DESIGN, DEVELOPMENT AND EVALUATION OF A TANGIBLE MOBILE APPLICATION FOR STUDENTS WITH SPECIFIC LEARNING DISABILITIES

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I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

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ABSTRACT

DESIGN, DEVELOPMENT AND EVALUATION OF A TANGIBLE MOBILE APPLICATION FOR STUDENTS WITH SPECIFIC LEARNING DISABILITIES

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Tangible objects used with multi touch tablets have a potential to enrich learning experience of students with specific learning disabilities. Providing multi-sensory interaction, physical engagement, accessibility, and collaboration can open a new learning way for students with specific learning disabilities (SLD). It can be ensured by well-designed tangible applications undoubtedly. The main purpose of this study was to determine design principles of a tangible mobile application for students with SLD and to examine the effectiveness of the tangible mobile application on the students' achievement.

Design-based research was employed in order to determine design principles for tangible mobile application for students with SLD by investigating special education experts' /science education expert's, teachers', and students' opinions. In addition, a single subject research design was performed in order to investigate the effectiveness of the tangible mobile application on students' achievement in 6^{th} grade cell concept. Usability issues about tangible mobile application by students and the reflections of special education teachers after using the tangible mobile application on students with SLD were examined by using observation and implementation.

Overall, the result of the study showed that: 1) 33 design principles of tangible mobile application in four categories –educational content, visual design, tangible object use and interaction- were determined for students with SLD. 2) Tangible mobile application was effective. 3) Students with SLD were willing to use tangible mobile application, they liked it and they use it easily. 4) Teachers thought that tangible mobile application is easy to use and useful for both teachers and students.

Keywords: Tangible Technologies, Tangible Mobile Applications, Specific Learning Disabilities, Design Principles

ÖZ

ÖZEL ÖĞRENME GÜÇLÜĞÜ YAŞAYAN ÖĞRENCİLER İÇİN KAVRANABİLİR BİR MOBİL UYGULAMA TASARIMI, GELİŞTİRİLMESİ VE DEĞERLENDİRİLMESİ

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Çoklu dokunmatik tabletler ile kullanılan kavranabilir nesneler özel öğrenme güçlüğü (ÖÖG) yaşayan öğrencilerin öğrenme deneyimlerini zenginleştirmede önemli bir potansiyele sahiptir. Çok-duyulu etkileşim, fiziksel katılım, erişilebilirlik ve işbirliği sağlanmasıyla kavranabilir teknolojiler ÖÖG yaşayan öğrenciler için yeni bir öğrenme yolu açabilir. Bu, şüphesiz iyi tasarlanmış kavranabilir uygulamalarla sağlanabilir. Bu çalışmanın temel amacı ÖÖG yaşayan öğrencilere yönelik geliştirilecek kavranabilir mobil bir uygulamanın tasarım prensiplerini belirlemek ve uygulamanın özel öğrenme güçlüğü yaşayan öğrencilerin öğrenmelerindeki etkisini incelemektir.

ÖÖG yaşayan öğrenciler için geliştirilecek kavranabilir mobil uygulamanın tasarım prensiplerini konu alanı uzmanları, öğrenciler ve öğretmenlerin görüşleri ışığında belirlemek için tasarım tabanlı araştırma kullanılmıştır. Ayrıca, kavranabilir mobil uygulamanın 6. sınıftaki hücre konusunda öğrencilerin başarısı üzerinde etkililiğinin

araştırılması için, tek denekli araştırma deseninin altında denekler arası çoklu yoklama modeli kullanılmıştır. Öğrenciler tarafından kullanılan kavranabilir uygulamanın kullanılabilirlik durumu ve özel eğitim öğretmenlerinin kavranabilir mobil uygulamayı kullandıktan sonraki yansımaları (görüşleri) gözlem ve uygulama yoluyla toplanmıştır.

Genel olarak, çalışmanın sonuçları: 1) ÖÖG yaşayan öğrenciler için geliştirilen kavranabilir mobil uygulamanın dört kategoride –eğitsel içerik, görsel tasarım, kavranabilir nesne kullanımı ve etkileşim- 33 tasarım prensibi belirlenmiştir. 2) Kavranabilir mobil uygulama etkilidir. 3) ÖÖG yaşayan öğrenciler kavranabilir mobil uygulamayı kullanmaya isteklidir, uygulamayı sevmiştir ve kolaylıkla kullanmışlardır. 4) Öğretmenler kavranabilir mobil uygulamanın kullanımını kolay ve öğretmen ve öğrenciler için yararlı bulmuştur.

Anahtar Kelimeler: Kavranabilir Teknolojiler, Kavranabilir Mobil Uygulamalar, Özel Öğrenme Güçlükleri, Tasarım Prensipleri

To my family, especially my MOM and my HUSBAND.

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CHAPTER 1

INTRODUCTION

This chapter presents background of the study, statement of the problem, purpose of the study, significance of the study, statement of research questions, definitions of terms, and organization of the study.

1.1 Background of the Study

In general, educational settings, there are students who cannot perform at expected level of achievement who are called as students with specific learning disabilities (SLD). According to NJCLD (National Joint Committee on Learning Disabilities) (1990) specific learning disability is a term, which manifests itself with difficulties in writing, reading, arithmetic, speech, and reasoning in general.

Specific learning disabilities are manifested throughout school years with learning demand or as unexpected low performance of an intelligent or gifted student in standardized tests. In addition, students with specific learning disability have permanent difficulties in reading, writing, and mathematics as academic skills. Besides, they have specific and lifelong deficits in processing/perceiving information accurately. They can succeed or not succeed these skills with an exceptional endeavor (APA (the American Psychological Association), 2013). Similarly, Korkmazlar (2003) defined special learning disabilities as the situation in intelligent or gifted individuals who exhibit lower academic performance than below their age and intelligence. They have significant deficiencies in acquiring and using some academic skills such as reading, writing, arithmetic, listening, reasoning and secondarily have self-management, social cohesion and interaction problems. On the other hand, they do not have pronounced brain-related diseases, primary mental illnesses or sensory deficiencies. In the related literature, different classifications can be seen for specific learning disabilities. Dyslexia, dyscalculia, and dysgraphia are commonly used for classifications. APA (2013) defined dyslexia as reading difficulties (difficulties with pace, accuracy, and comprehension), dyscalculia as mathematics deficits (difficulties with calculation, and mathematic reasoning), dysgraphia (impairment in writing) as difficulty in accuracy in writing, proficiency in written expression. Students with learning disabilities exhibit diverse and different characteristics. However, it is possible to mention some common characteristics of students with learning disabilities in academic, social, and cognitive domains.

