coding, etc. In addition, I also take part in designing STEM activities in primary school science and ICT lessons. We use mobile technologies in STEM activities for measurement, content presentation, assessment, simulation and augmented reality presentation. In brief, I have experience in implementing different technologies in classroom setting as a science teacher and in collaborating with in-service teachers to develop STEM activities and integrate mobile technologies.

Throughout the study, I took the interviewer role putting emphasis on conducting the interviews without intervening with the teachers. Based on my studies as a graduate student, experiences as a science teacher and curriculum development specialist, I attach importance to establishing rapport with the participants. For this reason, before conducting the interviews, I made phone calls with the teachers to present myself, summarizing the aim of the study and processes to be followed for interviews. This helped teachers feel comfortable with attending the study. Also, I provided the teachers with the information on approximate duration of the interviews, terms of confidentiality, content of the interview and contact information, adding that they could ask me about any doubts they have and they had the choice to stop or give up the interview. The interviews were conducted according to the preferences of the teachers in terms of communication channel and time. During the interviews, I was attentive to be clear explaining the procedures in the interview and gentle using my tone of voice, body language and gestures. I noted down the responses of the teachers and also took voice records with the permission of them. I also declared my appreciation for them contributing to my study.

CHAPTER 4

RESULTS

The purpose of the study was to investigate in-service teachers' perceptions on evaluating mobile apps for STEM education. The study focused on the following research question and relevant sub questions:

1. What are the perceptions of in-service teachers for mobile app use in STEM education?

1.1. How do in-service teachers perceive STEM education?

1.2. How do in-service teachers utilize mobile apps in STEM education?

2. Which criteria do in-service teachers consider while selecting mobile apps for STEM education?

2.1. How do in-service teachers assess PTC3 Evaluation Criteria in terms of selecting mobile apps for STEM education?

2.2. How do in service teachers assess mobile apps they frequently used based on the PTC3 framework criteria?

This chapter includes the results gathered from both qualitative and quantitative data.

4.1. What are the perceptions of in-service teachers for mobile app use in STEM education?

Perceptions of the participants on mobile app use in STEM education was examined under two main domains: how in-service teachers perceived STEM education and how they utilized mobile apps in STEM education.

4.1.1. How do in-service teachers perceive STEM education?

To examine how in-service teachers, perceive STEM education, they were asked to define STEM education including its distinguishing features and essentials. Also, they were asked to explain the contributions of STEM education on students, on teachers and on society.

4.1.1.1. STEM Definition

The participants of the study were asked to define STEM education considering its essentials and distinguishing features. The results indicated that almost all the teachers emphasized interdisciplinarity in STEM education (*n=9*). Farida stated that interdisciplinarity was not only for students but also for teachers, they needed to integrate different their disciplines into STEM practices. Similarly, Cedric, a science teacher, discussed that some teachers did science experiments called it as a STEM activity, however, to do so, teachers had to include all the STEM disciplines. Within this regard, Adam, an elementary science teachers working in a public school, indicated:

> STEM education provides individuals with the opportunity to use their content knowledge in science, mathematics, engineering and technology together. In STEM education, the disciplines are not classified as different from each other but parts of a whole. I think of an area that combines and associates integrals for STEM education.

Followingly, most of the teachers included product development (*n=7*) while defining STEM education. Eda, a private school ICT teacher, taught that STEM education made difference with its including material development. Hanna, a science teacher in a public school, said that students should design every part of their products; teachers could give theoretical information at the beginning (of the STEM activity) but then students had to be allowed to plan and develop each part of their products considering the cost and materials, they needed to be given opportunity to develop creativity.

Active learning, literacy in STEM disciplines and collaboration were touched in half (*n=5*) of the definitions. As an ICT teacher in a private school, Jenny said, STEM education required application-based practices; it was learning by doing, experiencing and applying. Similarly, Dalton, an elementary science teacher, stated that STEM education included project-based education, indeed, it was the evolved version of project-based learning. The high school physics teacher Ilona taught that STEM education created difference with teamwork and collaboration. In addition, Adam said:

> To combine and associate distinct parts, it is significant to have enough knowledge for each area (of science, technology, engineering and mathematics). STEM education makes difference translating knowledge to practice.

Design process was declared to be a part of STEM education by almost half of the participants (*n=4*). Surprisingly, a small number of teachers (*n=3*), highlighted problem solving, real-world connections and inquiry. According to Dalton, STEM was an education model required a real-life problem, being aware of the problem, finding solutions to that problem considering the needs of the society through engineering design process. Cedric also indicated that different disciplines were combined with the aim of finding solutions to previously defined problems.

Significantly, two of the participants included art into their STEM definition. According to Cedric, STEM included the four disciplines in addition to engineering and art design processes. Similarly, Gabi indicated:

> In product developed through STEM education, I need to see knowledge from science, mathematics and technology, also art, as well. STEM has turned into STEAM recently, and art is also accepted to be one of the disciplines.

Defining STEM education, with a descending order teachers emphasized the integration of interdisciplinary approach, students' developing products, active participation, developing literacy in STEM subjects, collaborative work, design process, problem solving, real-world connections, inquiry and art.

4.1.1.2 STEM Contributions

The teachers were asked to explain how STEM education contributed to the students, teachers and society.

4.1.1.2.1. Contributions on Students

Contributions of STEM education on students were examined under four categories: academic success, positive attitude, skill development and motivation. Science teacher Adam summarized contributions of STEM education for students as follows:

> The most boring environment for students is where they are passive and listening to the teacher. STEM education provides students active

participation and this positively affects students' motivation, positive attitude against the lesson as well as academic success.

As the responses were examined; skill development was the frequently mentioned impact on students (*n=6*). Hanna, an elementary science teacher from a public school in Urfa, said that, STEM education is design based, this allows students' creativity, manipulative skills, motor skills, engineering skills as well as computer skills develop. An ICT teacher from Adana, Farida declared that STEM education helped students develop the ability of using knowledge for multiple areas. Similarly, according to Cedric, students developed skills of problem solving facing new real-life problems, they also developed engineering skills.

In addition, positive attitude against STEM disciplines and academic success were highlighted with a frequency *n=3*. Gabi, ICT teacher from a private school said:

> Primarily, STEM education overcomes the standard bias about science. It is not delivering information asking students to learn and do what is asked based on a workbook but it focuses on students' creativity.

In coincide, elementary science teacher from a village school in Urfa, Beth highlighted:

> The most critical point is that our school took first place in TEOG (Passing from primary to secondary education) examination. I view this as the most important development.

Motivation among students was told to increase with the effect of STEM education by two of the participants. Beth, village science teacher, reported:

> I had students who were absent in the school, coming to the school one day and not coming for the next day. I realized that students attended only science classes, they were absent for the morning, present in my lesson and absent again.

Teachers reported STEM education contribution on students in terms of academic success in STEM disciplines, positive attitude against the courses, skill development such as problem solving, inquiry, engineering and motivation for participating in the lessons.

4.1.1.2.2 Contributions on Teachers

Positive impacts of STEM education on teachers were grouped in two main categories: job satisfaction and professional development. Seven teachers told that carrying out STEM activities promoted their professional development as a teacher. According to Farida, STEM education promoted collaboration among teachers from different disciplines and this increased awareness of the teachers related to issues about other disciplines. Similarly, Jenny thought that coming together with other teachers and sharing information helped her refresh and update herself as a teacher. Furthermore, four of the teachers told that their job satisfaction increased after starting STEM activities. Hanna, ICT teacher from a public school indicated:

> I can observe that knowledge I delivered does not result in incomprehension, and through STEM education, I can successfully assess theoretical knowledge, as well.

Additionally, Adam stated:

> If STEM education is integrated, lessons will be more entertaining and constructive and accordingly the teachers will feel that his/her job is valuable. The teachers will enjoy lessons as they realize their content knowledge is not cognitive load but it can be used in daily life.

Teachers highlighted job satisfaction observing the comprehension of students, having more entertaining lessons and professional development collaborating with other teachers, being aware of different disciplines as the positive impacts of STEM education on teachers.

4.1.1.2.3. Contributions on the Society

How STEM contributed to society was examined under four categories: individual profile needed, development, society problems and economy. Most frequently highlighted impact of STEM education on society was development. Additionally, three of the teachers viewed STEM education as a good opportunity to raise individual profile needed in the future. Two of teachers focus on contribution to economy and two of them emphasized that STEM education would help generating solutions to society problems. Adam said:

> Looking at the countries that practice STEM education, they are the economically developed ones, this serves as a model, if they invest in million dollar projects, they have an aim for that. With STEM education, we can have qualified labor force, develop in technology and compete with other. We can be a country that does not import but export technology.

Remarkably, Jenny, ICT teacher from a private school commented:

For society, it is significant that STEM is based on practice. Today, most of the individuals, even receiving quality education, have difficulty in work practice. In this sense, STEM model, supporting practice of knowledge will contribute to society.

Teachers highlighted raising individual profile needed for the future of the country, developing as a country, finding solutions to society problems and enhancing economy as the contributions of STEM education on society.

4.1.2. How do in-service teachers utilize mobile apps in STEM education?

For mobile app utilization, the teachers were asked to describe how integrated mobile apps into STEM education and which affordances they thought mobile apps had within STEM context.

4.1.2.1 Mobile App Use

Teachers were asked to explain what kind of mobile apps and for which purposes (communication, interaction, content presentation, sharing, collaboration, etc.) they used while teaching STEM disciplines. Adam told that he generally used apps such as Plickers and Kahoot for assessment, he also used apps such as Anatomy 4D and Elements 4D for content presentation considering their augmented reality feature. Similarly, Beth mentioned using Anatomy 4D, Elements 4D, and Quiver for content presentation. She also prepared content in Animoto, Powtoon, Algoodo and demonstrated these animations for taking attention of the students. Beth added that she also used different apps for assessment. Cedric told that he generally used apps for content presentation. Dalton told that they used App Inventor to develop their own apps with his students, they also used Google Science Journal for measurements during STEM projects. Eda indicated that, she generally used apps for content presentation to present students the image of science concepts that is not possible to observe such as solar system or human body. As Farida indicated, they generally used apps such as Scracth and Arduino with the aim of product development with her students. She also added she utilized mobile apps for sharing and communication. Gabi indicated that she used mobile app Edmodo for tracking students' progress, receiving student projects, feedback and communication. She applied Kahoot for pre-test and post-test before or after a new subject. Also, she used Edpuzzle for sharing information and Classdojo for behavioral assessment. Gabi also used apps for gamification and motivation. Hanna told that she used Quiver to demonstrate augmented reality image of student paintings. Ilona indicated that she used Phet Colorado simulations for content presentation. As Jenny said, she actively used Google Drive with her students for tracking students, communication and sharing, she also used App Inventor to allow students to develop their own mobile apps.

As the teachers indicated, they used mobile apps such as Kahoot (pre-test and post-test, quiz), Plickers (quiz), Classdojo (Behavioral assessment), Google Drive (collect student evidence), Google Classroom (track students) for assessment. They used apps such as Anatomy 4D, Elements 4D, Quiver, Edpuzzle, Phet Colorado to present information. Furthermore, Google Science Journal App was mentioned to be used for scientific measurements during STEM activities. For students to develop content or educational product, teachers preferred apps such as App Inventor, Scratch and Arduino.

4.1.2.2. Affordances of Mobile App Use

Participants were asked to explain affordances of mobile apps for STEM education. The affordances of mobile apps were examined under three main categories: authenticity, personalization and collaboration as suggested by the framework for pedagogy of mobile learning (Kearney et al., 2011). Half of the participants (*n=5*) focused on authenticity highlighting mobile apps could help students concretize abstract content or observe real-like concepts such as human body, elements, etc. and increased motivation and interest against the lesson. Similarly, collaboration was emphasized by five of the participants indicating mobile apps could enable students to interact with other students or teachers and promoted group work. It was also told to help teachers and students communicate, share and stay connected more easily. Almost all the teachers (*n=8*) agreed that mobile app integration into STEM activities could promote personalization that meant students could reach content with ease, they could perform autonomous learning making research, calculations or measurements during STEM activities and they could continue learning without time or place constrictions spending less time. As Beth indicated

> To illustrate with an activity; I explained the atom model to my students, I gave them some materials and asked them to construct an atom model. They tried but generally could not make a model because they had difficulty to show electron spin. Then, I showed elements using Elements 4D app to the kids. The kids went back to their models and managed to show electron spin in their models. Without this mobile application, they would not have comprehended the electron spin of elements.

Dalton explained role of mobile apps in STEM context as:

> There are some STEM activities that can be run with some pipets, recycled glasses, silicon gun or rubber band while there are some requiring technology utilization. When technology support is required mobile phones are helpful as they are always with us.

Allowing students to concretize abstract content or observe real-like concepts, increasing motivation and interest, interacting with other students or teachers, communicating, sharing and staying connected, reaching content, performing autonomous learning free of time or place, spending less time were the impacts of mobile apps reported by the in-service teachers.

4.2. Which criteria do in-service teachers consider while selecting mobile apps for STEM education?

Teachers were asked to give information about which criteria they considered while selecting mobile apps for STEM education. The responses were categorized under six categories, five categories were retrieved from PTC3 framework and one more category was included to reveal whether the teachers referred to further criteria that could not be placed in pedagogy, technical usability, content, connectivity, contextuality. As results indicated, teachers most frequently referred to criteria related to pedagogy (*n=27*) and technical usability (*n=17*) followed by content (*n=7*) and connectivity (*n=5*) while merely one of the participants referred to contextuality category criteria to evaluate mobile apps for STEM education. Besides, other criteria teachers proposed had a frequency of *n=37*.

For pedagogy, teachers mostly focused on the criterion that was about whether the app supported learning providing appropriate teaching methods and techniques. Teachers also emphasized criterion that stated if the app guided learners providing appropriate pedagogical instructions. The criterion that considered app's content being aligned with learners' cognitive level was focused by three of the participants. The criterions considering the apps' content stimulating learner interest, the app's providing appropriate multimedia design features with multiple content representations, and the app's providing new representations of course content was mentioned by two of the participants each. Finally, criterions: the app's presenting an entertaining learning environment and the app's presenting forms of intrinsic rewards the app's presenting forms of extrinsic rewards, the app's targeting meeting learners' needs, the app's reporting learning progress were mentioned by only one of the in-service teachers each. Adam declared:

> To integrate a mobile app into an activity, I consider whether the app is useful and beneficial for the activity, it is time saving, facilitating my work, supports group work of the students. For STEM context, I would again consider usefulness primarily, then I would consider if I the app is actively used for STEM activities, if it is really needed, it can be used by everyone that is not so difficult and complex.

Dalton suggested:

> A mobile app's essential is fitting for purpose. In addition, working offline is important because when we asked the students to bring their mobile devices, school's internet deny access to most of content.

For technical usability, a considerable number of the teachers suggested criterion related to app's providing a simple interface design without confusing or distracting elements. Followingly, the app's being compatible with different systems were mentioned by three of the teachers. Each criterion of the app's providing an interface in learners' native language and the app's including a help option easily accessed whenever needed were highlighted by two of the teachers. Additionally, Cedric indicated taking into consideration the apps' design being consistent within the app while selecting mobile apps for STEM education. Beth explained:

> Apps such as Socrative are not appropriate for my students so I do not use this kind of apps. They are in English and they need Internet. I cannot prepare a quiz and ask my students to take it at their house because most of my students do not have Internet connection. In addition, mobile apps shouldn't make students lose attention for the lesson, on the contrary, they should make take their attention more to the lesson.

For content category, half of the teachers (*n=5*) focused on criteria related to the app's content being accurate), Beth focused whether the content is up to date and Cedric considered the app's content is aligned with the curriculum. Cedric highlighted:

> Selecting mobile apps, its being in Turkish is attractive. I also consider the app's being free, appropriate for the lesson objectives and curriculum, appropriate for students' development level and having a nice and useful interface. An app specific for STEM education would be game that would include design, problem solving, indeed solving the given problem using design process. Through this process, having and using mathematics and science knowledge would be required. Also, this game would have different parts with cumulative difficulty level.

Among connectivity criteria, three of the teachers took attention to the app's allowing communication with other users and two of the teachers took attention to the app's allowing for sharing. Jenny stated:

> The app should work synchronized with the system in our school, for example, App Inventor that our students work with is compatible only with Android, therefore, the apps' working with Android is a crucial criterion for us. Furthermore, its being up-to-date and globally used important to be informed about what is been done around the world and also know up-to-date applications.

For contextuality, only one of the teachers, Cedric underlined app's engaging learner in real life practices.

In addition to the criterions matched with PTC3 framework criteria, further dimensions were mentioned in terms of selecting mobile apps for STEM education. These were categorized under interdisciplinarity, easy access, allowing teacher interference, product development, being free, offline working, connecting other hardware, gamification, allowing problem solving, multilingual, and being globally used.