There are different estimates regarding the prevalence of specific learning disabilities. In addition, it varies from one country to another. However, in terms of illustrating the current situation, various estimates are presented. In the USA public schools, it is indicated that approximately 5% of children, are diagnosed with specific learning disabilities. According to APA (2013), 5% to 15% of school age children who are from different cultures and different countries have specific learning disabilities (dyslexia, dyscalculia, and dysgraphia). Though not known exactly, it is estimated that 4% of adults have specific learning difficulties. IDEA (Individuals with Disabilities Education Act) (2014) reveals that prevalence of children with specific learning disabilities between the ages of 3 and 21 is 35% of special educational needs. OECD (Organization for Economic Co-operation and Development) (Robson, 2005) reveals that the ratio of specific learning disabilities varies across 11 different countries. While the highest percentage belongs to the USA, the lowest percentage belongs to Turkey. It can be interpreted by referring to the presented data that the prevalence of specific learning disabilities ranges from 0.01% to 6%. One possible reason for this low rate in Turkey is that, teachers and parents do not have awareness and sufficient knowledge about specific learning disabilities (Polat, Adıgüzel & Akgün, 2012). Hence, students were highly probably not being diagnosed with specific learning disabilities. OECD (2009) reports that the ratio of students with specific learning disabilities across Baltic countries ranges from 0.06% to 4.08% in compulsory education. As it is seen, there are many students with SLD with their growing needs in the education system. One of the interventions to meet these needs is making use of educational technology. However, traditional computer-assisted instruction applications remain insufficient for providing physical engagement and multisensory interaction for this target group. With the new emerging technologies, tangible objects used with multi touch tablets have a potential to enrich learning experiences of students with SLD.

Tangible technologies aim to provide interaction with the physical and digital environment without using the traditional input and output devices such as monitor, mouse, and keyboard (Ullmer & Ishii, 2000). Instead of pressing to keys, for interaction with the computer by using physical motion makes interface closer to the real world (Jacob et al., 2008). Fishkin (2004) states that the steps of interaction between tangible real world object and computer interface system are: 1) giving some inputs to computer system via physical movements 2) understanding the input by computer system 3) giving feedback to the user taking input into account. Eisenberg et al. (2003) underline that tangible technology does not reduce the value of educational technology used today, but ensuring interaction with the real world object is difficult for computer based educational systems. Decreasing the isolation between the virtual and the concrete world opens new doors for instructional designers to be able to make a more realistic design beyond computer-assisted materials.

Although aforementioned computer assisted instruction offers opportunities for facilitating learning for students with SLD, it remains limited especially in physical interaction. In line with this, Keay-Bright (2008) emphasize that many positive outcomes have come out for using ICT in learning difficulties, however, technologies used in sensory action, that help to facilitate creative and flexible thinking as well as collaborative learning, are still few in number. Thus, an emerging area of research is the use of tangible technology to support special education (Shaer & Hornecker, 2010). Falcão and Price (2010) state that with the development of new technology, tangible technologies provide extending opportunities for multi-sensory interaction for students with learning difficulties. Moreover, tangible technologies make learning environment richer than a traditional graphical user interface system by offering opportunities in cognitive, social, and linguistic learning for special education (Shaer & Hornecker, 2010).

There exist some teaching strategies and methods in the literature to facilitate learning of student with SLD (e.g. multiple sensory-based approach (MONE (Ministry of National Education), 2008) or collaboration-based approach (Sucuoğlu & Kargın, 2006). Tangible technologies can increase the probability of supporting these instructional strategies.

In the light of literature, the use of tangible technology in special education as well as general education is seen increasingly becoming more important. However, few research studies have yet revealed the use of tangible technologies for students with SLD. Nascent research focus on dyslexia to support reading by developing a tangible interface with different technologies (Antle, Fan & Cramer, 2015; Fan & Antle, 2015; Pandey & Srivastava, 2011a, 2011b). To the best of our knowledge, there has been only one similar study (Kara, 2015) conducted in Turkey despite differences in the target audience and the technology used, yet no existing empirical research in Turkish literature addresses the use of tangible technologies for students with SLD. There is an insufficient amount of theoretical and empirical studies about the usage of tangible technologies. As a result, studies are based on few design principles.

1.2 Statement of the Problem

The number of students with specific learning disabilities has been diagnosed more each day with the introduction of alternative methods. There has been a growing awareness of students with specific learning disabilities on parents, teachers, and counselors especially in the last few years. However, these children may have been neglected in mainstream classes. Hutinger (1996) and Florian (2004) emphasized ways in which instructional technologies support their academic and social integration in a class setting. The needs of these students could be answered through a multi-disciplinary approach, incorporating educational technology, special education, psychology, and other disciplines. Nevertheless, only a limited number of studies investigated the problem of student with SLD from a multi-disciplinary lens as well as developing a tangible technology that serves as a facilitator for their learning.

As can be seen in the background of problem section, the first problem is the lack of design principles of a tangible mobile application for students with SLD. The second problem is the lack of literature and insufficient empirical evidence about tangible mobile application for students with SLD. Derived from the needs of the students with SLD revealed both by the teachers at schools and the limited data in the scholarship, unique studies should be developed to enable students with SLD to get involved more in the classroom activities and to take an active part in the learning process. This study looks at the problems from the lenses of educational technology and special education and aims to bring a model that could help students with SLD to learn concept better. As well, this study is expected to serve as a road map for instructional designers as it could be seen in the remaining parts of this study.

1.3 Purpose of the Study

The main purpose of this study is to determine the design principles of tangible mobile application for students with SLD and to examine the effectiveness of a tangible mobile application on students' achievement in 6^{th} grade cell concept.

1.4 The Significance of the Study

Students with SLD and their needs has become one of the main priorities in the educational system. Traditional computer-assisted instruction applications fail to meet the changing needs of these children and the new systems are expected to cultivate their multi-sensory interaction as well as creating a physical engagement. In this context, tangible objects used with multi touch tablets have a potential to enrich learning experiences of students with SLD.