All the teachers showed regard to its supporting interdisciplinarity (especially STEM subjects) while selecting apps for STEM education. Furthermore, five of the teachers focused that the app needed to be easily accessed for both teachers and students to be selected for STEM activities. Also, half of the participants indicated that it would be better if the app allowed teachers to interfere with the app content. Furthermore, four of the participants took attention to product development using the app. For three of the participants, it was a selection criteria for the app to be free. Each criterion of being time saving, offline working, connecting other hardware, gamification and allowing problem solving was highlighted by two of the teachers. Finally, Jenny, the ICT teacher in private school, pointed out being a multi lingual and globally used app would be considerable criteria while selecting apps for STEM context.

Farida:

> For me, feedback is very important and whether I can add content or should remain constant with the existing content. For example, in Kodu Game Lab, I cannot interfere with the content and this is an insufficiency because each teacher has different unique teaching style.

With a descending frequency, pedagogy, technical usability, content and connectivity and contextuality category criteria were included in the suggestions of the teachers. Furthermore, teachers included supporting interdisciplinarity, easy access, allowing for interference, free use, time saving, offline working, connection to other hardware, gamification and problem-solving practices, multilingual and globally used features were other criteria proposed by the teachers for mobile app evaluation in STEM context.

4.2.1. How do in-service teachers assess PTC3 Evaluation Criteria in terms of selecting mobile apps for STEM education?

To examine how the teachers assessed PTC3 Evaluation Criteria, they were asked to rate each of 49 evaluation criterions in terms of importance for mobile app selection in STEM context. Then, they were asked to rank five evaluation categories from most important to least considering education of all disciplines and STEM education, separately.

4.2.1.1. Evaluation Criteria Ratings

The teachers were asked to rate each evaluation criteria from 1 (not important at all) to 5 (very important) in terms of importance for selecting mobile apps for STEM education. The results for the related criteria is presented for each category below.

Table 7.

Descriptive Statistics for Pedagogy Category Evaluation Criteria

EVALUATION CRITERIA	Not Important at All	Not Very Important	Important	Somewhat Important	Very Important		
	f	*f*	*f*	*f*	*f*	*M*	*SD*
Pedagogical strategy							
P1. The app guides learners while providing correct pedagogical instructions.	*0*	*1*	*1*	*1*	*7*	4.4	0.34
P2. The app applies appropriate content-based teaching methods.	0	0	1	3	6	4.5	0.22
P3. Pedagogical elements foster learning.	0	0	1	3	6	4.5	0.22
P4.Pedagogical elements reinforce learning.	0	0	0	4	6	4.6	0.16
Motivation							
P5. The apps' content stimulates learner interest.	*0*	*0*	*0*	*1*	*9*	4.9	0.10
P6. The apps' activities stimulate learner interest.	0	0	0	2	8	4.8	0.13
P7. The app presents an entertaining learning environment.	0	0	0	0	10	5.0	0.00
P8. The app presents forms of intrinsic (e.g., accomplishment) reward	0	0	1	2	7	4.6	0.22
P9. The app presents forms of extrinsic (e.g., badges, stickers, points) rewards.	1	1	2	1	5	3.8	0.47
P10. The difficulty level of activities is in a way to prevent students from getting bored.	0	0	0	4	6	4.6	0.16

Table 7 (continued)

EVALUATION CRITERIA	Not Important at All	Not Very Important	Important	Somewhat Important	Very Important		
Learner							
P11. The app content is aligned with learners' cognitive levels.	*0*	*0*	*0*	*2*	*8*	4.8	0.13
P12. The app design is aligned with learners' cognitive levels.	0	0	0	2	8	4.8	0.13
P14. The app addresses eliminating learners' misconceptions.	0	0	1	2	7	4.6	0.22
P15. The app allows learners to learn at their own pace.	0	0	0	0	10	5.0	0.00
Multimedia							
P16. The app provides appropriate multimedia design features with multiple content representations (e.g., pictures, text, video, sound).	0	0	0	2	8	4.8	0.13
P17. The app provides new representations of course content (e.g., 3D, animations, and simulations).	0	0	0	3	7	4.7	0.15
Assessment							
P18. The app includes assessment features that fit for purpose.	0	0	0	5	5	4.5	0.17
P19. The app tracks learning progress.	1	0	1	3	5	4.1	0.41
P20. The app reports learning progress.	0	0	3	4	3	4.0	0.26

According to the ratings for pedagogy category, P5 (*M=5.00*) and P17 (*M=5.00*) criteria were rated as very important by all the participants *(n=10)*. That means, all the in-service teachers placed great emphasis on a mobile apps providing an entertaining learning environment and enabling students to learn at their own pace in STEM education.

For pedagogical strategy, most of the participants rated P1 (*f=7*), P2 (*f=6*), P3 (*f=6*) and P4 (*f=6*) criteria as very important selecting mobile apps for STEM context which indicated that in-service teachers attached importance to pedagogical instructions, teaching methods, fostering and reinforcing learning in apps for STEM education.

Congruently, most of the participants ranked motivation criteria as very important such as P5 (*f=9*), P6 (*f=8*), P7 (*f=10*), P8 (*f=7*) and P10 (*f=6*). This pointed that the STEM teachers generally found stimulating learner interest, providing an entertaining learning environment, presenting intrinsic rewards and preventing students from getting bored as very important for mobile apps. Despite, P9 (*M=3.8*) had the lowest rating score among all the criteria indicating that the teachers did not regard presenting extrinsic reward as significant as the other criteria.

Similarly, among learner criteria, almost all of them were frequently rated as very important by most of the participants; P11 (*f=8*), P12 (*f=8*), P14 (*f=7*) and P15 (*f=10*). It could be inferred that the teachers considered being aligned with students' cognitive level, targeting students' misconceptions and allowing learners to learn at their own pace as quite significant for apps in STEM education. On the other hand, they did not pay such attention whether an app targeted students' needs or not.

For multimedia, the participants ranked both criterions as very important; P16 (*f=8*) and P17 (*f=7*) revealing that the teachers gave weight to mobile apps providing appropriate multimedia features and new presentations for course content.

As the ratings for assessment criterions were examined, it was seen that they were rated as very important by the participant with comparably lower frequencies P18 (*f=5*), P19 (*f=5*) and P20 (*f=3*). The rating scores indicated that in-service teachers deemed mobile apps providing expedient assessment features, tracking and reporting student progress as less significant than the other pedagogy criteria.

To summarize, among the in-service teachers, all attached foremost importance to providing an entertaining learning environment and enabling students to learn at their own pace, most of them found the other criterions as very important except presenting extrinsic rewards, targeting students' needs, presenting fit-for-purpose assessment features, tracking and reporting student progress while selecting mobile apps for STEM education.

Teachers were also asked to state any comments or opinions for each criteria of the pedagogy category. Adam stated that the item P1 (The app guides learners while providing correct pedagogical instructions) was difficult to understand, it would better be understood providing examples in bracelet. For P7 criteria (The app presents an entertaining learning environment), the term instruction could be replaced with learning environment to be better comprehended by the teachers. Also, Adam indicated that P19 item sentence (The app tracks learning progress) was problematic. Instead of using the term learning, it would be better to use development of student through the process. Cedric especially emphasized importance of P4 (Pedagogical elements reinforce learning) and it was told to be more important than P3 (Pedagogical elements foster learning). Also, importance of P10 was underlined indicating if students got bored they would be reluctant to learn. However, according to Dalton, the sentence of P10 (The difficulty level of activities is in a way to prevent students from getting bored) was difficult to understand because it was given as negative of a negative sentence. Gabi indicated that it was difficult to assess P11 criteria (The app content is aligned with learners' cognitive levels) as the content of Edmodo, the app she assessed, was prepared by the teachers.

Table 8.

Descriptive Statistics for Technical Usability Category Evaluation Criteria

EVALUATION CRITERIA	**Not Important at all**	**Not Very Important**	**Important**	**Somewhat Important**	**Very Important**		
	f	*f*	*f*	*f*	*f*	*M*	*SD*
Visibility							
T1. The app provides clear feedback about its usage (e.g., directions, hints, etc.).	*0*	*0*	*0*	*2*	*8*	4.8	0.13
User control							
T2. Learners can sequence tasks on the app.	0	0	0	4	6	4.6	0.16
Efficiency of use							

Table 8 (continued)

EVALUATION CRITERIA	**Not Important at all**	**Not Very Important**	**Important**	**Somewhat Important**	**Very Important**		
	f	*f*	*f*	*f*	*f*	*M*	*SD*
T4. The app provides a simple interface design without confusing or distracting elements.	*0*	*0*	*0*	*2*	*8*	4.8	0.13
T5. The app allows learners to save their actions.	*0*	*0*	*1*	*1*	*8*	4.7	0.21
T6. The app provides an interface in learners' native language.	*1*	*0*	*0*	*1*	*8*	4.5	0.40
Support							
T7. The app provides a tutorial about its usage.	*0*	*0*	*0*	*1*	*9*	4.9	0.10
T8. The app includes a search option.	*0*	*0*	*4*	*4*	*2*	3.8	0.25
T9. The app includes a help option easily accessed whenever needed.	*0*	*0*	*0*	*4*	*6*	4.6	0.16
Recognition							
T10. Symbols are presented clearly.	*0*	*0*	*0*	*5*	*5*	4.5	0.17
Visual design							
T11. The app only includes information, visual elements, and functionality necessary for core tasks.	*0*	*0*	*0*	*3*	*7*	4.7	0.15
T12. The app design is visually aesthetic.	*0*	*0*	*0*	*1*	*9*	4.9	0.10
T13. The app's interface design complements the relevant context.	*0*	*0*	*0*	*5*	*5*	4.5	0.17
Error prevention							
T14. The app prevents errors.	*1*	*0*	*0*	*6*	*3*	4.0	0.37
T15. The app recovers from errors.	*0*	*0*	*0*	*6*	*4*	4.4	0.16
Consistency and Standards							
T16. The app is compatible with different systems (e.g., PC, iOS, Android, Windows mobile).	*0*	*1*	*0*	*2*	*7*	4.5	0.31

Table 8 (continued)

T17. The apps' design is consistent within the app (e.g., pages or actions of buttons).	*0*	*0*	*1*	*1*	*8*	4.7	0.21
T18. The apps' design is consistent between versions (e.g., iOS and Android)	*0*	*0*	*2*	*2*	*6*	4.4	0.27

According to the rating for technical usability category, visibility, T1 (*f=8*) and user control T2 (*f=6*) were ranked as very important by most of the participants. That means, in-service teachers found it significant for an app to provide clear feedback about its usage and let user sequence the tasks in STEM education.

For efficiency of usage, all the criterions T3 (*f=8*), T4 (*f=8*), T5 (*f=8*) and T6 (*f=8*) were rated as very important by most the participants, as well. The results showed that, almost all the in-service teachers put emphasis on providing a tutorial about functions, a simple interface in students' native language and enabling students save their action for mobile apps to bu used in STEM context.

Among support criterions, two of them were rated as very important mostly; T7 (*f=9*) and T9 (*f=6*) while T8 (*f=2*) were rated as very important only by two of the participants. This indicated that, teachers placed significance into presenting a tutorial about usage and a help options but did not made much of providing a search option to select mobile apps.

Similarly, for recognition, only half of the participants rated T10 (*f=5*) as very important meaning that presenting symbols clearly is not a primary criterion for in-service teachers.

Looking at the ratings for visual design, most of the teachers rated T 11 (*f=7*) and T 13 (*f=9*) as very important. This showed that in-service teachers considered apps' having only necessary items and aesthetic design as very important. On the other hand, only half of the participants ranked T12 (*f=5*) as very important that inferred teachers put less emphasis on apps' having an interface complementing the related context when compared to others.

For error prevention, a small group of teachers rated T14 (*f=3*) and T15 (*f=4*) as very important most of them rated both criteria as somewhat important (*f=6*). This revealed that, preventing and recovering errors were not found such significant for mobile apps to be used in STEM education.

As the consistency and standards criteria were examined, it was recognized that most of the teachers rated T16 (*f=7*) and T18 (*f=9*) as very important. This showed almost all the in-service teachers placed importance to being compatible with different systems, consistent within app and between versions.

In sum, the in-service teachers mostly regarded significance to all technical usability criteria except providing a search option, presenting clear symbols and an interface complementing the context, preventing and recovering errors. Those were mostly stated as somewhat important selecting mobile apps for STEM education.

As the comments and opinions of the participants on the technical usability criteria were reviewed, as Adam A suggested that T5 (The app's allowing learners to save their actions) could be refined as making the sentence passive such as "actions in the app can be saved". For Beth, T13 (The app's interface design complementing the relevant context) criterion was difficult to understand, she recommended that this item could be better understood if examples are given in parenthesis. Similarly, Cedric suggested that the item could be easier to understood using the terms "topic" or "objective" words. For Dalton, T14 (The app's preventing errors) and T15 (The app's recovering from errors) are controversy items because if the app prevented errors there would be no need to recover errors.

Table 9.

Descriptive Statistics for Content Category Evaluation Criteria

EVALUATION CRITERIA	Not Important at All	Not Very Important	Important	Somewhat Important	Very Important		
	f	*f*	*f*	*f*	*f*	*M*	*SD*
Curricular Fit							
CO1. The app's content is aligned with the curriculum	*0*	*0*	*1*	*1*	*8*	4.7	0.21
Scope							
CO2. The app covers content required for learning the concepts.	*0*	*0*	*1*	*1*	*8*	4.7	0.21
CO3. The app presents content with enough detail but without redundancy.	*0*	*0*	*0*	*2*	*8*	4.8	0.13
Validity							
CO4. The app's content is accurate.	*0*	*0*	*1*	*0*	*9*	4.8	0.20
CO5. The app's content is up- to-date.	*0*	*0*	*2*	*0*	*8*	4.6	0.27
CO6. The app's content is culturally appropriate.	*3*	*0*	*1*	*1*	*5*	3.5	0.59
Sequence							
CO7. The app's content is sequenced appropriately.	*1*	*1*	*0*	*1*	*7*	4.2	0.47

Looking at the rankings for content category, CO1 was ranked as very important by most of the participants (*f=8*) meaning that most of the in-service teachers showed regard to curricular fit selecting mobile apps.

Similarly, CO2 (*f=8*) and CO3 (*f=8*) were also ranked as very important with high frequencies. That showed, almost all the in-service teachers agreed that apps' well covering and presenting related content was quite significant.

For validity, CO4 (*f=9*) and CO5 (*f=8*) were mostly ranked as very important while merely half of the participant ranked CO5 (*f=5*) as very important indicating that almost all the participants found app's content being accurate and up-to-date quite significant while only half of them thought app's being culturally appropriate was such significant.

In sequence, most of the participants rated CO7 (*f=7*) as very important showing that the teachers put emphasis on app's content being sequenced appropriately. In short, for content category, almost all the criteria were declared to be so important except app's content being culturally appropriate.

As revealed from the comments of Cedric, for CO2 item (The app covers content required for learning the concepts) could be refined as "The app covers content required to achieve objectives".

Table 10.

Descriptive Statistics for Connectivity Criteria

EVALUATION CRITERIA	**Not Important at all**	**Not Very Important**	**Important**	**Somewhat Important**	**Very Important**		
	f	*f*	*f*	*f*	*f*	*M*	*SD*
Sharing							
CN1. The app allows for sharing findings, content, and scores through features such as e-mail, social media platforms, etc.	*0*	*0*	*2*	*2*	*6*	4.4	0.27
Communication							
CN2. The app allows communication with other users (e.g.,comments, ratings).	*1*	*0*	*1*	*3*	*5*	4.1	0.41

For connectivity, more than half of the participants rated CN1 (*f*=*6*) and half of them rated CN2 (*f*=*5*) as very important. It could be inferred that, the teachers found sharing and communication features of mobile apps significant to be used in STEM education.

Table 11.

Descriptive Statistics for Contextuality Category Evaluation Criteria

EVALUATION CRITERIA	**Not Important at all**	**Not Very Important**	**Important**	**Somewhat Important**	**Very Important**		
	f	*f*	*f*	*f*	*f*	*M*	*SD*
Real world contexts							
CT1. The app engages learners in real world practices both in and outside of the classroom.	*0*	*1*	*0*	*2*	*7*	4.5	0.31
Authenticiy							
CT2. The app supports learning in contexts where actual practice takes place (e.g., museums, nature).	*0*	*1*	*1*	*2*	*6*	4.3	0.33

In contextuality criteria, CT1 (*f=7*) and CT2 (*f=6*) were mostly ranked as very important by the participants. This indicated that, the teachers would consider whether an app provided real world context and authenticity.

4.2.1.2. Evaluation Category Rankings

The participants were asked to rank the five categories (pedagogy, technical usability, content, connectivity and contextuality) in terms of importance for selecting mobile apps for education in general and STEM-specific, as well. The ranking results are presented below.