Tangible technologies serve as one of the instruments that could be used for the students with SLD. Only a few number of studies investigated the use of tangible technologies and the ways in which they provide remedies for the learning difficulties for the children with SLD (Antle et al., 2015; Fan & Antle, 2015; Pandey

& Srivastava, 2011a, 2011b). It should also be noted that there has been only one similar study conducted in Turkey applied on different target audience (Kara, 2015). Turkish literature lacks both theoretical and empirical evidence that addresses the use of tangible technologies for students with SLD. Marshall (2007) underlines the infancy of using tangible technology for learning and adds that most of the research concentrate on developmental studies in a technical way. There is an insufficient amount of theoretical and empirical studies about the usage of tangible technologies. Because of the fact Marshall (2007) acknowledges, studies are based on few design principles. The need for further research is to identify which elements and features of tangible interfaces are critical in learning environment. It is obvious that there is an emerging need to determine design principles of tangible mobile applications for students with SLD.

In the present study, special education experts', teachers', and students' opinions about the tangible mobile application for students with SLD were carefully investigated. Design principles for tangible mobile application for students with SLD were determined by investigating special education experts', teachers', and students' opinions. It is thought that the findings of this study may be enlightening for teachers to use tangible mobile applications and for practitioners to design and develop similar applications.

Although some tangible technologies for students with SLD have been developed to date (Antle et al., 2015; Fan & Antle, 2015; Pandey & Srivastava, 2011a, 2011b), there is still an insufficient amount of empirical research as mentioned above. This study examined the effectiveness of the tangible mobile application on students' achievement in 6th grade cell concept. In this respect, this study is expected to provide empirical evidence for both educational technology and special education fields.

Overall, this study might be pioneer in special education field and contribute to both educational technology and special education literature by determining design principles and investigating the effectiveness of tangible mobile applications for students with SLD. This study can open a path to use tangible mobile applications in special education field. The findings of the study might provide useful information from the basis of practice and theory. This study is expected to provide teachers, administrators, parents, researchers, and designers with the practical information that could be used in their learning settings. The study sought answers to the research questions below.

1.5 Research Questions

1. What are the design principles of a tangible mobile application for students with SLD?
2. Is the tangible mobile application effective on students' achievement in the 6th grade cell concept?
3. What are the reflections of special education teachers after using the tangible mobile application on students with SLD?

1.6 Definition of Terms

Specific Learning Disabilities: Specific learning disabilities are manifested in school years with learning demand or as unexpected low performance of an intelligent or gifted student in standardized tests. In addition, students with specific learning disability have permanent difficulties in reading, writing, and mathematics as academic skills. Besides, they have specific and lifelong deficits in processing and perceiving information accurately. They can succeed or not succeed these skills with exceptional endeavor (APA, 2013).

Tangible Mobile-Based Application: It is an educational tablet application, which provides interaction with tangible objects.

1.7 Organization of the Study

Chapter 1 presents background of the study, statement of the problem, purpose of the study, significance of the study, statement of the research questions, definitions of terms, and organization of the study. Chapter 2 presents the review of the related literature. Chapter 3 presents the methodology of the study. Chapter 4 reports finding of the study. Finally, Chapter 5 presents discussion of the findings, conclusion, suggestions, and limitations.

CHAPTER 2

LITERATURE REVIEW

2.1 Definition of Specific Learning Disabilities

The definition of specific learning disabilities varies enormously. Before 1940s, it was thought that a student with specific learning disabilities had mental retardation or emotional problems or cultural and social disadvantages. In early 1940s, minimal brain damage was added as the fourth category (Silver, 2010). Although students with SLD could not be defined as brain damaged individuals by neurologists, in 1940s and 1950s they were defined so. At a conference in 1963, Kirk used the term of learning disability and emphasized that children with learning disabilities have disorders in reading, language, and speech. On the other hand, these children do not have blindness or deafness or mental retardation (Kirk, 1977).

Hammill (1990) discussed 11 definitions of learning disabilities and found that contrary to what is commonly accepted, an agreement on the definition was seen and NJCLD (1997) made one of the most widely accepted definition. According to NJCLD (1990) learning disability is a term, which manifests itself with difficulties in writing, reading, arithmetic, speech, and reasoning in general.

In addition to the definition of NJCLD (1990), IDEA (2004) defined specific learning disability as having any disorder in one or more psychological processes including to understand or use verbal or written language. The term covers perceptual defiance, minimal brain injury, dyslexia, and developmental aphasia while it does not cover primarily visual, auditory, kinesthetic, mental, or emotional disabilities or learning difficulties emerging because of negative environment.

In some definitions, expressions such as learning difficulties or learning disorders instead of learning disabilities are preferred. With a broader definition, specific learning disabilities are manifested in school years with learning demand or as unexpected low performance of an intelligent or gifted student in standardized tests. In addition, students with specific learning disability have permanent difficulties in reading, writing, and mathematics as academic skills. Besides, they have specific and lifelong deficits in processing and perceiving information accurately. They can succeed or not succeed these skills with exceptional endeavor (APA, 2013). Similarly, Korkmazlar (2003) defined special learning disabilities as the situation in intelligent or gifted individuals who exhibit lower academic performance than below their age and intelligence. Additionally, they have significant deficiencies in acquiring and using some academic skills such as reading, writing, arithmetic, listening, reasoning and secondarily have self-management, social cohesion, interaction problems. On the other hand, they do not have pronounced brain-related diseases, primary mental illnesses or sensory deficiencies. Overall, it may be said that an unexpected academic failure is the common point in these definitions.

2.2 Classification of Specific Learning Disabilities

In the literature, different classifications can be seen for specific learning disabilities. Under this title, dyslexia, dyscalculia, and dysgraphia that are commonly used will be covered.

APA (2013) defined dyslexia as impairment in reading, is a term including problems in reading fluency, accuracy, comprehension, and spelling. Dyslexia is unexpected difficulty in accurate and fluent reading, also correct spelling and word decoding although individuals with SLD have necessary factors such as age, intelligence, and motivation (Lyon, 1995; Lyon, Shaywitz & Shaywitz, 2003; Shaywitz, 1996; Shaywitz & Shaywitz, 2005; Shaywitz & Shaywitz, 2008). In addition, dyslexia has neurobiological origin (Lyon et al., 2003). Dyslexia is characterized by the difficulties in acquisition of reading, writing, and spelling; also, it has an impact on cognitive processes such as memory, attention, and time management (Reid, 2013).

Dyscalculia (impairment in arithmetic) is associated with problems in number sense, fluency in calculation, comprehending arithmetic facts, and math reasoning (APA, 2013). With another similar definition by Department for Education and Skills, dyscalculia is characterized by difficulties of acquisition in arithmetic skills such as number sense, number concept, number facts and procedures (DfES (the Department for Education and Skills), 2001). This definition underlines the “grasp of numbers”. In line with this, Butterworth (2005) claims that problems in dyscalculia occur because of the deficiency of intuitive grasp of numbers. Butterworth (2003), who has conducted a number of research about dyscalculia, called it as math blindness for the reason that dyscalculia affects acquiring arithmetic skills. One of pioneer researchers in the field of dyscalculia, Kosc (1974) says that dyscalculia is a specific mathematic disability although general mental disabilities are flawless. According to Butterworth (2005), dyscalculia, which causes low performance even in simple tasks such as counting and comparing numbers, is about fundamental difficulties in arithmetic skills including basic number concept.

Dysgraphia (impairment in writing) is defined as difficulty in accuracy in writing, and proficiency in written expression (APA, 2013). It manifests itself as poor and illegible handwriting (Simner & Eidlitz, 2000). Dysgraphia is a writing difficulty, which manifests itself with poor handwriting despite adequate instruction and practice (Hamstra-Beltz & Blöte, 1993).

Dyslexia, dyscalculia, and dysgraphia affect both academic and daily lives of students (APA, 2013). A child may have one or more than one of these disabilities (Myers & Hammill, 1976; Reid, 2011). Despite the classifications, some experts claim that the specific learning disabilities could be different for each child and even they may not be classified (Myers & Hammill, 1976).

2.3 Characteristics of Specific Learning Disabilities

Students with learning disabilities exhibit diverse and different characteristics. Observing the same features is not possible. It can be emphasized that each one is unique. However, it is possible to mention some common characteristics of students with learning disabilities. Under this title, academic, social, and cognitive characteristics, that are often exhibited, will be explained.

2.3.1 Academic characteristics

One of the most common features of students with learning disabilities is underachievement in acquiring reading and writing skills. In addition to failures in acquiring literacy skills, another common case is the difficulties in basic arithmetic (Alberta Learning and Teaching Branch, 2002; Larkin & Ellis, 2004; MacInnis & Hemming, 1995; Westwood, 2008). More specifically, students with SLD may display distractions, follow lines with finger, have physical stress (i.e. staying too close to text, yawning, reading too fast or too slow) compared to normal peers. In addition, they may have difficulties in using strategies to understand while reading texts. They exhibit lower performance in written exams and assignments than verbal ones. Furthermore, cramped pencil grip and illegible, reluctant and slow writing can be observed (Alberta Learning and Teaching Branch, 2002). During the process of learning, they tend to be dependent on others (MacInnis & Hemming, 1995). Using academic skills and learning strategies effectively is another problem observed in these students (Larkin & Ellis, 2004). Concerning the above-mentioned problems, they may not find school enjoyable (Reid, Elbeheri & Everatt, 2015).

Failures in both literacy and arithmetic may have a negative effect on all academic areas (Westwood, 2008). The failure rate of students in academic tasks is almost as much as the number of exams they took and assessment processes they went through (Sideridis, 2007). Thus, these students exhibit less positive attitude to new learning tasks (MacInnis & Hemming, 1995), frustrations and adverse attribution (Tsatsanis, Fuerst & Rourke, 1997). Moreover, experiences of repeated failures may lead to dropping out of school (Watson & Boman, 2005).

2.3.2 Social characteristics

In addition to the problems in the academic field, there are problems faced in the social field as well. There may be misreading in both nonverbal (Alberta Learning and Teaching Branch, 2002; Westwood, 2008) and verbal communication (Alberta Learning and Teaching Branch, 2002) in social interactions. They may also lack basic social skills. Students with SLD participate in social activities less compared to their peers and have difficulties in solving social problems they face (Westwood, 2008). Less social competence, unsuccessful social interactions, low self-esteem (Tsatsanis et al., 1997), difficulties in making and keeping friend, low self-worth perception, poor sense of humor, and learned helplessness (such as attributing getting high grades in exams to other things) are some other problems (Alberta Learning and Teaching Branch, 2002). Also participating in class discussions is not preferable by students with SLD (Alberta Learning and Teaching Branch, 2002).

2.3.3 Cognitive characteristics

As well as in academic and social domains, there can be common problems in cognitive domain too. Attention (Alberta Learning and Teaching Branch, 2002; MacInnis & Hemming, 1995; Mayes, Calhoun & Crowell, 2000), memory (Alberta Learning and Teaching Branch, 2002; Elliot, 2000; Reid et al., 2015), recall (Alberta Learning and Teaching Branch, 2002; McNamara & Wong, 2003), transfer (Elliot, 2000; MacInnis & Hemming, 1995), and generalization (MacInnis & Hemming, 1995) problems may be observed. Along with these, difficulties may be seen in generating strategies for solving problems (Alberta Learning and Teaching Branch, 2002; Elliot, 2000), selecting appropriate strategies for different academic domains (MacInnis & Hemming, 1995), self-monitoring (Alberta Learning and Teaching Branch, 2002; MacInnis & Hemming, 1995), recognizing needs and strengths/weaknesses of students with specific learning disabilities, understanding and using learning strategies, time management as metacognitive skills (Alberta Learning and Teaching Branch, 2002).

2.4 Prevalence of Specific Learning Disabilities

There are different estimates regarding the prevalence of specific learning disabilities. In addition, it varies from country to country. However, in terms of illustrating the current situation, various estimates are presented.

According to APA (2013), 5% to 15% of school age children who are from different cultures and different countries have specific learning disabilities (dyslexia, dyscalculia, and dysgraphia). Though not known exactly, it is estimated that 4% of adults have specific learning difficulties.

OECD (Robson, 2005) shows the varied distribution of the ratio on individuals with specific learning disabilities across 11 different countries (Figure 2.1). As it can be seen in the graph, while the highest percentage belongs to the USA, the lowest percentage belongs to Turkey. Overall, it can be interpreted by referring to the graphic that the prevalence of specific learning disabilities ranges from 0.01% to 6% (Figure 2.1). The reason for this low rate in Turkey is that, teachers and parents do not have awareness and sufficient knowledge about specific learning disabilities (Polat et al., 2012). Hence, it is highly probable that students may not be diagnosed with specific learning disabilities.