Table 12.

Evaluation Category Rankings for Education of Disciplines

Category	Most Important	2nd Choice	3rd Choice	4th Choice	Least Important	Mean Score
Pedagogy	4	2	4	0	0	4.00
Technical Usability	1	2	5	2	0	3.60
Content	4	5	1	0	0	4.30
Connectivity	0	0	0	4	6	1.40
Contextuality	1	1	1	3	4	2.20

According to the rankings in terms of importance for selecting educational mobile apps, pedagogy (*n=4*) and content (*n=4*) were most frequently ranked as most important evaluation categories. Furthermore, half of the participants (*n=5*) ranked content as 2^{nd} choice followed by pedagogy (*n=2*) and technical usability (*n=2*). The third choice of the participating teachers were generally pedagogy (*n=4*) and technical usability (*n=5*). Participants mostly considered connectivity (*n=4*) and contextuality (*n=3*) as their third choice while selecting educational mobile apps. Similarly, they ranked connectivity (*n=6*) and contextuality (*n=4*) as the least important evaluation category in common.

The results indicate that the participating teachers considered pedagogy and content primarily while selecting educational mobile apps. Indeed, the most important evaluation category would be content (*M=4.00*) and the second important one would be pedagogy (*M=4.00*) to be considered for the teachers to select educational mobile apps. On the other hand, the in-service teachers would lastly show regard to connectivity (*M=1.40*) deciding mobile apps to be used for educational purposes. Likewise, contextuality (*M=2.20*) would be the fourth choice among 5 categories while selecting educational mobile apps.

Table 13.

Evaluation Category Rankings for STEM Education

Category	Most Important	2nd Choice	3rd Choice	4th Choice	Least Important	Mean Score
Pedagogy	1	4	5	0	0	3.60
Technical Usability	2	2	4	2	1	3.50
Content	6	3	1	0	0	4.50
Connectivity	0	0	0	4	6	1.40
Contextuality	1	1	0	4	4	1.20

In the table above, the ranking of evaluation categories in terms of importance for selecting mobile apps for STEM education are shown. The participating teachers ranked content as the most important category (*n=6*) among all. As the second choice, the teachers commonly indicated pedagogy (*n=4*) while selecting mobile apps for STEM education. On the contrary, connectivity (*n=4*) and contextuality (*n=4*) were ranked as the fourth choice by equal number of participants. Furthermore, most of the teachers ranked connectivity (*n=6*) as the last choice in terms of selecting mobile apps for STEM education.

It can be inferred from the results that the teachers take primarily pedagogy and content into consideration as they select mobile apps for STEM education. More precisely, the most important evaluation category would be content (*M=4.50*) and the second important one would be pedagogy (*M=3.60*) followed by technical usability (*M=3.50*) to be considered in mobile apps for STEM education. On the other hand, the teachers would lastly show regard to contextuality (*M=1.20*) and connectivity (*M=2.20*) would be the fourth choice among 5 categories for mobile app selection in STEM education.

The rankings of mobile app evaluation categories for education (in general) and STEM showed similarities and differences, as well. The most important category was ranked as content in both with different mean scores.

Parallel to this result, the second choice to consider for mobile app selection was pedagogy for education (in general) and STEM. On the other hand, the teachers referred connectivity as the least important evaluation category for educational apps but contextuality for apps in STEM education.

Table 14.

Evaluation Category Rankings

In-service teachers Apps for All Disciplines	**In-service teachers Apps for STEM Education**
Content	Content
Pedagogy	Pedagogy
Technical Usability	Technical Usability
Contextuality	Connectivity
Connectivity	Contextuality

4.2.2. How do in service teachers assess mobile apps they frequently used based on the PTC3 framework criteria?

The teachers of the study were asked to select an educational mobile app that frequently used in their lessons. Followingly, they were asked to evaluate the selected apps in terms of meeting the criteria provided in PTC3 evaluation rubric selecting one of “Yes” (the app meet the criteria), “No” (the app does not meet the criteria) and “N/A” (the criteria is not applicable for the app) options. Evaluation results are presented for each selected educational mobile app as follows.

Table 15.

Evaluation of the App “Plickers”

Category	**Yes**		**No**		**N/A**	
	f	%	*f*	%	*f*	%
Pedagogy	17	85	3	15	-	-
Technical Usability	9	50	7	38.9	2	11.1
Content	2	28.6	-	-	5	71.4
Connectivity	1	50	1	50	-	50
Contextuality	1	50	1	50	-	-
Total:	30	61.2	12	24.5	7	14.3

According to the science teacher Adam, Plickers app met more than half of the 49 evaluation criteria (61.2%) while it did not meet 24.5% of them. On the other hand, 14.3% of the criteria was reported as not applicable to evaluate the app.

As Adam declared, Plickers met almost all the criteria in pedagogy (85%) category except P1, P2 and P15. That means, the app suggested all other features but neither provided pedagogical instructions and teaching method nor allowed students to learn at their own pace. For technical usability, the app was stated to meet half (50%) of the 18 criteria but did not meet 38.9% of them and 2 of the criteria were not applicable. As participant A reflected, Plickers did not meet T1, T3, T4, T5, T7, T17 and T19 criteria. This showed Plickers did not provide clear feedbacks about usage, an interface in students' native language, a search option, did not allow students to sequence tasks and did not prevent or recover errors. Furthermore, T16 and T18 were stated not to be applicable while evaluating the app. Thus, being compatible and consistent between different systems were not evaluated by the participant A. For content category, Plickers was noted to meet only two of the criteria (CO1 and CO2) meaning that its content was aligned with the curriculum and it provided enough information to learn concepts. Notably, 71.4% of the content criteria (CO3, CO4, CO5, CO6 and CO7) were noted as not applicable to evaluate Plickers showing the apps content's being enough detailed, accurate, up-to-date and culturally appropriate were not evaluated. For connectivity, the app was stated to meet CN1, allowing sharing in digital environment but not to meet CN2, allowing communicating with other users. Among contextuality criteria, Plickers did not meet CT1, engaging students in real world practices but met CT2, supporting learning where actual practice took place as participant A indicated.

Table 16.

Evaluation of the App "Anatomy 4D"

	Participant B						Participant H					
Category	**Yes**		**No**		**N/A**		**Yes**		**No**		**N/A**	
	f	%	f	%	f	%	f	%	f	%	f	%
Pedagogy	12	60	7	35	1	5	14	70	6	30	-	-
Technical Usability	12	66.7	4	22.2	2	11.1	11	61.1	7	3.9	-	-
Content	6	85.7	1	14.3	-	-	4	57.1	3	42.9	-	-
Connectivity	-	-	2	100	-	-	-	-	2	100	-	-
Contextuality	2	100	-		-	-	1	50	1	50	-	-
Total:	32	65.3	14	28.6	3	6.1	30	61.2	19	38.8	-	-

The mobile app Anatomy 4D was evaluated by both participant Beth and Hanna. However, there are commonalities and discrepancies between the two evaluations. Among all criteria, Beth indicated that Anatomy 4D met 65.3% of the criteria, did not meet 28.6% and 6.1% could not be applicable while according to Hanna, the app met 61.2 of the total criteria, did not meet 38.8 and none of the criteria was reported as not applicable.

For pedagogy, as Beth, the app met 60% of the related criteria, did not meet 35% (P8, P9, P11, P14, P18 and P20) and 5% (P10) was not applicable. Indeed, Anatomy 4D was told not to provide forms of intrinsic and extrinsic rewards, have a design appropriate for students' cognitive level, target eliminating misconceptions, present rich multimedia features, providing fit-for-purpose assessment features and report student progress. In addition, for Beth preventing students from getting bored could not be evaluated for the app. Different from Beth, participant Hanna indicated that the app met P10, P11 and P14 criteria and it design was appropriate for students' cognitive level, it targeted eliminating misconceptions and it prevented students from getting bored. In technical usability, Beth stated that Anatomy 4D met 66.7& of the criteria, did not meet 22.2 (T5, T6, T8 and T10) of them and 11.1% (T13 and T18) could not be applicable. In particular, the app did not allow students to sequence tasks, did not have an interface in students' native language, did not have a search option and its symbols were not clear. Furthermore, it could not be evaluated in terms of having an interface that complements the related context and being compatible with different systems. Varying from Beth, Hanna indicated that Anatomy 4D had clear symbols (T10) interface complemented relevant context (T13) and its design was consistent between different versions (T18) but it did not have a tutorial (T7) and a help option (T9). As the content criteria was examined, Beth indicated that the app met 66.7 of the related criteria but did not meet 14.3% (CO4) showing that Anatomy 4D did not meet the criteria of having a correct content but Hanna stated that the app's content was correct. Furthermore, different from the evaluation of Beth, Anatomy 4D was told not to meet CO3, CO6 and CO7 referring that its content was not presented with enough detail, its content was not culturally appropriate and its content was correctly sequenced. For connectivity, both teachers stated that the app met neither of the related criteria. Additionally, for contextuality, Beth stated that Anatomy 4D met both criteria while Hanna told that it met CT1 (engaging students in real world practices) but did not meet CT2 (supporting learning where actual practice took place.

Table 17.

Evaluation of the App "Elements 4D"

Category	**Yes**		**No**		**N/A**	
	f	%	*f*	%	*f*	%
Pedagogy	15	75	5	25	-	-
Technical Usability	12	66.7	6	33.3	-	-
Content	6	85.7	-	-	1	14.3
Connectivity	-	-	2	100	-	-
Contextuality	1	50	1	50	-	-
Total:	34	69.4	14	28.6	1	2.0

Cedric decided to evaluate Elements 4D based on the given criteria. As evaluation results indicated, the app met 69.4% of the total criteria and did not meet 28.6 of them and 2.0% of the criteria was not applicable. None of the criteria was reported as not applicable for the app.

Among pedagogy criteria the app was stated to meet 75% and not to meet 25% (P9, P10, P14, P19 and P20) of the related items. That showed Elements 4D did not present forms of extrinsic rewards, prevent students from getting bored, target eliminating misconceptions, track or report student progress. For technical usability, the app was told to meet more than half of the related criteria (66.7%) while no to meet 33.3% (T5, T6, T8, T9, T14 and T15) of them. In particular, Elements 4D did not allow students to sequence tasks, did not have an interface in students' native language, did not provide search and help options, did not prevent and recover errors as Cedric declared. Among content criteria, the app met 85.7 but could not be evaluated in terms of CO7 (the app's content is sequenced appropriately). Elements 4D was indicated to meet neither of the two connectivity criteria. In contextuality, it was told to meet CT1 (engaging students in real world practices) and not to meet CT2 (supporting learning where actual practices take place) by Cedric.

Table 18.

Evaluation of the App "App Inventor"

Category	Yes		No		N/A	
	f	%	*f*	%	*f*	%
Pedagogy	11	55	7	35	2	10
Technical Usability	8	44.4	6	33.3	4	22.2
Content	6	85.7	-	-	1	14.3
Connectivity	2	100	-	-	-	-
Contextuality	1	50	1	50	-	
Total:	28	57.1	14	28.6	7	14.3

As Dalton indicated, App Inventor met approximately half of the total criteria (57.1%) while did not meet 28.6% of them and 14.3% of the criteria could not be evaluated for the app.

For pedagogy, the app met a small percentile (55%) of the related criteria. It was reported not no meet P7, P19, P10, P14, P16, P17 and P20. That meant, App Inventor did not provide an entertaining environment, extrinsic rewards, reach multimedia and new presentations of course content, did not prevent students from getting bored and did not report student progress. Furthermore, P1 and P6 were not applicable for the app showing it could not be evaluated in terms of providing pedagogical instructions and intriguing activities. For technical usability, the app was reported as meeting 44.4% of the related criteria but not meeting 33.3% criteria such as T6, T7, T8, T9, T16 and T18. This showed, App Inventor did not present an interface in students' native language, a search option, a help option; it was not compatible with different systems and consistent between different versions. In addition, 33.3% of the technical usability criteria was not applicable for the app (T3, T12, T13 and T15). It referred that App Inventor could not be evaluated in terms of allowing students to sequence tasks, having an aesthetic design, an interface design complements the relevant context and recovering errors. For content, the app was stated to meet almost all the related criteria (85.75) except CO6 (having a concept appropriate for culture). App Inventor was indicated to meet all connectivity criteria. For contextually, the app met CT1 (engaging students in real world activities) but did not meet CT2 (supporting learning in learning environment where actual practice takes place) according to the reflections of Dalton.

Table 19.

Evaluation of the App "Quiver"

Category	**Yes**		**No**		**N/A**	
	f	%	f	%	f	%
Pedagogy	12	60	7	35	1	5
Technical Usability	8	44.4	9	50	1	5.6
Content	1	14.3	5	71.4	1	14.3
Connectivity	-	.	2	100	-	-
Contextuality	1	50	1	50	-	-
Total:	22	44.9	24	49	3	6.1

Ela selected Quiver to review based on the given criteria. According to the results, the app met 44.9 of the total criteria, did not meet 49% of them and 6.1% of the criteria could not be applicable.

Among pedagogy criteria, the app was reported to meet more than half (60%) of them while not to meet 35% (P9, P10, P12, P14, P18, P19 and P20) of them and 5% of the criteria were not applicable. That revealed Quiver did not present intrinsic and extrinsic rewards, its visual design was not appropriate for students' cognitive level, it did not target eliminating misconceptions, it did not provide assessment features, it did not track and report student progress. Furthermore, using appropriate content-based teaching methods was not applicable for the app. Quiver was declared to meet less than half (44.4%) of technical usability criteria, not to meet half of them (50%) that are T3, T4, T5, T6, T7, T8, T10, T13 and T14; not to be evaluated in terms of T9 criteria. That showed the app were told not to provide explanations or a tutorial, a simple and native language interface that complements related context, a search option, clear symbols and not to allow students to sequence tasks. In addition, it could not be evaluated considering providing a help option. For content, the app was reported to meet only one of the related criteria (14.3%) but no to meet 71.4 of them and 14.3% was not applicable. That meant, Quiver did not have a content which was aligned with the curriculum, covering necessary information to learn concepts, appropriately detailed, up-to-date or culturally appropriate. Furthermore, the app content' being correct could not be evaluated. For connectivity, the app was told neither of the two related criteria. For contextually, Quiver did not meet CT1 but met CT2 meaning that it did not engage students in real world practices but supported learning where actual practice took place as Ela indicated.

Table 20.

Evaluation of the App "Scratch"

Category	**Yes**		**No**		**N/A**	
	F	%	F	%	F	%
Pedagogy	13	65	7	35	-	-
Technical Usability	13	72.2	5	27.8	-	-
Content	1	17.3	3	42.9	3	42.9
Connectivity	2	100	-	-	-	-
Contextuality	1	50	1	50	-	-
Total:	30	61.2	16	32.7	3	6.1

Farida selected Scratch to be evaluated and the results showed that the app was reported to meet more than half of the criteria (61.2%) and 6.1% of them were not applicable for the app.

Scratch was stated to meet 65% of the pedagogy criteria except P1, P3, P14, P18, P19 and P20. That indicated the app did not provide pedagogical instructions, pedagogical elements did not foster learning, it did not target eliminating misconceptions, it did not provide new presentations of course content and appropriate assessment features, it did not track and report student progress. Followingly, in technical usability category, Scratch were told to meet most of the related criteria except T2, T3, T7, T14 and T15 which meant it did not allow students to sequence tasks, did not provide explanations about items and a tutorial, did not prevent and recover errors. Notably, a small number of criteria 17.3% were expressed to meet content criteria. CN1, CN2 and CN7 were told not to be met by Scratch meaning that the app content was not aligned with curriculum, did not cover all to learn related concepts and was not appropriately sequenced. In connectivity, all criteria were stated to be met by the app. Scratch was stated to meet CT1 but not CT2 meaning that it engaged students in real world practices but did not support learning in environments were actual practices took place.

Table 21.

Evaluation of the App "Edmodo"

Category	**Yes**		**No**		**N/A**	
	f	%	f	%	f	%
Pedagogy	14	70	-	-	6	30
Technical Usability	14	77.8	2	11.1	2	11.1
Content	-	-	-	-	7	100
Connectivity	2	100	-	-	-	-
Contextuality	2	100	-	-	-	-
Total:	32	65.3	2	4.1	15	30.6

As the results retrieved from Gabi were examined, it could be seen that Edmodo was suggested to meet most of the criteria (65.3%) while 30.6% of the criteria were told to be not applicable to evaluate the app. Followingly, P2, P7, P11, P14, P17 and P18 criteria were mentioned not be applicable while evaluating Edmodo. This inferred that, the app could not be evaluated considering the apps' using appropriate teaching methods, being appropriate for students' cognitive level, targeting to eliminate misconceptions, presenting an entertaining learning environment, providing new presentations of course content and providing fit-for-purpose assessment features.

For pedagogy, a significant percentage (77.8) of the criteria were told to be met by Edmodo except P16 and P19 which indicated that the app did not provide multimedia design features and did not track student progress. For content category, all the related criteria were stated not to be applicable evaluating Edmodo. On the other hand, the app was stated to meet all connectivity and contextuality criterions.

Table 22.

Evaluation of the App "Phet Colorado"

Category	**Yes**		**No**		**N/A**	
	f	%	*f*	%	*f*	%
Pedagogy	18	90	2	10	-	-
Technical Usability	16	88.9	2	11.1	-	-
Content	7	100	-	-	-	-
Connectivity	2	100	-	-	-	-
Contextuality	-	-	2	100	-	-
Total:	43	87.8	6	12.2	-	-

Ilona evaluated Phet Colorado and stated that it met almost all the criteria (87.8) and none of them were expressed as not applicable. In pedagogy, the app was mentioned to meet 90% of the criteria except P19 and P20 which illustrated that Phet Colorado include all pedagogy-related features except tracking and reporting student progress. Similarly, most of the technical usability criteria were told to be met by the app except T5 and T7. This indicated that, according to Ilona, Phet Colorado includes all technical usability functions with exceptions of allowing students to save their work and providing a tutorial about its usage. As the results for the following categories were examined, it could be inferred that Phet Colorado was stated to meet all criteria in content, connectivity and contextuality.

Table 23.

Evaluation of the App "Google Classroom"

Category	Yes		No		N/A	
	f	%	*f*	%	*f*	%
Pedagogy	15	75	3	15	2	10
Technical Usability	10	55.6	7	38.9	1	5.6
Content	7	100	-	-	-	-
Connectivity	2	100	-	-	-	-
Contextuality	-	-	2	100	-	-
Total:	34	69.4	12	24.5	3	6.1

According to Jenny, Google Classroom met most of the evaluation criteria (69.4%) but did not meet 24.5% of the criteria and 6.1% of the criteria were not applicable for the app.

In pedagogy category, Google Classroom were expressed to meet almost all the criteria but did not meet P8, P17 and P20 criteria, that showed the app did not present new presentations of course content, did not provide forms of intrinsic rewards and did not report student progress. In addition, the apps' using appropriate teaching methods (P2) and preventing students from getting board (P10) could not be evaluated as Jenny stated. For technical usability category, 55.6% of the criteria were met while did not meet 38.9% of them (T2, T3, T7, T8, T9, T12 and T14) and 5.6% of the criteria was not applicable. Indeed, the app had other features but did not allow student to sequence tasks, did not provide explanation about functions, did not provide a search option and a help option, did not prevent errors and was not visually aesthetic. Furthermore, T13 criteria was stated to be not applicable meaning that Google Classroom could not be evaluated in terms of providing an interface that compliments the context. For content and connectivity, the app was declared to meet all the relevant criteria. In contrast, Google Classroom was mentioned to meet none of the contextuality criteria.

4.3. Summary of the Results

The study aimed to investigate evaluating mobile apps for STEM education through in-service teachers' perspectives. There were two focuses of the study: perceptions of in-service teachers for mobile app use in STEM context and mobile app evaluation criteria. Firstly, how in-service science and ICT teachers perceived mobile app use in STEM education was examined under two main domains: STEM perception and mobile app use description.

For STEM perception, teachers were asked to define STEM education and explain how STEM contributed to students, teachers and society. With a descending frequency, STEM definitions emphasized interdisciplinarity, active learning, STEM literacy, collaboration, design process, problem solving, real-world connections, inquiry and art discipline. Contributions of STEM for students were explained in term of academic success, positive attitude, skill development and motivation. Contributions on teachers were generally referred as fostering professional development and increasing job satisfaction. Contributions to society were reported as STEM helped raising individual profile needed for the future, it supported country development, provided solutions to society problems and it contributed to enhancement of economy.

For mobile app utilization in STEM education, teachers were asked to share for which purposes they integrated mobile apps into STEM education and also, they were asked to explain what affordances mobile apps had in STEM contexts. Teachers generally used apps for content presentation, assessment, communication and sharing, measurement. Affordances of mobile apps for STEM context were explained in terms of authenticity (concretizing abstract content, increased motivation and interest in the lesson), personalization (reaching content with ease, autonomous learning, no time and place restrictions).

To reveal evaluation criteria of the in-service teachers, they were asked to share which criteria they considered while selecting mobile apps for STEM education. The responses were given under six categories: pedagogy, technical usability, content, connectivity, contextuality, and other. Criteria suggested by the teachers most frequently fell under pedagogy category, followed by technical usability, content and connectivity. Other criteria were related to interdisciplinarity, access, teacher interference, product development, gratis, connecting to other hardware, gamification and problem solving.

PTC3 Framework (Baran et al., 2017) categories were asked to be ranked in terms of both education of all disciplines and STEM education. Results showed that teachers ranked first three most important categories as content, pedagogy and technical usability. Connectivity was in the last place considering education of all disciplines and contextuality was the last in rankings for STEM education.

The teachers were asked to rate each evaluation criteria in terms of importance for selecting mobile apps for STEM education. Criteria ratings showed that, in pedagogy, providing an entertaining learning environment and enabling students to learn at their own pace was found quite significant for all the teachers; except presenting extrinsic rewards, targeting students' needs, presenting fit-for-purpose assessment features, tracking and reporting student progress were rated as important. Teachers mostly regarded significance to all technical usability criteria except providing a search option, presenting clear symbols and an interface complementing the context, preventing and recovering errors. For content, curricular fit, app's content being accurate and up-to-date, sequenced appropriately. For connectivity, the teachers found sharing and communication features of mobile apps significant. In contextuality, the teachers would consider whether an app provided real world context and authenticity.

Finally, mobile apps that teachers frequently used in their lessons were also assessed based on the PTC3 framework criteria. According to Adam, Plickers met 30 of the 49 evaluation criteria, did not meet 12 of them and 7 criterions were not applicable for the app. As Beth indicated Anatomy 4D met 32 of the criteria, did not meet 14 of them and 3 of the criteria were not applicable for the app. On the other hand, according to Hanna, Anatomy 4D met 30 of the criterions, did not meet 19 of them and none of the criteria was not applicable for the app. Cedric's assessment revealed that Elements 4D met 34 of the criterions, did not meet 14 of them and 1 criterion was not applicable. According to Dalton, App Inventor met 28 of the evaluation criteria, did not meet 14 of them and 7 of the criteria was not applicable. Eda indicated that 22 of the criterions were met by the app Quiver while 24 of them were not, also 3 of the criterions were not applicable. Farida's assessment revealed that Scratch met 30 of the criteria, did not meet 16 of them and 3 of the criterions were not applicable. Edmodo met 32 of the criteria, did not meet 2 of them and 15 criterions were not applicable according to Gabi's assessment. Ilona stated that 43 of the criterions were met by Phet Colorado, 6 of them were not and there was no criterion as not applicable. Finally, according to Jenny, Google Classroom met 34 of the criterions, did not meet 12 of them 3 of the criteria were not applicable. The summary of the results is presented in Figure 8

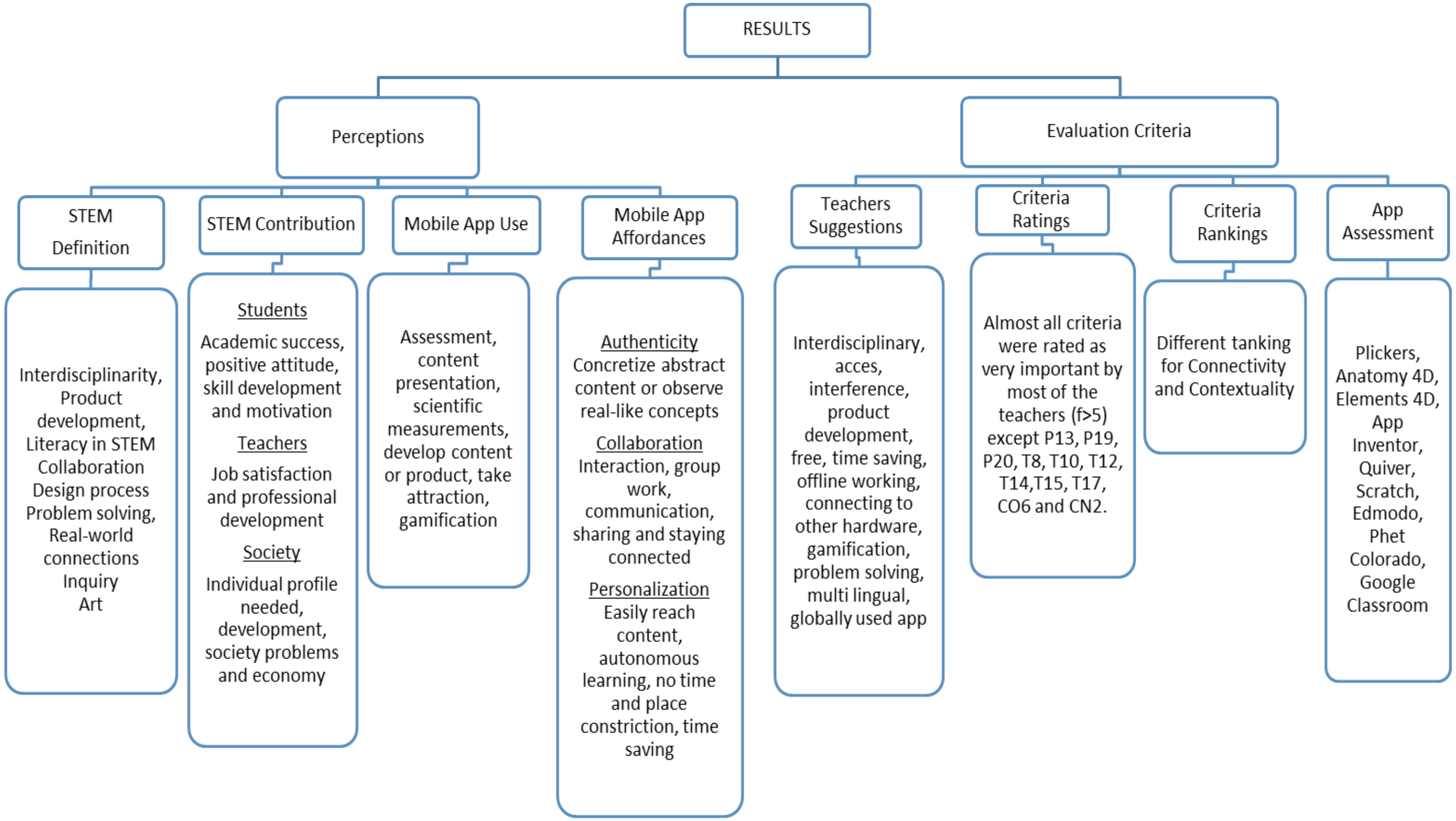

Figure 8. Summary of Results

CHAPTER 5

DISCUSSION

This study examined the evaluation criteria of mobile apps for STEM education through the lens of in-service science and ICT teachers following a qualitatively driven multimethod research. In attempt to validate and refine PTC3 Framework (Baran et al., 2017) for STEM context, previously developed evaluation rubrics and frameworks were examined, an extensive interview form was developed and mobile app selection criteria of the participants for STEM education was examined coupled with empirical evidence on STEM perception and mobile app utilization of the participants within the scope of the research questions. The study was presumed to unveil mobile app evaluation criteria for STEM context suggesting related research area with criteria to be used in studies to further examine and identify mobile technology utilization for STEM education and provide a more comprehensive view of making informed mobile app integration into STEM practices. The following parts of this chapter include review of the findings coupled with related literature in mobile learning and STEM education.

5.1. STEM Education Practices

In this study, most of the teachers indicated conducting STEM activities through problem-based learning defining a problem or a challenge and asking students to develop products following the design cycle within their lessons. A small number of teachers indicated practicing STEM education through term-long projects or specific themes. The results are aligned with the statement that integrated STEM education generally refers to problem-based, project-based, theme-based and inquiry-based pedagogies (Heil, Pearson, & Burger, 2013). The attempts for applying integrated STEM education is an extension of continuing STEM education reform studies (Sanders, 2009). According to Kain (1993) integration is employed for two main reasons: developing learning of students and for engaging in the current instructional sytem or for completely changing the system. However, the shared problem of elementary school curriculum is that related topics are delivered to the students with making no rational connections between the topics (Wineburg & Grossman, 2000). Significantly, for an effective STEM education, teachers need to be dedicated, organized and knowledgable rather than expecting the STEM disciplines appear (Stohlmann et al., 2012). As the results indicate, only four of the teachers, that work in private schools stated that they systematically plan STEM activities through collaborative team work and discussion meetings with teachers from other disciplines. For the science teachers that work in public schools, collaboration with other teachers are only by means of asking for technological support or directing students to ICT teachers for help, not in ICT lesson class hours. This reveals the need guidance and support for all the public shools in the country to effectively organize integrated STEM education practices. Meanwhile, the ICT teachers in the study mentioned planning STEM activities through implementing objectives, problems or themes based on other subjects such as science, social sciences or mathematics and developing a part or total content, project or product in ICT lessons. This confirms the claim that technology education allows students to conceptualize and bring into real world use of knowledge from other disciplines (Ritz & Fan, 2014). Despite the related studies examining appropriate ways for effective education of STEM subjects separately, limited studies are present examining in which ways, to what extend these subjects could be integrated for improved teaching and learning, considering the possible challenges and impacts of this integration on learning, motivation and other desirable outcomes (Heil, Pearson, & Burger, 2013). On this note, Figliano (2007) suggested the following strategies for integrated STEM education: planning lessons based on a specific theme that has connections to multiple disciplines, deciding the lesson topics through collaborative discussions giving priority to the teacher interests and knowledge of practice, arranging the topics with the content standards, developing a collaborative teacher teams and having scheduled meetings, integrating group works in lesson plans, including activities to assess knowledge presentation and interdisciplinary connection skills of the students.

For assessment in STEM practices, teachers generally reported that they considered if the final work of the students met the previously defined criteria and they also shared ideas of how to develop the final work of students. Only one of the teachers, Beth, indicated that she asked questions directly related to the STEM activities conducted in the exam. This is significant for students' learning as it enhances communication and collaboration skills of the students as well as the ability to welcome and apply constructive feedback (Diaz & King, 2007). For better evaluation in integrated STEM education, strategies such as formatively assessing and grading the students' knowledge of interdisciplinary connections, project presentation and discussion considering the entire teachers from the related disciplines (Figliano, 2007).

5.2. STEM Education Perception

For STEM perceptions, teachers' STEM definition and their explanations on the contributions of STEM education were examined. As the results indicated, in-service teachers gave priority to interdisciplinarity, product development, literacy in STEM disciplines and collaboration while defining STEM education. Its interdisciplinary nature was also underlined for the common definition of STEM education (Gonzalez & Kuenzi, 2012). The findings are parallel to the study of Turner (2013) in which STEM definition of educational professionals were examined. As Turner indicates, the educational professionals in her study used student centered approach, integrating STEM disciplines, hands on activities, project based learning processes and application (Turner, 2013). Also, problem solving, inquiry and real-world connections were included in STEM definition of in-service teachers. STEM education's developing life skills and supporting advanced thinking is supported with the definitions of the in-service teachers (Yıldırım & Altun, 2015). According to the definition of Tennessee STEM Innovation Network (2012) STEM education is a research area, but beyond, it is also a way of teaching and learning integrating project based activities, collaboration, and focusing on real-world problem solving. Through STEM programs students are educated putting emphasis on innovation, problem solving, critical thinking, and creativity (Johnson, 2012).

Therefore, the participants' focus on problem solving, inquiry and real-world connections supports the STEM definition provided by the network. Another aspect underlined by some of the participants was art in STEM definition. This shows the influence of the approach proposing the acronym STEAM adding A to the acronym STEM that emphasizes the artistic or creative learning experiences becoming a part of STEM education (Bequette & Bequette, 2012). However, according to the definition of National Science Foundation (NSF), STEM fields embodies further disciplines in addition to the four main disciplines it focuses (Green, 2007). Providing a common definition for STEM can present a clear conceptualization but it is a quite challenging. Therefore, it is better to define common outcomes of STEM education that aims to develop better teachers, students and workface for a globally competitive country (Breiner, Johnson, Harkness, & Koehler, 2012).

The contributions of STEM education were another dimension asked to the teachers. As results indicate, given with a descending frequency, STEM education was told to contribute skill development, positive attitude, academic success and motivation on students. Morrison explained major contributions of STEM education as 1) developing problem solving skills, developing creativity through using basic knowledge and skills in engineering area, 3) fostering rational thinking, 4) developing self-esteem, and 5) explaining and comprehending the nature of technology (Morrison, 2006). The results are parallel to this list as skills development was mentioned, also motivation and academic success would bring self-esteem for the students. Effective STEM instructions characterized as capitalizing on students' interest and experience and providing experience to engage students in the practice of science (National Research Council, 2011).