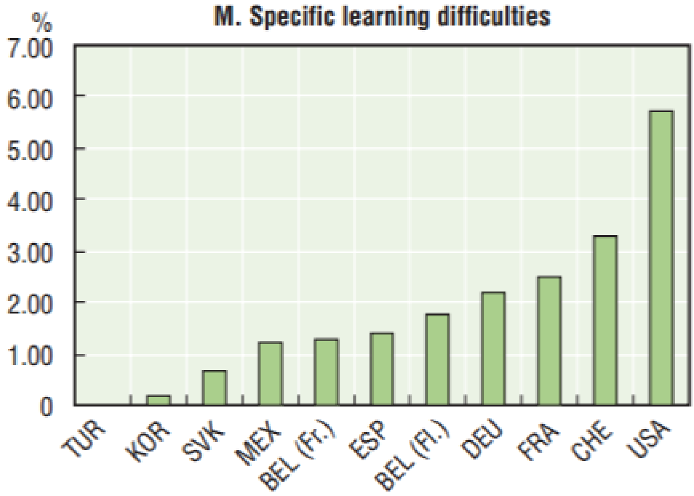

Figure 2.1 Proportion of specific learning disabilities

According to OECD (2009) reports, the ratios of specific learning disabilities across Baltic countries are as can be seen in Figure 2.2. As can be interpreted from the graph, the ratio of specific learning disabilities is the highest in Estonia while it is the lowest in Malta. Generally, it can be concluded that the prevalence of specific learning disabilities in Baltic countries ranges from 0.06% to 4.08% in compulsory education (Figure 2.2).

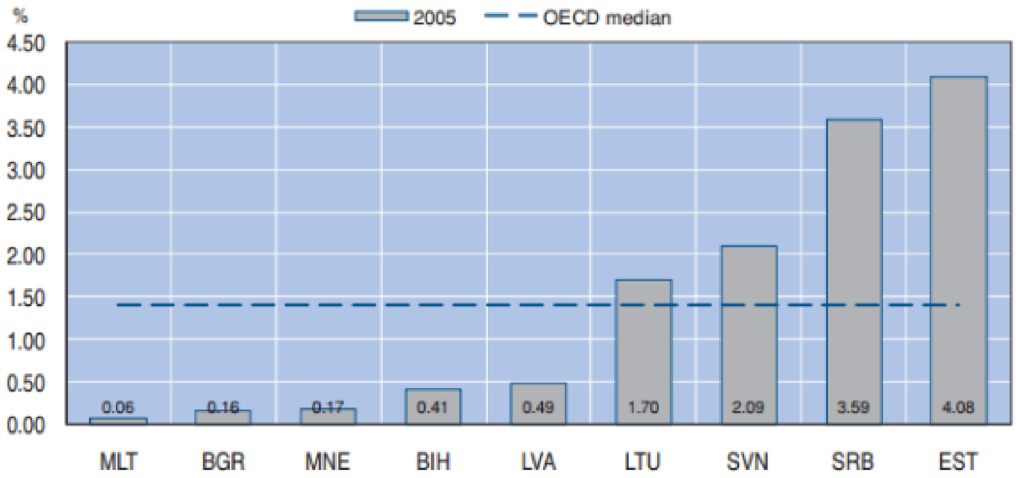

Figure 2.2 Proportion of specific learning disabilities across Baltic countries

IDEA (2014) reveals the prevalence of children at the ages of 3 and 21 by disability type for 2012-2013 school year in the USA is as in Figure 2.3. According to the graphic, children with specific learning disabilities comprise 35% of special educational needs. In other words, specific learning disabilities covers one third of the whole disability types.

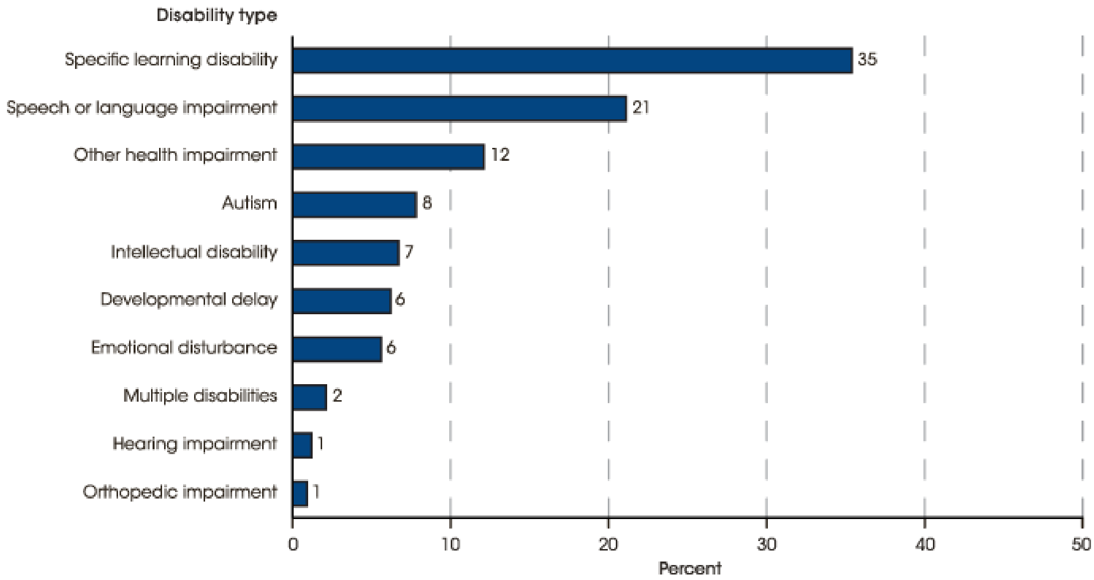

Figure 2.3 Proportions of children with 3-21 ages by disability type for 2012-2013 school year in the USA

There is no data that have been kept on regular basis, on the prevalence of specific learning disabilities for Turkey. However, the data on students diagnosed with SLD in mainstream classes are presented in Figure 2.4. (MONE, 2011a; MONE, 2011b). In spite of a small number of students in this chart, there exist many students who cannot be identified as can be inferred from the literature.

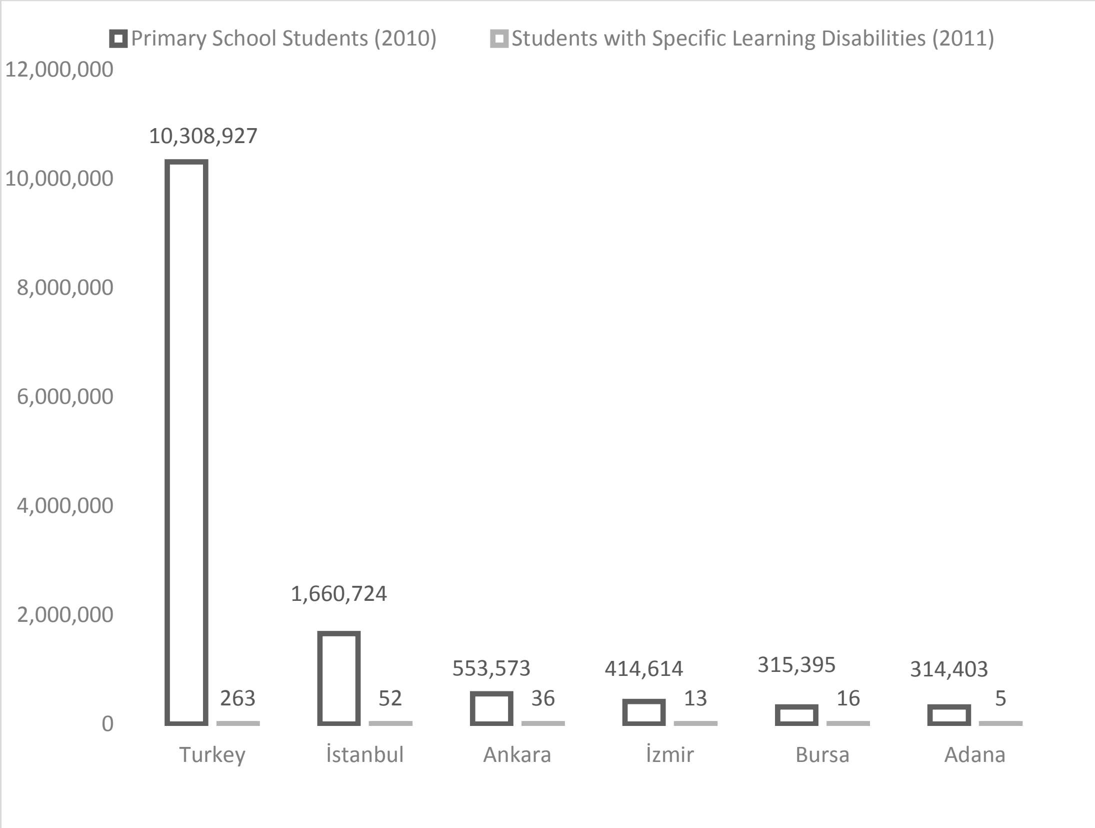

Figure 2.4 Number of all students and five large cities in Turkey with number of diagnosed students with SLD in mainstream classes

2.5 Tangible Technologies

Tangible technologies aim to provide interaction with the physical and digital environment without using the traditional input and output devices such as monitor, mouse, and keyboard (Ullmer & Ishii, 2000). Instead of pressing keys, for interaction with the computer by using the physical motion makes interface closer to the real world (Jacob et al., 2008). Fishkin (2004) states that the steps of interaction between tangible real world object and computer interface system are: 1) giving some inputs to computer system via physical movements 2) understanding the input by computer system 3) giving feedback to the user taking input into account.

Tangible technologies can be used in many fields; education is one of the main areas of use. O'Malley and Fraser (2004) emphasize that tangible technologies have a promising potential and the capacity for education with particular and innovative features. Tangible technologies provide benefits to students for moving the physical world into the interface and they have a significant role in education in this way (Horn, Solovey, Crouser, & Jacob, 2009). That is to say, tangible technologies enable students to understand real world in real world (Antle, 2007).

Eisenberg et al. (2003) underline that tangible technology does not reduce the value of educational technology used today. However, ensuring interaction with the real world object is difficult for computer based educational systems. Decreasing the isolation between the virtual and concrete opens new doors for instructional designers to be able to make a more realistic design beyond computer-assisted materials.

2.5.1 Potential benefits for learning of tangible technologies

The classification below was made taking the characteristics of tangible technology into account and under the light of empirical and theoretical studies from the literature. In this context, physical interaction and manipulation, accessibility, and collaboration were mentioned.

Physical interaction and manipulation

Physical activities play an important role in learning. As one of the benefits of tangible technology usage in learning, Marshall (2007) and O’Malley and Fraser (2004) emphasize that according to Piagetian developmental theory, manipulation of concrete physical objects can enhance thinking and learning. Employing visual, auditory, and touch sense as multiple sense helps students to construct knowledge in abstract problems (Zuckerman, Arida & Resnick, 2005). Evidence indicates that there is some information that young children or adults cannot express verbally, however surprisingly they are physically able to express it with gestures (O'Malley & Fraser, 2004).

Tangible and spatial interaction can be gestural, haptic, full bodied, and spatial. Through these interactions, it opens new doors to students for learning (Antle, 2007).

Different devices have different physical actions that can cause digital manipulations (Manches & Price, 2011). Interaction in tangible technology is more natural and familiar compared to other types of interaction (Jacob, Ishii, Pangaro & Patten, 2002). Touch-screen interaction is easier than mouse interaction. In parallel to this, interaction is easier with tangible objects that are similar to real-life (O'Malley & Fraser, 2004).

Accessibility and Collaboration

Tangible technologies make abstract information accessible to the application level regardless of the age level of abstract thinking and skills (Shaer & Hornecker, 2010). Tangible technologies increase accessibility to abstract concepts that are difficult to learn, for different target audiences like students with learning disabilities (Zuckerman et al., 2005). Tangible interfaces provide both better manipulative access owing to multiple learners to manipulate many objects simultaneously and superior perceptual access owing to horizontal screens having better visibility than vertical ones. Hence, learners can understand each other easily (Horn et al., 2009).