For teachers, contributions of STEM are professional development and job satisfaction. This result is parallel with the study findings of Kearney and Maher (2013) that using iPad could promote the pre-service teachers' productivity and efficiency and develop perceived Technological Pedagogical Content Knowledge (TPACK) of the pre-service teachers for mobile learning in STEM context (Kearney & Maher's, 2013). However, further empirical evidence of the effectiveness of mobile learning is necessary to decide for the good examples of utilizing STEM apps in classroom settings (Hu & Garimella, 2014).

The teachers listed positive impacts of STEM education on society focusing on development as a society, raising the individual profile needed for the future, generating solutions to society problems and economic growth. The reasons that the countries gave importance to STEM education are listed as: 1. being world leader in technology and economy, 2. raising individuals successful in science and mathematics disciplines, 3. developing qualified individuals, 4. having a sustainable economy, 5. providing citizens with skill development in scientific process, inquiry, critical thinking, 6. Helping students solve real world problems and be productive 6. Increase the number of individuals needed in twenty first century workface (National Academy of Science [NAS], 2007). As the impacts of STEM education were described by the in-service teachers it is seen that STEM education meets the countries' expectations in terms of developing required skills, preparing a base for STEM literacy and profession promoting positive attitude, motivation and academic success among students. STEM education is also reported to foster country development, raising demanded students in the future, solving society problems and economic growth. Therefore, the implementation of STEM education has potential to fulfil the expectations.

5.3. Mobile Apps in STEM Education

The in-service teachers stated that they used mobile apps for the purposes of assessment, content presentation, measurement, content development and gamification to attract students' attention. However, to maximize the contribution of mobile technologies' unique features to learning outcomes, key concerns to mobile technology integration coupled with instructional strategies should be researched and the features of these technologies should be matched with the specific pedagogical challenges (Sung, Chang, & Liu, 2015). In the report "Interactive Technologies in STEM Teaching and Learning", Loui et al. (2015), suggested that, to promote mathematical thinking in early primary years, distinguishing the related features of mobile technologies and their utilization, considering the pedagogical environments required with interactive mobile technologies and taking into consideration the individual and organizational supports should be considered. These guidelines may be referred while integrating mobile technologies in STEM activities, as well.

Mobile apps were told to help students concretize abstract content or observe real-like concepts raise motivation and interest for the disciplines by the teachers. Similarly, facilitating interaction and collaboration and helping teachers and students communicate, share and stay connected with more ease were underlined. The positive impacts of mobile apps reported by the teachers supports the claim of Traxler that mobile technologies used in education enhance transmission and delivery of rich multi-media content, support multiple methods of communication (Traxler, 2007). Personalization, reaching content anytime anywhere and performing autonomous learning were highlighted by the in-service teachers. This is comparable with the study of Hu and Garimella (2014) that reported, from the perspective of participating in-service teachers, facilitation in learning new things, exploring further materials, and reaching information related to the course before or after the study. The focus of the teachers on time and place free learning, personalization and communication opportunities of mobile learning supports the study of Chiong and Shuler (2010), that reported some of the unique affordances of mobile learning to improve education were fostering learning regardless of time and place, improving communication and collaboration, suiting different learning environments and allowing for personalized learning. One of the attributes of mobile learning is providing learners with authentic learning practices when an alternative way of access to related material is impractical (Kukulska-Hulme, 2009). Mobile learning enables these authentic learning, allowing learning tasks built around data capture, location-awareness, and collaborative working, even for distance learning students physically remote from each other (Traxler, 2007, p. 8). The case for Beth, who is a science teacher in a village school with no computer lab or other technologies in the school, shows how mobile apps could be used to support authentic learning as she mentioned she showed atomic structure to the students using mobile apps within a STEM activity. According to Traxler (2007) mobile learning supported situated learning via context-sensitive and instant learning and provided authentic learning that is based on real-world problems and project. The case for Dalton, who practiced STEM education through long term projects on real-world society problems, supported this as they used scientific measurement apps while working on a project to resolve the problem. Mobile learning is also reported to improve communication with other students and receive more teacher feedback (Traxler, 2007). Similarly, it can easily adopt to evolving needs of students since it enables students to learn at their own pace anytime, anywhere and anyhow making learning become more effective (Looi et al., 2010). In addition to the abovementioned positive impacts of interaction and feedback opportunities of mobile learning for students, Linsey-Marion and Panayiotidis (2008) also focused on its benefits for teachers such as revealing misconception of students or challenges, improving teaching practices, and promoting individual assessment and feedback. Although the positive impacts of mobile apps for STEM education is reported in this study and supported with previous studies, the potential of mobile apps to enhance learning and teaching STEM disciplines should be comprehensively examined by long-term practices, extensively integrating mobile technologies in curriculum, and future investigation of higher-level skills (Sung, Chang, & Liu, 2015).

5.4. Mobile App Evaluation for STEM Education

The teachers were asked to list criteria they took into consideration for mobile app selection in STEM context. As the criteria suggested by the participants was placed into the PTC3 framework categories, with a descending order of frequency, pedagogy, technical usability, content, connectivity and contextuality. Pedagogy category's being the primary focus for evaluation is parallel to the findings of Green et al.'s (2014) study, that revealed teachers place great emphasis on pedagogical factors and utilizing mobile apps in classroom settings. These findings are also in line with the study that examined the significance of feedback to support teaching and learning; according to John Hattie (2009), feedback the unique most effective educational tool to develop student performance. Hohlfeld, Ritzhaupt, and Barron (2010) explains the importance of pedagogy aspect as its providing teachers with the opportunity to make use of educational technologies in accordance with the curriculumn and learning needs of the students, promoting more creative and specialized teaching methods through integrating these technologies. On the other hand, contextuality, including authenticity and real world context, criteria had the lowest frequency according to the criteria suggestion of teachers. It is contradictory with the emphasis STEM education places on real-worl connections. The compared low frequency for contextuality for evaluating mobile apps within STEM context requires further investigations. This may be explained with the fact that the number of mobile apps employing problem based approachers are limited (Walker, 2013). Another point is, criteria teachers in this study focused for mobile app evaluation within STEM context is in line with the criteria for mobile device evaluation for educational purposes; Economides and Nicolaou (2008), suggested three main domains for evaluating mobile devices: usability, technical, and functional. Usability domain focuses on understanding easily, learning, remembering and using the device and its tools; technical domain deals with the performance of the tools, connectivity, compatibility, security and reliability; functional domain, on the other hand is for the different features, functions and tools of the mobile device.

The criteria suggested by the participants but could not be placed in PTC3 framework followed from high to low frequency as interdisciplinary, easy access, flexibility for teacher interference, product development, gratuitousness, time saving, offline working, connecting to other hardware, gamification and allowing problem solving, multi lingual and used globally. Accessibility and cost were also suggested in the study of Walker (2013) to refine and validate the evaluation rubric for mobile apps (ERMA). Teachers in this study indicated that being a free app would be a reason for preference while selecting mobile apps for STEM education. The cost concern is controversary regarding to the current situation of mobile app market (Walker, 2013). However, considering not all the schools have budget or financial support for technological tool integration, it is reasonable that teachers would primarily prefer free apps not to face cost-related problems while integrating mobile technologies in STEM context.

In this study, it is revealed that in-service teachers' ranking of PTC3 framework criteria in terms of importance follows as content, pedagogy, technical usability, contextuality, and connectivity for mobile app selection while selecting mobile apps for education in general. For STEM education, content, pedagogy, technical usability, connectivity and contextuality. In the same way, teachers also focused on collaboration while defining STEM education. This may be explained with the fact that STEM education puts emphasis on communication and collaboration, so they found connectivity more significant than contextuality. Referring to the Situated STEM learning framework, it was stressed that not all four disciplines had to be included in all practices but it was significant to successfully connect STEM disciplines and community of practice (Kelley and Knowles, 2016).

According to the study of Baran and her colleagues (2017), pre-service teachers ranked the categories from most important to the least as pedagogy, technical usability, content, connectivity and contextuality. Ranking of the categories differ from others but it could be inferred that pedagogy, technical usability and content criteria are placed at the top while connectivity and contextuality are generally placed at bottom of the ranking. This can be explained with the study that states pre-service teachers view technology as a means of tools, process, and design because teacher education programs lack providing a consensus on how technology is supposed to be modeled and integrated in classroom environments, in other words, pre-service teachers do not receive technology integration information within methodology courses (Ruggiero & Mong, 2013). Another study revealed that experienced teachers use technology while delivering instruction or having students engage in learning activities but on the other hand new teachers use it more for preparation (Russell, Bebell, O'Dwyer, & O'Connor, 2003). Using technology oftenly for content presentation may explain the teacher’s emphasis on content while evaluating mobile apps for STEM education.

Table 24.

Comparison of Evaluation Category Rankings

Preservice teachers Apps for Education (Baran et al., 2017)	**In-service teachers Apps for Education**	**In-service teachers Apps for STEM Education**
Pedagogy	Content	Content
Technical Usability	Pedagogy	Pedagogy
Content	Technical Usability	Technical Usability
Connectivity	Contextuality	Connectivity
Contextuality	Connectivity	Contextuality

Among the in-service teachers, all attached foremost importance to providing an entertaining learning environment and enabling students to learn at their own pace, most of them found the other criterions as very important except presenting extrinsic rewards, targeting students' needs, presenting fit-for-purpose assessment features, tracking and reporting student progress while selecting mobile apps for STEM education. The in-service teachers mostly regarded significance to all technical usability criteria except providing a search option, presenting clear symbols and an interface complementing the context, preventing and recovering errors. Those were mostly stated as somewhat important selecting mobile apps for STEM education. For content category, almost all the criteria were declared to be so important except app's content being culturally appropriate. The teachers found sharing and communication features of mobile apps significant to be used in STEM education. The teachers would consider whether an app provided real world context and authenticity.

According to the assessment results of the participants, 14.3% of the PTC3 framework criteria for Plickers, 6.1% for Anatomy 4D, 14.3% for App Inventor, 6.1% for Quiver, 6.1% for Scratch, 30.6% for Edmodo 6.1% for Google Classroom could were not applicable. It was stated by the participants that not all the apps have content or some of them requires content integration by the teacher. This shows, not all the criteria of PTC3 framework could be utilized to evaluate all types of mobile app for STEM education. The results provided empirical evidence on selected mobile apps that would contribute to effectively use mobile technologies in educational settings (Walker, 2013). Furthermore, the PTC3 mobile app evaluation framework was put in practiced as it called for further studies to refine the existing criteria and specify it for different educational context (Baran et al., 2017).

CHAPTER 6

CONCLUSION

This study was conducted to investigate evaluating mobile apps for STEM education through the in-service teacher's perspectives following a qualitatively driven multimethod research design. The participants of the study were ten in-service science and ICT teachers from K-12 schools from both public and private schools in different cities of Turkey. Data was collected via demographic information form, structured interview questions and evaluation form integrated in interviews.

The context for STEM practices varied but most of the participants conducted STEM activities through problem-based approach in which they applied short term activities within their lessons. A small number of participants conducted project-based term-long STEM education. Teachers focused on interdisciplinarity, product development, literacy in STEM, collaboration, design process, problem solving, real-world connections, inquiry and art in their STEM definition. Teachers indicated that STEM has positive impacts on students such as academic success, positive attitude, skill development and motivation, for teacher's job satisfaction and professional development, for society individual profile needed, development, solving society problems and supporting economy. Assessment, content presentation, scientific measurements, develop content or product, take attraction, gamification were the purposes that teachers integrated mobile apps in STEM context. The affordances of mobile apps were suggested as concretizing abstract content or observe real-like concepts, Interaction, group work, communication, sharing and staying connected, easily reach content, autonomous learning, no time and place constriction, time saving. The evaluation criteria suggested in PTC3 framework was refined through experts and teachers in the study. The teachers also suggested interdisciplinarity, acces, interference, product development, free, time saving, offline working, connecting to other hardware, gamification, problem solving, multi lingual, globally used app as selection criteria for mobile apps in STEM context.

6.1. Limitations of the Study

This study is expected to contribute both mobile learning and STEM education literature. However, limitations of the study need to be underlined to guide further studies. Firstly, the participant selection criteria were highly tight in the study. Reaching in-service teachers who had background and experience in both STEM education and mobile app integration, more specifically, using mobile apps in STEM context was quite difficult since STEM education, indeed, mobile app use in STEM education is relatively new for Turkey context. The small number of the participants limited a diversity of the data collected in terms of criteria referred while selecting mobile apps. Teachers from different disciplines such as mathematics could perceive or practice mobile learning in STEM context and could suggest different criteria for selection. Another limitation was that, teachers had varying contexts in terms of STEM practice; they had varying planning and infrastructure in their schools. For example, Beth was a science teacher in a village school in Urfa, they had no computer lab in their school neither an ICT teacher. On the other hand, Jenny was working in a private school in Ankara as an ICT teacher, they had computers for all the students and teacher, and they could integrate and develop mobile apps into their lessons. As illustrated, the discrepancy among context of the teachers were recognizable. Furthermore, teachers had different definitions for STEM education and they had different strategies to conduct STEM activities. More importantly, none of the participants were from a STEM school, implementing STEM education in organization level. The teachers generally practiced STEM as a part of their courses or in collaboration with one or two other disciplines. Data gathered from a STEM school where the approach is totally adopted could contribute further criteria in terms of evaluating mobile apps for STEM education. Another limitation was that, the whole data was collected through 1-session interview that took approximately forty minutes. Even the participants were informed about the approximate duration of the interview and its content before data collection, it was difficult to keep interviewees focused.

6.2. Recommendation for Future Research

The findings of the study have potential for further investigation both in mobile learning and STEM literature. Firstly, the teachers had varying contexts for STEM education. Some of the teachers focused on problem based approach, some of them employed project based STEM education while some underlined theme based STEM education. The potential for different approaches could be investigated for the most effective STEM integration. A picture on STEM definition of in-service teachers was drawn in the study, the definition may be compared with pre-service teachers, teacher educators or researchers in STEM fields to examine whether all the related groups had a similar understanding of STEM education in terms of its distinguishing features and essentials. The contributions of STEM education on students, teachers and society may be further investigated within different context and participant profiles such as students or parents. Furthermore, the suggested positive impacts could be analyzed together with the long-term practices of STEM education integration to unveil whether the promise of STEM education really realize its suggested contributions. The criteria list suggested for mobile app selection in STEM context requires more examination with the contributions of teachers form other disciplines such as mathematics, technology and design, arts, etc. Further research is recommended to reveal selection criteria of students, experts, school administrators and view educational mobile apps through the lens of different related groups. Higher number of currently used mobile apps could be assessed through the suggested evaluation criteria to unveil the specific affordances and inefficacies of selected educational mobile applications. As the mobile technologies develop new features each day, the impact of features such as augmented reality should be investigated in education context. With the given opportunities, not only the technology companies but also teacher, students or interested individuals are able to develop mobile apps. The evaluation criteria on mobile app selection for STEM education can be integrated into educational practices that include mobile app development and role of previously defined selection criteria could be examined among mobile apps developed by the learners. The criteria list suggested in this study could provide guidance to technology companies for developing quality apps demanded in STEM education context. Finally, the criteria list could be tested, refined or improved through further studies with broader context or participant profiles. The evaluation criteria retrieved from this study could be extended to higher grades of education such as university or adult education. The findings of the study for mobile app selection in STEM context could be extended with further studies including students, pedagogues or technology experts.

6.3. Implications for Practice

The empirical findings on STEM perception and mobile app integration, and evaluation criteria list developed through this study hold potential for implications for both mobile learning and STEM education studies. Firstly, the context that different teachers practiced STEM education could be adopted by the schools or related organizations that plan to integrated STEM education. In-service teachers' perception of STEM education could be utilized to organize and carry out more extensive STEM programs or projects. The in-service teachers' description of STEM activities' preparation, implementation and evaluation phases could provide guidance for organizations or educators that are novice at conducting STEM activities. The affordances of educational mobile apps described by the users (in-service teachers) could inform other teachers about how to utilize mobile technologies while teaching STEM disciplines. Also, the communication channels used by the participating teachers to gather information about the current mobile apps could set light to the other teachers for reaching selective educational mobile apps. Another implication for practice is, a list of frequently used mobile apps was suggested in the study, this could guidance teachers to integrate specific apps in science, technology, engineering and mathematics education. Also, the apps were assessed based on the PTC3 framework criteria, the assessment results could help the developers of this specific apps improve the apps based on the reflections of in-service teachers. The in-service science and ICT teachers specified what type of mobile apps they had difficulty to find to be utilized in STEM education. Findings for this could promote mobile app development considering the need and demand from the educational practices. Most importantly, STEM and mobile app integration experienced teachers assessed PTC3 framework criteria for STEM education and underlined further criteria for mobile app selection in STEM context, this may guide teachers on how to select and integrate mobile apps for STEM education. The teachers focused on easy and free access to mobile apps as selection criteria, this need may initiate a database or an online library for quality apps to be utilized in STEM context.