Tangible technologies allow learners to collaborate with each other. Marshall (2007) states that numerous design-oriented studies emphasized appropriateness of tangible interface for collaboration. Tangible technology helps to ensure collaborative interaction in the shared space (Horn et al., 2009). In line with this, it also allows for group work (Zuckerman et al., 2005). Unlike traditional computer systems, which consist of mouse, keyboard, and a monitor, tangible interfaces provide simultaneous interaction by sharing control among students (Marshall, 2007).

2.5.2 Tangible technologies and specific learning disabilities

In recent years, development of new technology has played an important role in meeting the needs of students with special education need. Educational technology offers opportunities for learning of students with special education needs. Hutinger (1996) emphasizes the positive impacts of technology on special education as being a facilitator for the inclusion, increasing social interaction and communication.

Computer applications serve as an equalizer to make similar activities for both a child with special education need and a normal child. In line with this, Florian (2004) says that computer assisted instruction is like a cognitive prosthesis by compensating difficulties which students faced, and also ensuring equal opportunities to learn. Moreover, children with learning difficulties seem to accept failure. However, no matter how many mistakes made by the child while interacting with a computer, the child does not face any judgmental people. Due to fact that computers are not being judgmental against the child, using computers has also an important role in special education. It is important to embrace this kind of strategy to prevent the child from learned helplessness (UNESCO, 2000).

The use of educational technology in special education encompasses tutorial software, exploratory learning environments such as simulation and virtual environments, drill and practice software, educational games, assessment and management tools and communicative tools (Florian, 2004). Individualized learning program, in particular, is said to support students with special education needs. Integrated Learning Systems (ILS) are preferred in schools (Abbott, 2007; Florian, 2004). Although there exist different definitions of ILS, generally, they include diagnostic tools and a number of learning activities mostly related to literacy and numeracy (Abbott, 2007).

With the use of technologies in education, exploratory learning environments including virtual environments emerged. These environments, which reflect a constructivist approach, allow students to interact with materials and to have control of their own learning. In this regard, it is different from the tutor, drill, and practice (Florian, 2004). Moreover, the use of technologies in education allows the teachers to make the evaluation easier and faster and helps to diagnose learning difficulties, to prepare individualized education plans, and to monitor the progress of students (Florian, 2004).

Although aforementioned computer assisted instruction offers opportunities for facilitating learning for students with SLD, it remains limited especially in physical interaction. In line with this, Keay-Bright (2008) emphasizes that many positive outcomes have come out of using ICT in learning difficulties. However, technologies used in sensory action, that help to provide creative and flexible thinking as well as collaborative learning, are still few in number. In Turkey, despite differences in the target audience and the technology used in this study, one study has been found. Moreover, there has been a scarcity of scholarship based on the use of tangible technologies for students with SLD in Turkish literature. An emerging area of research is the use of tangible technology to support special education (Shaer & Hornecker, 2010). Falcão and Price (2010) stated that with the development of new technology, tangible technologies provide extending opportunities for multi-sensory interaction for students with learning difficulties. Moreover, tangible technologies make learning environment richer than a traditional graphical user interface system by offering opportunities in cognitive, social, and linguistic learning for special education (Shaer & Hornecker, 2010).

There exist some teaching strategies and methods in the literature to facilitate learning of student with SLD (e.g. multiple sensory-based approach (MONE, 2008)) or collaboration-based approach (Sucuoğlu & Kargın, 2006). Tangible technologies can increase the probability of supporting these or similar teaching strategies.

In the light of literature, the use of tangible technology in special education as well as general education is seen increasingly becoming more important. However, few studies have yet revealed the use of tangible technologies for students with SLD. Nascent research focus on dyslexia to support reading (Antle et al., 2015; Fan & Antle, 2015; Pandey & Srivastava, 2011a, 2011b).

Pandey and Srivastava (2011a) developed a tangible, interaction learning aid system named as SpellBound to teach the spelling of basic English words for students with dyslexia who are aged between 8 and 12 years (Figure 2.5). It was a developmental study that aimed at designing and developing an activity-based prototype by using tangible objects. As a conclusion, how the children interact with images, colors, and tangible objects was figured out. The numbers, basic arithmetic operations, and working on the shape of the letters will be incorporated to their future studies.

Figure 2.5 Spellbound

Antle et al. (2015) developed a tangible system named as PhonoBlocks to support children with dyslexia who are aged between 5 and 8 years and have difficulties in decoding English sound-letter (Figure 2.6). PhonoBlocks includes 3D tangible letters with colors as a cue providing help to distinguish the sounds of letters. In addition, it consists of a touch screen laptop, an input platform, and 27 tangible letters. It has been stated in the mentioned study that the authors will conduct a pretest-posttest experimental study to investigate the long-term use and its impacts on reading skills for students with dyslexia in follow-up studies.

Figure 2.6 PhonoBlocks

Cramer, Antle, and Fan (2016) investigated effectiveness of PhonoBlocks that was a tangible software system in terms of a dynamic color-coding scheme on students with dyslexia in 3rd- 7th grades. They mainly focused on teaching to spell of the words that includes in one or double consonants and end with –le (cuddle, stable, topple etc.). They conducted a comparative study with four males and five female students. Five of students were randomly assigned to Vowel Color Based on Design Principle Group (V-DP) and the rest assigned to Vowel Color Based on Identity (V-ID). The authors used red color for long vowels and used yellow color for short vowels in V-DP group while they used different colors for each vowel in V-ID group. The study was carried out for four weeks. Students were given new two words in a 15 minutes practice session three times a week. As a result, even though there was no significant difference between two groups, improvement was seen for both groups.

Fan and Antle (2015) developed a tangible tabletop system to help 5 and 6-year-old children with dyslexia who have difficulties in decoding English sound-letter (Figure 2.7). It uses texture cues to promote learning letter-sound correspondence. In further studies, the authors will conduct a user test to investigate prototype design and experimental studies to reveal the impact of tangible tabletop with texture cues in alphabetic learning.

Figure 2.7 Tactile Letters

Pandey and Srivastava (2011b) developed a tangible user interface with color and sound cues named as Tiblo to help remembering and following sequential instructions in reading stories or words for students with dyslexia aged between 8 and 12 years (Figure 2.8). Rapid ethnography to investigate emotional and psychical aspects and contextual enquiry were employed in this study. As a result, it was found out students had interest in using Tiblo.