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APPENDICES

APPENDIX A: INTERVIEW

STEM EĞİTİMİNDE KULLANILAN MOBİL UYGULAMALARIN DEĞERLENDİRİLMESİ İLE İLGİLİ ÖĞRETMEN GÖRÜŞLERİNİN BELİRLENMESİ GÖRÜŞME FORMU

Tarih:
Görüşme Süresi:
Katılımcı Kodu:

Değerli Öğretmenimiz,

Bildiğiniz gibi STEM (Fen, Teknoloji, Matematik ve Mühendislik) eğitimi son yıllarda ülkemizde ve dünyada büyük ilgi uyandırmaktadır. İçinde bulunduğumuz dijital çağın gerektirdiği özelliklere sahip bireyler yetiştirmeyi hedefleyen bu eğitim anlayışı halen farklı boyutlarda ele alınarak araştırılmaya devam etmektedir. Yapılan araştırmalara katkı getirmek adına dâhil olmanızı istediğimiz bu çalışmanın amacı ortaokul öğretmenlerinin STEM eğitimi kapsamında kullanılan mobil uygulamaları seçerken göz önünde bulundurdukları ölçütleri belirlemektir.

Görüşme sorularında değerlendirmenizi beklediğimiz mobil uygulamalar ile kastedilen akıllı telefon, tablet veya diğer taşınabilir dokunmatik ekran cihazlar için tasarlanmış, öğrencilerin veya öğretmenlerin sınıf içinde/dışında kullanabileceği eğitim içerikli yazılımlardır.

Görüşmemiz yaklaşık bir saat sürecektir. Görüşme sırasında, hiç bir detayı kaçırmamak için sizin için bir sakıncası da yoksa ses kaydı almak istiyorum. Sizin için de uygun mudur?

Bu bağlamda sizinle yapacağımız görüşme sırasında kimlik belirleyici herhangi bir bilgi istenmemektedir ancak katılım sırasında herhangi bir nedenden dolayı kendinizi rahatsız hissederseniz veya devam etmek istemezseniz görüşmeyi durdurabilir veya çalışmadan tamamen ayrılabilirsiniz. Toplanan veriler gizli tutulacak ve sadece araştırmacılar tarafından değerlendirilecektir. Bilgilerden elde edilecek toplu sonuçlar sadece bilimsel yayınlarda kullanılacaktır. Görüşmeye başlamadan önce sizi daha iyi tanıyabilmek için demografik bilgi formunu doldurmanızı rica ediyorum.

Belirtmek istediğiniz bir husus varsa lütfen söyleyiniz. Kendinizi hazır hissettiğinizde görüşmeyi başlatabiliriz.

Katkılarınız için şimdiden çok teşekkür ederiz.
Özlem Tantu
Yrd. Doç. Dr. Evrim Baran

Bölüm 1. Demografik Bilgi Fo

SORU NO	SORULAR	YANITLAR
1.	Cinsiyet	☐Kadın ☐ Erkek
2.	Yaş	
3.	Branşınız	
4.	Mezuniyet Düzeyiniz	☐ Ön lisans ☐ Lisans ☐ Yüksek lisans ☐ Doktora ☐ Diğer (Lütfen belirtiniz)
5.	Görev Yaptığınız İl	
6.	Görev Yaptığınız Yerleşim Yeri	☐ Köy ☐ Kasaba ☐ İlçe merkezi ☐ İl merkezi
7.	Görev Yaptığınız Okul Tipi	☐ Devlet ☐ Özel
8.	H izmet Süreniz	
9.	Size ait veya kullandığınız mobil cihaz türü (Lütfen size uygun olan bütün seçenekleri işaretleyiniz):	☐ Herhangi bir mobil cihaz kullanmıyorum ☐ Dizüstü bilgisayar (Notebook, netbook gibi) ☐ Tablet ☐ Akıllı Telefon ☐ Diğer (Lütfen belirtiniz)
10.	Mobil cihazları hangi amaçlar için kullanıyorsunuz?	
11.	Günlük hayatınızda en sık kullandığınız 3 mobil uygulama hangileridir?	
12.	Günde kaç saat mobil cihaz/internet kullanıyorsunuz?	

Bölüm 2. STEM Eğitimi ve Mobil Uygulamalar

Bu bölümde STEM eğitimi ve mobil uygulamalar hakkındaki görüşlerinizi ve tecrübelerinizi paylaşmanız beklenmektedir.

SORU NO	SORULAR
13.	STEM eğitimi size ne ifade ediyor, örneklerle açıklayabilir misiniz? *STEM eğitimini nasıl tanımlarsınız? STEM eğitiminin olmazsa olmazları nelerdir? STEM eğitimi hangi özellikleri ile fark yaratır?*
14.	STEM eğitimi ile ilgili hangi eğitim/eğitimleri aldınız? *Nerede? Süresi Ne kadar? İçeriği nedir? Hangi kurum tarafından?*
15.	STEM eğitiminin ne gibi katkıları olduğunu düşünüyorsunuz? *Öğretmenler, öğrenciler ve toplum için ayrı ayrı değerlendiriniz.*
16.	Dâhil olduğunuz STEM etkinliği örneklerinden bahseder misiniz? *Sizin için etkili olduğunu düşündüğünüz ve içinize sinen bir etkinlik örneğini paylaşır mısınız? Bu etkinliğin planlama, uygulama ve değerlendirme aşamalarını nasıl gerçekleştirdiniz?*
17.	Okulunuzda yürüttüğünüz STEM etkinlikleri kapsamında diğer branş öğretmenleriyle veya eğitim personeliyle ne gibi işbirlikleri yapıyorsunuz?
18.	STEM etkinlikleri kapsamında hangi mobil uygulamaları kullanıyorsunuz? *Nasıl? Hangi amaçla (iletişim, etkileşim, içerik sunumu, paylaşım işbirlikli çalışma)?*

Bölüm 2. STEM Eğitimi ve Mobil Uygulamalar-Devamı

Bu bölümde STEM eğitimi ve mobil uygulamalar hakkındaki görüşlerinizi ve tecrübelerinizi paylaşmanız beklenmektedir.

SO RU NO	**SORULAR**
19.	STEM eğitimi kapsamında mobil uygulama kullanımının ne gibi etkileri olduğunu düşünüyorsunuz? *Öğrenciler ve öğretmenler, varsa diğer ilgili gruplar açısından değerlendiriniz.*
20.	STEM eğitimi kapsamında kullanacağınız mobil uygulamaları seçerken hangi ölçütleri dikkate alırsınız? *Açıklayınız.*
21.	Siz STEM eğitimi kapsamında kullanılacak bir mobil uygulama geliştirmek isteseydiniz mobil uygulamanızın en önemli üç özelliği ne olurdu? *STEM eğitiminin özelliklerini göz önünde bulundurarak cevaplayınız.*
22.	Ne tür mobil uygulamalara daha rahat erişebiliyorsunuz? *Hangi içerikte olan? Hangi amaçla kullanılan?*
23.	Ne tür mobil uygulamalara erişmekte sıkıntı yaşıyorsunuz? *Hangi içerikte olan? Hangi amaçla kullanılan?*
24.	STEM etkinlikleri kapsamında kullanacağınız mobil uygulamalar ile ilgili nasıl bilgi ediniyorsunuz? *Uygulamalardan nasıl haberdar oluyorsunuz? Uygulamaları nasıl ediniyorsunuzsunuz?*

Bölüm 3. Mobil Uygulama Değerlendirme Ölçütleri

Eğitimde kullanılan mobil uygulamaları seçerken göz önünde bulundurulacak ölçütler ile ilgili;
3.1. bölümünde STEM eğitimi kapsamında derslerinizde kullandığınız bir mobil uygulama belirleyin:_____________________________
Bu mobil uygulamayı aşağıdaki kriterleri karşılayıp karşılamama durumuna göre "Evet", "Hayır" veya "Değerlendirme Dışı" şeklinde değerlendiriniz.
3.2. bölümünde verilen ölçütün STEM Eğitiminde mobil uygulama seçerken ne kadar önemli olduğunu 1'den 5'e kadar bir puan vererek belirtiniz. (1=önemsiz, 2=kısmen önemli, 3=önemli, 4=oldukça önemli, 5=çok önemli)
3.3. bölümünde ölçütün ifade ediliş biçimi ile ilgili (anlaşılırlık, değerlendirmeye uygunluk, vb.) yorumlarınızı söyleyiniz.

SORU NO	**DEĞERLENDİRME KRİTERLERİ**	**3.1. MOBİL UYGULAMANIN DEĞERLENDİRİLMESİ**			**3.2. ÖNEM DERECESİ**	**3.3. YORUMLAR**
		Evet	**Hayır**	**Değerlendirme Dışı**	**1=Önemsiz 5 =Çok önemli**	**Görüşlerinizi açıklayınız**
	Pedagoji/Pedagojik Strateji					
1.	Öğrencilere görevle ilgili doğru pedagojik yönergeler sunarak rehberlik etmektedir.					
2.	İçeriğe uygun öğretim yöntemlerini kullanmaktadır.					
3.	Pedagojik yöntem ve teknikler öğrenmeyi desteklemektedir.					
4.	Pedagojik yöntem ve teknikler öğrenmeye teşvik etmektedir.					
	Pedagoji/Motivasyon					
5.	İçerik öğrencide ilgi uyandırmaktadır.					
6.	Öğrenme etkinlikleri öğrencide ilgi uyandırmaktadır.					
7.	Eğlenceli bir öğretim ortamı sunmaktadır.					

SORU NO	DEĞERLENDİRME KRİTERLERİ	3.1. MOBİL UYGULAMANIN DEĞERLENDİRİLMESİ			3.2. ÖNEM DERECESİ	3.3. YORUMLAR
		Evet	Hayır	Değerlendirme Dışı	1=Önemsiz 5 =Çok önemli	Görüşlerinizi açıklayınız
8.	İçsel pekiştireçlerin (ör, başarma) farklı biçimlerini sunmaktadır.					
9.	Dışsal pekiştireçlerin (ör, rozet, etiket, puanlar) farklı biçimlerini sunmaktadır.					
10.	Etkinliklerin güçlük düzeyi öğrencileri sıkılmasına engel olacak şekildedir.					
	Pedagoji/Öğrenci					
11.	İçerik öğrencinin bilişsel düzeyine uygundur.					
12.	Tasarım öğrencinin bilişsel düzeyine uygundur.					
13.	Öğrencilerin ihtiyaçlarını karşılamayı hedef almaktadır.					
14.	Öğrencilerin kavram yanılgılarını gidermeye yöneliktir.					
15.	Öğrencilerin kendi hızlarında öğrenmelerine izin vermektedir.					
	Pedagoji/Multimedya					
16.	Çoklu içerik sunumlarını (multimedya) zengin bir şekilde bulundurmaktadır (ör. resimler, yazı, video, ses).					
17.	Ders içeriğinin yeni gösterim şekillerini sunmaktadır (ör, 3 boyut, animasyon, simülasyon).					
	Pedagoji/Değerlendirme					
18.	Amaca uygun ölçme değerlendirme araçları sunmaktadır.					
19.	Öğrenme gelişimini takip etmektedir.					

SORU NO	DEĞERLENDİRME KRİTERLERİ	3.1. MOBİL UYGULAMANIN DEĞERLENDİRİLMESİ			3.2. ÖNEM DERECESİ	3.3. YORUMLAR
		Evet	**Hayır**	**Değerlendirme Dışı**	**1=Önemsiz 5 =Çok önemli**	**Görüşlerinizi açıklayınız**
20.	Öğrenme gelişimini raporlaştırmaktadır.					
	Teknik Açıdan Kullanılabilirlik/ Görünürlük					
21.	Kullanım ile ilgili dönütler açıktır (yönergeler, ipuçları, vb.).					
	Teknik Açıdan Kullanılabilirlik/ Kullanıcı Denetimi					
22.	Kullanıcı uygulama üzerindeki görevleri isteği doğrultusunda seçebilmektedir.					
	Teknik Açıdan Kullanılabilirlik/ Kullanım Verimliliği					
23.	Araçların ve tuşların işlevi ile ilgili açıklamalar sağlamaktadır.					
24.	Kafa karıştırıcı ve dikkat dağıtıcı unsurlar bulundurmayan basit bir ara yüz tasarımı sunmaktadır.					
25.	Öğrenciler uygulama üzerindeki çalışmalarını kaydedebilmektedir.					
26.	Öğrencinin ana dilinde bir ara yüz bulundurmaktadır.					
	Teknik Açıdan Kullanılabilirlik/Destek					
27.	Başlangıçta uygulamanın kullanımı ile ilgili bir açıklama yer almaktadır.					
28.	Arama seçeneği içermektedir.					
29.	Kolayca erişilebilen bir yardım seçeneği içermektedir.					

SORU NO	DEĞERLENDİRME KRİTERLERİ	3.1. MOBİL UYGULAMANIN DEĞERLENDİRİLMESİ			3.2. ÖNEM DERECESİ	3.3. YORUMLAR
		Evet	**Hayır**	**Değerlendirme Dışı**	**1=Önemsiz 5 =Çok önemli**	**Görüşlerinizi açıklayınız**
	Teknik Açıdan Kullanılabilirlik/ Görsel Tasarım					
30.	Semboller (araçlar, menü ve tuşlar) ilk bakışta anlaşılır niteliktedir.					
	Teknik Açıdan Kullanılabilirlik/ Açıklık					
31.	Sadece amaca yönelik unsurları (bilgi, görsel, işlevsellik) içermektedir.					
32.	Tasarım görsel açıdan estetiktir.					
33.	Ara yüz tasarımı, ilgili bağlamı desteklemektedir.					
	Teknik Açıdan Kullanılabilirlik/ Hata Önleme					
34.	Hataları önlemektedir.					
35.	Hatalardan geri dönüş sağlamaktadır					
	Teknik Açıdan Kullanılabilirlik/ Tutarlılık ve Standartlar					
36.	Farklı işletim sistemleriyle uyumludur. (kişisel bilgisayar, iOS, Android, Windows Mobile, vb).					
37.	Tasarım kendi içinde (sayfalar ile tuşların eylemleri) tutarlıdır.					

SORU NO	DEĞERLENDİRME KRİTERLERİ	3.1. MOBİL UYGULAMANIN DEĞERLENDİRİLMESİ			3.2. ÖNEM DERECESİ	3.3. YORUMLAR
		Evet	**Hayır**	**Değerlendirme Dışı**	**1=Önemsiz 5 =Çok önemli**	**Görüşlerinizi açıklayınız**
	İçerik/ Geçerlilik					
38.	Tasarım farklı işletim sistemi versiyonları arasında (iOS ve Android) tutarlıdır.					
	İçerik/ Öğretim Programına Uygunluk					
39.	İçerik öğretim programına uygundur.					
	İçerik/ Kapsam					
40.	Kavramları öğrenmek için gerekli içeriği kapsamaktadır.					
41.	İçerik yeterli ayrıntıyla ancak gereksiz bilgi olmadan sunulmaktadır.					
42.	İçerik doğrudur.					
43.	İçerik günceldir.					
44.	İçerik kültürel açıdan uygundur.					
	İçerik/ Sıralama					
45.	İçerik kendi içinde doğru sıralanmıştır.					
	Bağlantısallık/Paylaşım					
46.	Dijital ortamda paylaşıma izin vermektedir (bulguların, içeriğin ve puanların paylaşımı).					
	Bağlantısallık/ İletişim					

SORU NO	DEĞERLENDİRME KRİTERLERİ	3.1. MOBİL UYGULAMANIN DEĞERLENDİRİLMESİ			3.2. ÖNEM DERECESİ	3.3. YORUMLAR
		Evet	**Hayır**	**Değerlendirme Dışı**	**1=Önemsiz 5 =Çok önemli**	**Görüşlerinizi açıklayınız**
47.	Diğer kullanıcılarla iletişim kurmaya imkân sağlamaktadır (yorumlar, sıralama, değerlendirme).					
	Bağlamsallık/ Gerçek Yaşam Bağlamı					
48.	Öğrencileri hem sınıf içinde de hem de sınıf dışında gerçek yaşamla ilgili etkinliklere dâhil etmektedir.					
	Bağlamsallık/ Otantiklik					
49.	Gerçek yaşam deneyimlerinin yer aldığı ortamlarda (ör; müzeler, doğa) öğrenmeyi desteklemektedir.					

Bölüm 4. Mobil Uygulama Değerlendirme Kategorileri

Bir önceki bölümde verilen ölçütleri de göz önünde bulundurarak mobil uygulamalar ile ilgili aşağıda verilen değerlendirme kategorilerini bütün disiplinler için ve STEM disiplinlerinin eğitiminde olacak şekilde, en önemli gördüğünüzden başlayarak en az önemli gördüğünüze doğru sıralayınız. (1=en önemli, 5=önemsiz)

SORU NO	DEĞERLENDİRME KATEGORİLERİ	EĞİTİM İÇİN ÖNEMİ (BÜTÜN DİSİPLİNLER)	STEM EĞİTİMİ İÇİN ÖNEMİ (STEM DİSİPLİNLERİ)
	Pedagoji		
	Teknik Açıdan Kullanılabilirlik		
	İçerik		
	Bağlantısallık		
	Bağlamsallık		

Bölüm 5. Eklenmesi Gerekli Görülen Ölçütler

5.1. Bir önceki bölümde değerlendirmesini yaptığınız ölçütlerin dışında STEM eğitiminde kullanılan mobil uygulamaların değerlendirilmesine eklenmesi gerektiğini düşündüğünüz ölçütler nelerdir?

STEM Eğitiminin belirttiğiniz özelliklerini göz önünde bulundurunuz.

5.2. Bu çalışmaya katkı sağlayacağını düşündüğünüz, benim gözden kaçırdığım ve sizin eklemek istediğiniz başka bir şey var mı?

Katkılarınız ve zamanınız için teşekkür ederiz.

APPENDIX B: APPROVAL OF THE ETHICS COMMITTEE

UYGULAMALI ETİK ARAŞTIRMA MERKEZİ
APPLIED ETHICS RESEARCH CENTER

ORTA DOĞU TEKNİK ÜNİVERSİTESİ
MIDDLE EAST TECHNICAL UNIVERSITY

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Sayı: 28620816 / 65

08 ŞUBAT 2017

Konu: Değerlendirme Sonucu

Gönderen: ODTÜ İnsan Araştırmaları Etik Kurulu (İAEK)

İlgi: İnsan Araştırmaları Etik Kurulu Başvurusu

Sayın Yrd. Doç. Dr. Evrim BARAN- JOVANOVİC;

Danışmanlığını yaptığınız yüksek lisans öğrencisi Özlem TANTU' nun ***"STEM Eğitimi Kapsamında Kullanılan Mobil Uygulamaların Değerlendirilmesi"*** başlıklı araştırması İnsan Araştırmaları Etik Kurulu tarafından uygun görülerek gerekli onay **2017-EGT-019** protokol numarası ile **08.02.2017 – 10.06.2017** tarihleri arasında geçerli olmak üzere verilmiştir.

Bilgilerinize saygılarımla sunarım.

Prof. Dr. Canan SÜMER

İnsan Araştırmaları Etik Kurulu Başkanı

Prof. Dr. Mehmet UTKU

İAEK Üyesi

Prof. Dr. Ayhan SOL

İAEK Üyesi

Prof. Dr. Ayhan Gürbüz DEMİR

İAEK Üyesi

Doç. Dr. Yaşar KONDAKÇI

İAEK Üyesi

Yrd. Doç. Dr. Pınar KAYGAN

İAEK Üyesi

Yrd. Doç. Dr. Emre SELÇUK

İAEK Üyesi

APPENDIX C: TURKISH SUMMARY

Yirminci yüzyılın sonlarından itibaren hızla artan teknolojik gelişmeler insan hayatındaki bir çok soruna çözüm getirdi ancak farklı kaygılar da doğurdu. Teknolojik gelişmelerin eğitime yansıyan tarafına baktığımızda, bu kaygılar genel olarak teknolojinin eğitimde nasıl kullanılabileceği ve öğrencilere değişen teknolojiye nasıl ayak uydurulabileceğinin öğretilmesi üzerinedir (Mishra, Koehler, & Kereluik, 2009). Bu noktada öğrencileri geleceğe hazırlamak için farklı öğretim yollarına ihtiyaç vardır. STEM (Bilim, Teknoloji, Mühendislik ve Matematik) eğitimi, sürekli gelişen dünyaya ayak uydurabilmek adına umut vaat etmektedir. Adından da anlaşılabileceği gibi STEM eğitimi, en basit tanımıyla; bilim, teknoloji, mühendislik ve matematik disiplinlerinin, bütün sınıf düzeylerindeki öğretme ve öğrenme sürecidir (Gonzalez & Kuenzi, 2012). STEM eğitimi, sadece bu dört disiplinin öğretimi anlamına gelmez, bütün bu disiplinleri içinde barındıran daha kapsamlı bir anlamı vardır (Yıldırım & Altun, 2015).

Mobil teknolojiler yenilikçi eğitim yöntemlerini kolaylaştırmak adına potansiyel taşıdığı için, STEM eğitiminde de ön plana çıkmaktadır (Sung, Chang, & Liu, 2016). Mobil öğrenme genellikle teknoloji ve bağlam ifadelerine vurgu yaparak tanımlanır; teknoloji mobil araçları temsil eder ve bu araçlar taşınabilir oldukları için öğrenme bağlamınını geleneksel sınıf ortamının dışına taşırlar (Mundie & Hooper, 2014). Mobil teknolojilerin eğitimde etkili bir şekilde kullanılabilmesinde öğretmenler kritik bir role sahiptir (Traxler, 2007). Mobil araçların uygun öğretme yöntemleriyle eğitim için faydalı hale getirmek eğitimde karşılaşılan zorlukların üzerinden gelinmesi için önemlidir (Sung, Chang, & Liu, 2016). Bu doğrultuda mobil uygulamaları değerlendirmek ve seçmek öğretmenlerin dikkate almaları gereken bir noktadır. Mobil uygulamaları değerlendirirken ortak bir yapı sağlamak amacıyla farklı çalışmalar yapılmıştır (Ahmed & Parsons, 2013; Baran, Uygun, & Altan, 2017; Economides & Nikolaou, 2008; Green, Hechter, Tysinger, & Chassereau, 2014; Huang & Chiu, 2015; Vavoula & Sharples, 2009; Walker, 2013). Problem şu ki mobil öğrenme, gelişen mobil uygulamalar ve ortaya çıkan yeni özellikler ile birlikte sürekli evrilmektedir. Bu nedenle daha önce geliştirilmiş bir değerlendirme çerçevesi geçerliliğini ve güncelliğini yitirebilir. Bu nedenle, bir değerlendirme rubriği hazırlarken ilgili dersin özellikleri ve güncel mobil teknolojiler dikkate alınmalıdır (Walker, 2013). Ancak bugünün mobil uygulamalarının özellikleri göz önünde bulundurulduğunda, geliştirilen değerlendirme araçlarının STEM eğitimi için mobil uygulama seçimi konusunda etkili olup olmadığını gösteren bir çalışma literatürde bulunmamaktadır. Bunun yanında öğretmenlere STEM eğitimi kapsamında mobil uygulama seçme konusunda rehberlik eden bir araştırma bulunmamaktadır. Aynı zamanda, mobil öğrenme literatürü öğretmenlerin STEM eğitimi kapsamında mobil uygulama kullanımı hakkında bir araştırma bulunmamaktadır. Bu nedenle öğretmenlerin varolan mobil uygulama criterlerini nasıl değerlendirdikleri ve STEM eğitimi kapsamında kullanılacak mobil uygulamaların neler olduğunu gösteren araştırmalar ihtiyaç vardır.

Yukarıda belirtilenler doğrultusunda bu araştırmanın amacı STEM eğitimi kapsamında kullanılan mobil uygulamaların öğretmenler tarafından değerlendirilmesidir. Bütüncül bir bakış açısıyla, öğretmenlerin STEM eğitimi kapsamında mobil uygulama kullanımı ile ilgili görüşlerine de yer vermek araştırmanın amaçlarındandır. Araştırma soruları: 1. Öğretmenlerin STEM eğitimi kapsamında mobil uygulama kullanımı ile ilgili algıları nedir? 1.1. Öğretmenler STEM eğitimini nasıl algılar? 1.2. Öğretmenler STEM eğitimi kapsamında mobil uygulamalardan nasıl faydalanır? 2. Öğretmenler STEM eğitimi kapsamında mobil uygulama seçerken hangi ölçütleri göz önünde bulundurur? 2.1. Öğretmenler PTC3 değerlendirme kriterlerini nasıl değerlendirir? 2.2. Öğretmenler sık kullandıkları mobil uygulamaları PTC3 değerlendirme kriterlerine dayanarak nasıl değerlendirir?

Mobil uygulamalar STEM eğitimini zenginleştirecek ve destekleyecek özelliklere sahiptir. Mobil uygulamalar toplumda bir çok kesim tarafından kullanılsa da öğretmenler bu uygulamaların eğitim amaçlı kullanımı konusunda sorumluluk sahibi olmalıdır. Bu nedenle öğretmenlerin beceri gelişimi mobil teknolojilerdeki gelişmelere paralel olmalıdır (Hu & Garimella, 2014). Mobil teknolojileri değerlendirirken öğrenme ortamını bir bütün olarak ele almak ve pedagojik boyutları da dahil etmek önemlidir (Traxler, 2007). Bu bağlamda geliştirilen farklı mobil uygulama değerlendirme çerçeveleri araştırmaların devamının mobil uygulamaların farklı eğitim ortamlarındki rolünü ve değerlendirme araçlarının etkililiğini inceleyebilmek adına önemli olduğunu belirtmiştir (Baran et al., 2017; Green et al., 2014). Kukulska-Hulme (2009) mobil uygulama değerlendirme çalışmaları için dört önemli öneride bulunmuştur: güncel eğitim yaklaşımlarıyla uyumlu olması, bağlamın etkilerini göz önünde bulundurması, çeşitli data ve analizlerini içermesi ve öğrencilerin tasarımcı ve araştırmacı olarak çalışmalarda yer alması. Bu çalışma, mobil uygulamaların STEM eğitimi kapsamında öğretmenler tarafından değerlendirilmesini, ilgili bağlam ve öğretmenlerin STEM eğitiminde mobil uygulama kullanımı ile ilgili algılarını, farklı data türleriyle ortaya koyarak hem mobil öğrenme hem de STEM eğitimi araştırmalarına katkı sağlayacaktır.

STEM eğitim reformu diğer reform süreçlerinden üç noktada ayrılır: STEM eğitimi (a) küresel ekonomik kaygıların getirdiği zorlukları çözmeyi hedefler, (b) dünyanın teknolojik ve çevresel problemlerine çözüm getirmek için STEM okuryazarlığının gerekliliğini dikkate alır, (c) 21. yüzyılda gereken mesleki becerileri geliştirecek bilgiyi merkeze alır. STEM eğitiminin temelleri 1957 yılında Rusya tarafından gönderilen Sputnik isimli uyduyla atılmıştır (Banks & Barlex, 2014). STEM eğitimi yeni bir yaklaşım gibi görünse de tarihine bakıldığında süregelen eğitim iyileştirme çalışmalarının bir sonucu olduğu görülmektedir.

STEM eğitimine ait araştırma sonuçları ve uygulama çıktıları ortaya çıktıkça farklı tanımları ve yaklaşımları da beraberinde getirmekte. STEM eğitimi genel olarak disiplinler arası olma özelliğiyle fark yaratan, okulöncesi eğitimden yüksek öğretime kadar bütün süreçleri kapsayan bie eğitim yaklaşımıdır (Gonzalez & Kuenzi, 2012). STEM terimi sadece bilim, teknoloji, mühendislik ve matematik disiplinlerini kapsasa da STEM eğitiminin farklı disiplinleri barındıran daha derin bir anlamı vardır. Bütüncül STEM eğitimi tasarım odaklı öğrenme yaklaşımlarını kapsar, bilim ve matematik disiplinlerindeki kavram ve uygulamaları teknoloji ve mühendislik eğitimi ile birleştirir (Sanders & Wells, 2006).

STEM eğitimi, günümüzde gelişmiş ülkelerde farklı boyutlarda uygulanmaktadır. Türkiye STEM eğitimi için özel bir plana sahip olmamakla birlikte Milli Eğitim Bakanlığı'nın yayınladığı "2015-2019 Stratejik Plan" kapsamında STEM eğitimini destekleyen amaçlara yer verilmiştir. Türkiye'de STEM eğitimini desteklemek için çeşitli üniversiteler STEM merkezleri kurarak öğretmenler ve öğrenciler için proje ve eğitimler düzenlemektedir ancak bu üniversitelerin sayısı sınırlıdır (MoNE, 2016a). Türkiye'deki STEM eğitimi uygulamalarına bakıldığında okul seviyesi, okul türü ve öğretmen özellikleri nedeniyle farklılıkların olduğu gözlemlenmekte (Corlu, Capraro, & Capraro, 2014). Yıldırım ve Selvi'nin çalışması (2016) gösteriyor ki aday öğretmenler STEM eğitimi hakkında yeterince bilgi ve beceri sahibi değil, STEM ile ilgili kavram yanılgıları var. STEM eğitiminin Türkiye'deki durumuna bakıldığında başlangıç adımları atılmış olsa da daha kapsamlı uygulamalara ihtiyaç duyulduğu görülüyor.

Yapılan araştırmalar gösteriyor ki STEM eğitimi öğrencilerin ilgili derslerdeki performanslarını olumlu yönde etkiliyor. Robotik kurslarına katılmanın ortaokul öğrencilerinin başarı düzeylerinin artmasını sağladığı (Barker & Ansorge, 2007; Sullivan, 2008), derste veya ders dışında mühendislik tasarım sürecinini uygulamak öğrencilerin alan bilgisi ve bilimsel okuryazarlık konularında gelişim göstermesini yardımcı olduğu (Apedoe, et al., 2008, Rikowski, et al., 2009), STEM eğitimi almanın öğrencilerin fen, matematik ve okuma gibi alanlarda akademik başarısının arttırdığı (Cotabis, et.al., 2013; Olivarez, 2012), yapılan çalışmalarla ortaya konmuştur.

STEM eğitim reformunun odaklarından biri de etkili tekoloji eğitimidir. Mobil teknolojilerin özellikleri düşünüldüğünde, bu teknolojilerin STEM eğitim süreçlerine uygun bir şekilde entegre edilmesi önem taşımaktadır. Mobil öğrenme genellikle öğrenme, mobil araçlar ve bunların etkileşimini içine alacak şekilde tanımlanır (Kearney, et al., 2012). Frame modeli ile mobil öğrenme araç, öğrenci ve sosyal açı olacak şekilde çerçevelenmiştir (Koole, 2009). Mobil öğrenmenin pedagojisi üç başlıkta açıklanabilir: otantiklik, işbirliği ve bireyselleştirme (Kearney et al., 2012). Mobil öğrenme, eğitim için önemli katkılar sağlar ancak STEM eğitiminin özgün ihtiyaç ve taleplerini de karşılayacak potansiyele sahiptir (Krishnamurthi & Richter, 2013). STEM eğitimi ve mobil öğrenme benzer pedagojik yaklaşımlara sahiptir; problem odaklı öğrenme, otantik öğrenme, öğrenci-odaklı öğrenme ve işbirlikli öğrenme bu pedagojilerdendir. Mobil uygulamalardan STEM eğitimi kapsamında faydalanılması çeşitli pilot projelerde araştırılmış olsa da müfredat planları bütün seviyeler için sınırlıdır (Becker & Kyungsuk, 2011). Mobil uygulamaların eğitim çerçevesinde değerlendirilmesi amacıyla çeşitli çalışmalar yapılmıştır (Ahmed & Parsons, 2013; Baran, Uygun, & Altan, 2017; Economides & Nikolaou, 2008; Green, Hechter, Tysinger, & Chassereau, 2014; Huang & Chiu, 2015; Vavoula & Sharples, 2009; Walker, 2013). Bu çalışmada temel alınan PTC3 değerlendirme ölçeği Baran ve diğerleri tarafından eğitsel mobil uygulamaların değerlendirilmesinde bir ortak dil oluşturabilmek adına geliştirilmiştir ve beş kategoriden oluşmaktadır: pedagoji, teknik açıdan kullanılabilirlik, içerik, bağlantısallık ve bağlamsallık.

Bu çalışma nitel ağırlıklı çoklu yöntem araştırma deseni ile,STEM eğitimi kapsamında mobil uygulamaların değerlendirilmesinin öğretmenlerin bakış açısıyla incelenmesi amacıyla yürütülmüştür. Araştırmada kar topu örneklem uygulanmıştır. Katılımcılar Türkiye'nin farklı şehirlerinde, devlet veya özel okullarda, farklı yerleşim yerlerinde görev yapan fen bilimleri ve bilişim teknoloji öğretmenleridir. Araştırmaya katılan öğretmenler STEM eğitimi kapsamında mobil uygulama kullanımı ile ilgili öğretme deneyimine sahiptir. Araştırma verileri, ilk ve orta seviyeli okullarda görev yapan 10 öğretmen ile yapılan görüşmeler yoluyla toplanmıştır. Görüşme formu hem nitel hem de nicel veri elde edebilmek adına üç bölümden oluşmaktadır: demografik bilgi formu, yapılandırılmış görüşme soruları ve değerlendirme formu. Çalışmanın veri toplama süreci PTC3 değerlendirme kriterlerinin Türkçe'ye çevrilmesi, çevirinin uzman görüşüne sunulması, görüşme formunun hazırlanması, formda yer alan soruların ve değerlendirme kriterleri için uzman görüşü alınması, pilot uygulama, görüşme formuna son halinin verilmesi, öğretmenlerle görüşmelerin yapılması şeklinde gerçekleştirilmiştir. Data analizi hem nitel hem de nicel verilerin incelenmesini kapsamaktadır. Nitel veri öğretmenlerin STEM eğitimi ve bu kapsamda mobil uygulama kullanımı, STEM eğitiminde mobil uygulama seçerken dikkat edilecek ölçütler ve PTC3 kriterleri ile ilgili görüşlerini ortaya çıkarmak için toplanmış ve temalara ayrılarak, MAXQDA yazılımı üzerinde oluşturulan veri tabanı ile analiz edilmiştir. Nicel veri ise değerlendirme formunda yer alan PTC3 kriterlerinin ve seçilen mobil uygulamaların değerlendirilmesi için kullanılmış, Microsoft Excel program kullanılarak betimleyici istatistikler elde edilecek şekilde analiz edilmiştir.

Araştırma sonuçları öğretmenlerin STEM eğitimini tanımlarken, azalan bir sıklıkla, disiplinlerarası olma, ürün geliştirme, aktif öğrenme, STEM disiplinlerinde okur-yazar olma, işbirliği, tasarım süreci, problem çözme, gerçek hayat bağlantısı, sorgulama ve sanat kavramlarının üzerinde durduğunu göstermektedir. STEM eğitiminin öğrencilere faydaları akademik başarı, olumlu tutum, beceri gelişimi ve motivasyon olarak belirtilmiştir. Öğretmenlere ise mesleki haz ve mesleki gelişme yönünden katkı sağladığı üzerinde durulmuştur. STEM eğitiminin topluma katkıları, ülkenin geleceği için ihtiyaç duyulan bireyler yetiştirmek, ülke olarak gelişmek, toplum sorunlarına çözüm bulmak ve ekonomiyi geliştirmek olarak ifade edilmiştir. Öğretmenler mobil uygulamaları STEM eğitimi kapsamında değerlendirme, öğrenci ürünü toplama, öğrenci takibi, içerik sunma, bilimsel ölçümler yapma, içerik ve eğitsel ürün oluşturma amaçlarıyla kullandıklarını belirtmiştir. Çalışmanın sonuçları gösteriyor ki öğretmenler mobil uygulamaların soyut kavramları somutlaştırma, ilgi ve motivasyonu arttırma, diğer öğrenci ve öğretmenlerle iletişim kurma, paylaşımda bulunma, içeriğe ulaşma, zaman ve yerden bağımsız özerk öğrenme, daha az zaman harcama özellikleri eğitime olumlu etkileri olarak görülmektedir.

Öğretmenlere STEM eğitimi kapsamında mobil uygulama seçerken dikkat ettikleri ölçütler sorulduğunda, azalan bir sıklıkla, PTC3 değerlendirme kategorilerinden pegagoji, teknik açıdan kullanılabilirlik, içerik, bağlantısallık ve bağlamsallık categorilerine ait ölçütlerin önerildiği ortaya çıkmıştır. Bunun yanında, öğretmenlerin uygulama seçerken disiplinler arası çalışmayı desteklemesi, kolay erişim, öğretmen müdahalesine izin verme, ücretsiz kullanım, zaman kazandırma, internetten bağımsız çalışma, diğer donanımlara bağlanabilme, oyunlaştırma ve problem çözme etkinlikleri, birden fazla dil seçeneği bulundurma, küresel olarak kullanımla özelliklerini de göz önünde bulundurduğu belirtilmiştir.

PTC3 değerlendirme ölçütleri, bütün disiplinlerin eğitimi ve STEM eğitimi bağlamında önem sırasına konulduğunda en önemli görülen kategorilerin sırayla içerik, pedagoji ve teknik açıdan kullanılabilirlik olduğu sonucuna ulaşılmıştır. Bunun yanında, bağlantısallık bütün disiplinler için bakıldığında en son sırada yer alırken, STEM eğimi özelinde bakıldığında son sırada yer alan kategori bağlamsallıktır. Öğretmenlerin bütün kriterler için yaptıkları puanlama incelendiğinde, pedagoji kategorisinde, eğlenceli bir öğrenme ortamı sunma ve öğrencilerin kendi hızlarında öğrenmelerine izin verme bütün öğretmenler açısından çok önemli görülmüştür. Teknik açıdan kullanılabilirlik kriterleri için bir arama seçeneği içerme, açık semboller ve bağlamı destekleyen bir arayüz sunma, hataları önleme ve kurtarma kriterleri hariç bütün kriterler çok önemli olarak puanlanmıştır. İçerik için öğretim programına uygunluk, doğru ve güncel olma, uygun şekilde sıralanma kriterlerine önem verildiği puanlama sonuçları ile ortaya çıkmıştır. Bağlantısallık kategorisi için paylaşım ve iletişim özellikleri önemli görülmüştür. Bağlamsallık kategorisi için gerçek hayat bağlamı ve otantiklik önemli görülmüştür. Öğretmenlerin sıklıkla kullandıkları mobil uygulamaların puanlamaları incelendiğinde Plickers, Anatomy 4D, Elements 4D, App Inventor, Quiver, Scratch, Edmodo, Phet Colorado, Google Classroom uygulamalarının genellikle PTC3 kriterlerinin çoğunu karşıladığı görülmektedir ancak Plicker ve Edmodo gibi içeriğin öğretmen tarafından hazırlandığı, genellikle değerlendirme için kullanılan mobil uygulamalar için içerik kategorisi kriterleri çoğunlukla değerlendirme dışı olarak işaretlenmiştir.

Araştırmada yer alan öğretmenlerin çoğu STEM etkinliklerini probleme dayalı şekilde uyguladığını belirtmiştir. Çok az sayıda öğretmen STEM çalışmalarını dönem boyunca devam eden projeler halinde yürüttüğünü ifade etmiştir. Bu sonuçlar STEM eğitiminin genellikle probleme dayalı, proje tabanlı veya tematik pedagojilere dayandığı ifadesii desteklemektedir (Heil, Pearson, & Burger, 2013) Öğretmenlerden sadece özel okullarda çalışan bir kaçı STEM uygulamalarını sistematik bir şekilde planlanan, haftalık toplantılar ve diğer branşlardan öğretmenlerleiş birliği içinde yürüttüğünü dile getirmiştir. Bu durum etkili STEM eğitimi için okullara öğretmenlerin işbirlikli çalışması konusunda rehberlik ve desteğin verilmesi ihtiyacını ortaya çıkarmıştır. Çünkü Figliano (2007), etkili STEM eğitimi için derslerin farklı branş öğretmenlerinin işbirliki çalışması ve disiplinlerarası bağlantıların kurulmasını desteklemeye yönelik uygulamaların gerçekletirilmesi üzerinde durmuştur. Öğretmenler STEM eğitimini tanımlarken disiplinlerarası olma, ürün geliştirme, STEM disiplinler okuryazarlığı, işbirliği üzerinde durmuştur. Disiplinlerarası yaklaşım yaygın STEM tanımı ile örtüşmektedir (Gonzalez & Kuenzi, 2012). STEM eğitimini tanımlarken öğretmenlerin kullandığı kavramlar Turner tarafından (2013) yapılan çalışmada eğitim uzmanlarının tanımları ile benzerlik göstermektedir. Öğretmenlerden biri STEM eğitimini tanımlardan sanat kavramı üzerinde durmuştur. Bu durum STEM kısaltmasına sanat (art) kelimesinin baş harfi getirilerek oluşturulan ve STEM eğitiminde sanatın da vurgulanması gerektiğini savunan STEAM yaklaşımının etkisini göstermektedir (Bequette & Bequette, 2012). Öğretmenler tarafından belirtilen STEM eğitiminin öğrencilere katkıları Morrison'un (2006) açıkladığı STEM'in temel katkıları ve National Research Council (NRC) (2011) tarafından açıklanan etkili STEM eğitiminin öğrenciye bilgiyi uygulamaya dönüştürme adına kattıklarıyla tutarlılık göstermektedir. STEM eğitiminin öğretmenlere ve topluma faydaları, daha önce yapılan çalışmalar ile benzerlik göstermektedir. Öğretmenler mobil uygulamaları STEM eğitimi kapsamında değerlendirme, içerik sunma, ölçüm yapma, vb. gibi amaçlar için kullandığını belirtmiştir. Loui ve çalışma arkadaşları (2015), mobil uygulamaların matematiksel düşünmeyi desteklemek için ilkokul düzeyindeki derslere nasıl entegre edilebileceğini mobil uygulamaların özellikleri, öğrenme ortamı, bireysel ve kurumsal destek kavramlarının üzerinde durarak açıklamıştır. Bu yönergeler STEM eğitiminde mobil uygulamaların etkili bir şekilde entegre edilmesi konusunda yol gösterici olabilir. Öğretmenlerin STEM eğitimi kapsamında mobil uygulama seçerken göz önünde bulundurduğu kriterler incelendiğinde pedagoji kategorisine ağırlık verildiği ortaya çıkmıştır. Bu sonuç Green ve arkadaşlarının (2014) öğretmenlerle yaptığı çalışma ile benzerlik göstermektedir. STEM eğitimi için önemli görülen gerçek yaşam bağlamını bulunduran bağlamsallık kategorisi, bu durumla çelişkili olarak STEM eğitimi kapsamında mobil uygulama seçerken göz önünde bulundurulacak kriterler sıralamasında sonda yer almaktadır. Bunun nedeni, günümüzde var olan mobil uygulamaların problem çözme odaklı olmamasıdır (Walker, 2013). PTC3 değerlendirme kriterleri arasında yer almayan kolay erişim ve ücretsiz kullanım Walker'ın (2013) ERMA (Evaluation Rubric for Mobile Apps) isimli değerlendirme aracının geliştirilmesi için eklenmesi önerilen kriterler arasında yer almaktadır. Bunun yanında, öğretmenlerin mobil uygulamaları STEM eğitimi kapsamında değerlendirirken göz önünde bulundurdukları kriterler Economides ve Nicolaou (2008) tarafından ortaya koyulan mobil cihazların eğitsel amaçlarla kullanılırken dikkat edilmesi beklenen kriterlerle örtüşmektedir, bu kriterler üç ana başlık altında toplanmıştır: kullanılabilirlik, teknik ve işlevsel. Araştırmadaki öğretmenler tarafından önerilen ancak PTC3 değerlendirme kriterleriyle eşleşmeyen kriterlere bakıldığında ortak noktalar görülmektedir. Öğretmenlerin bütün dersler ve STEM eğitimi için mobil uygulama değerlendirirken en önemli gördükleri üç kategori ortaktır: içerik, teknik açıdan kullanılabilirlik ve pedagoji. Bunun yanında, eğitimin geneli için dördüncü sıradaki kategori bağlamsallık, STEM eğitimi içinse bağlantısallıktır. Bu farklılığın nedeni STEM eğitiminde iletişim ve işbirliğine vurgu yapılması olabilir. Baran ve çalışma arkadaşları (2017) tarafından yapılan araştırma sonucunda ise aday öğretmenlerin içerikten daha çok pedagoji kategorisine önem verildiği görülmüştür. Bu çalışma kapsamında fen bilimleri ve bilişim teknolojileri öğretmenlerinin STEM eğitimi kapsamında kullandıkları güncel mobil uygulamalar PTC3 değerlendirme kriterlerine göre değerlendirilmiştir. Bunun sonucunda içeriğin öğretmen tarafından oluşturulduuğu mobil uygulamalar, içerik kategorisinde değerlendirme dışı olarak not edilmiştir.

Araştırma sonuçlarının hem mobil öğrenme hem de STEM eğitimi literatürüne katkı sağlaması beklenmektedir ancak ileriki araştırmaları doğru yönlendirmek adına çalışmanın kısıtlamalarına yer verilmesi anlamlı olacaktır. Öncelikle araştırmanın katılımcılarını seçerken belirlenen ölçütler çok kısıtlı bir sayıda katılımcı ile yürütülmesine sebep olmuştur. Günümüzde Türkiye'de STEM eğitimi yeni uygulanmaya başlanan bir model olduğu için, mobil cihaz kullanımı bütün okullarda yaygın bir şekilde uygulanmadığı için STEM eğitimi kapsamında mobil uygulamalar kullanan öğretmenlerin sayısı sınırlıdır. Fen bilimleri ve bilişim teknolojileri dersi öğretmenleri dışında da katılımcılar ile çalışılması konunun farklı boyutlarının da ortaya çıkarılmasını sağlayacaktır. Bunun yanında, araştırmada yer alan öğretmenler STEM eğitimini ve mobil uygulamaları farklı bağlamlarda uygulamaktadır. Öğretmenlerin çalıştığı okulların sunduğu imkanlar, STEM eğitimi kapsamında uygulanan öğretim yöntemleri ve teknolojik donanım da çeşitlilik göstermektedir. Bu durum hem STEM algısı hem de mobil uygulama kullanımı ve değerlendirilmesi noktalarında çeşitliliklere sebep olmuştur. Son olarak, öğretmenler öncesinde görüşmenin tahmini süresi hakkında bilgilendirilmiş olsa da, uzun süren görüşmelerde öğretmenleri konuya odaklı tutmak konusunda zorluklar yaşanmıştır.

Bu araştırmadan elde edilen veriler, gelecek araştırmalarına farklı noktalarda katkı sağlayabilir. Öncelikle öğretmenlerin STEM eğitimini uygularken kullandıkları farklı yöntemler ayrıntılı bir şekilde incelenebilir. Araştırma kapsamında ortaya konan, öğretmenlerin STEM algısı aday öğretmenlerle çalışılarak incelenebilir, benzerlik ve farklılıklar, bu durumlara sebep olabilecek unsurlar araştırılabilir. Öğretmenlerin öne sürdüğü, STEM eğitiminin öğrencilere, öğretmenlere ve topluma katkıları uzun dönem projelerle daha ayrıntılı bir şekilde incelenebilir. STEM eğitimi kapsamında mobil uygulamaları değerlendirirken dikkate alınacak kriterler farklı disiplinlerden öğretmenlerin katkılarıyla zenginleştirilebilir veya tekrar düzenlenebilir. Mobil teknolojiler sürekli geliştiği için, ortaya çıkan farklı özellikte uygulamaların değerlendirilmesi için araştırma sonuçlarından faydalanılabilir. Bunun yanında, öğretmenlerin açıkladığı STEM eğitimi uygulamaları diğer eğitim personeli tarafından kullanılarak doğru öğrenme yaşantılarının hazırlanmasında kullanılabilir. Mobil uygulamalardan beklenen özellikler göz önünde bulundurularak teknoloji şirketleri amaca, ihtiyaca ve talebe uygun mobil uygulamalar geliştirebilir. En önemlisi, araştırma sonuçları STEM eğitimi kapsamında mobil uygulama kullanan öğretmenlere rehberlik ederek doğru uygulamaların kullanılması, öğrencilere anlamlı öğrenme yaşantılarının sunulması, eğitsel mobil uygulamaların amaca uygun bir şekilde değerlendirilmesi noktalarında rehberlik edebilir.

APPENDIX D: TEZ FOTOKOPİSİ İZİN FORMU

ENSTİTÜ

Fen Bilimleri Enstitüsü ☐

Sosyal Bilimler ■

Uygulamalı Matematik Enstitüsü ☐

Enformatik Enstitüsü ☐

Deniz Bilimleri Enstitüsü ☐

YAZARIN

Soyadı : Tantu

Adı : Özlem

Bölümü : Eğitim Programları ve Öğretim

TEZİN ADI (İngilizce) : Evaluating Mobile Apps for STEM Education with In-service Teachers

TEZİN TÜRÜ: Yüksek Lisans ■ Doktora ☐

1. Tezimin tamamından kaynak gösterilmek şartıyla fotokopi alınabilir. ■

2. Tezimin içindekiler sayfası, özet, indeks sayfalarından ve/veya bir bölümünden kaynak gösterilmek şartıyla fotokopi alınabilir. ☐

3. Tezimden bir (1) yıl süreyle fotokopi alınamaz. ☐

TEZİN KÜTÜPHANEYE TESLİM TARİHİ