Figure 2.8 Tiblo

Kara, Aydın, and Cagiltay (2014a) designed and developed a computer application for supporting storytelling activities of preschool students. The authors carried out a usability study with 24 participants. The smart storytelling toy contains three parts background cards for showing stories, RFID (radio-frequency identification) system for transferring data to computer and a computer with Flash application. The system based on the principle that “when the student put the toy on the receiver panel, Flash application displayed the stories on the screen”. As a result of this study, design principles in terms of usability, storytelling, visual design and interaction were revealed.

Kara, Aydın, and Cagiltay (2014b) carried out a user study of StoryTech. 90 preschool students from five different kindergartens in Ankara were the participants of the study. Experimental design was employed in this study. The result of the study revealed that StoryTech exhibited rich experiences for storytelling particularly for five and six-year-old students.

Kara, Aydın, and Cagiltay (2013) investigated the impact of playing with a smart storytelling toy (StoryTech) on children’ narrative activities and creativity. As aforementioned, StoryTech contains three parts that are background cards for showing stories, RFID (radio-frequency identification) system for transferring data to computer and a computer with Flash application. Experimental design was used in the study. 90 preschool students from five different kindergartens in Ankara participated in the study. Results showed that StoryTech contributed to narrative activities of preschool students and had a positive effect on creativity.

Kara (2015) designed, developed and used a smart toy for preschool children. Design and development research method was used in the study. Results of the study showed that the participant pre-school teacher had positive thoughts about the appropriate use of technology in pre-school education. According to teachers, the content, the visual design and interaction components of the smart toys should be improved more. As a result of the study, the design principles covering content, visual design and interaction components were revealed. Results of the study indicated that 36 and 48 month old children demonstrated lower performance in completing cognitive activities of the smart toy when compared to 48 and 72 months old children. Teachers have also preferred to play with smart toys for collaborative activity.

2.6 Implications of Literature Review

As can be seen from the literature review of this study, one of the interventions to meet the needs of students with students with specific learning disabilities is making use of educational technology. However, traditional computer-assisted instruction applications remain insufficient for providing physical engagement and multisensory interaction for this target group. With the new emerging technologies, tangible objects used with multi touch tablets have a potential to enrich learning experience of students with specific learning disabilities. Despite the promising potential and agreement on the value of tangible technologies, few studies have yet revealed the use of tangible technologies for students with SLD. Nascent research focus on dyslexia to support reading by developing a tangible interface with different technologies. In Turkey, despite differences in the target audience and the technology used in this study, one study has found to be similar (Kara, 2015). Moreover, scholarship lacks both theoretical and empirical studies in relation with the use of tangible technologies for students with SLD in Turkish literature.

There is an insufficient amount of theoretical and empirical studies about the usage of tangible technologies. As a result, studies appeared to be based on few design principles. There is a need for further research to identify which elements and features of tangible interfaces are critical in learning environment. It is obvious that there is an emerging need to determine the design principles of tangible mobile application for students with SLD.

Although some tangible technologies for students with SLD have been developed to date, as above-mentioned there is still an insufficient amount of empirical research. This study examines the effectiveness of the tangible mobile application on students' achievement in the 6th grade cell concept. In this respect, this study is expected to provide empirical evidence for both educational technology and special education fields from an interdisciplinary perspective.

Overall, this study might be pioneer in special education field and contribute to both educational technology and special education literature by determining design principles and investigating the effectiveness of tangible mobile application for students with SLD. This can lead to start using tangible mobile application in special education field. It is expected that the findings of the study might provide useful information for both practice and theory and for teachers, administrators, and parents as well as researchers and designers.

CHAPTER 3

METHODOLOGY

This chapter presents research questions, research design, participants, instruments, procedures, data analysis, validity-internal and external-, and reliability of the present study.

3.1 Research Questions

1. What are the design principles of a tangible mobile application for students with SLD?
2. Is the tangible mobile application effective on students' achievement in the 6^{th} grade cell concept?
3. What are the reflections of special education teachers after using the tangible mobile application on students with SLD?

3.2 Research Design

In this study, both qualitative and quantitative methods were used. The qualitative data collection techniques were employed to determine the design principles of tangible mobile application for students with SLD in the light of special education experts', science education expert's, teachers' and students' opinions and in the quantitative part, multiple-probes across participants design was conducted to examine the effectiveness of tangible mobile application on students' achievement in the 6^{th} grade cell concept.

3.2.1 Qualitative Part

Reeves's (2000) development research model was employed under the design-based research in order to implement qualitative research. In addition, an implementation was conducted in order to examine the reflections of special education teachers after using the tangible mobile application on students with SLD. For this aim, a pilot study was held with a special education teacher and a student with SLD in 6th grade, the main study was held with a psychologist and a student with SLD in 6th grade.

In the literature, a wide range definitions have been encountered about design based research. Barab and Squire (2004) described design based research as "a series of approaches, with the intent of producing new theories, artifacts, and practices that account for and potentially impact learning and teaching in naturalistic settings" (p. 2). Herrington, McKenney, Reeves, and Oliver (2007) highlighted that "a series of approaches" have been named in many ways such as developmental research, design experiments, formative research. In this study, design based research is used.

Wang and Hannafin (2005) defined design-based research as "a systematic but flexible methodology aimed to improve educational practices through iterative analysis, design, development, and implementation, based on collaboration among researchers and practitioners in real-world settings, and leading to contextually-sensitive design principles and theories." (p.6-7). They also identified the chief characteristics of design-based research (Wang & Hannafin, 2005, p.7):

- pragmatic;
- grounded;
- interactive, iterative, and flexible;
- integrative;
- and contextual.

One of the outcome of design-based research is design principles. In order to reveal the design principles of tangible mobile application for students with SLD, four stages of design-based research (Amiel & Reeves, 2008, p.34) was conducted in this study:

- Analysis of Practical Problems by Researchers and Practitioners in Collaboration
- Development of Solutions Informed by Existing Design Principles and Technological Innovations
- Iterative Cycles of Testing and Refinement of Solutions in Practice
- Reflection to Produce "Design Principles" and Enhance Solution Implementation

This study is based on three vital principles of design-based research by using Reeves (2006) as a reference. First, the complex problems were addressed in relation with the real life contexts in collaboration with the practitioners. Then known hypothetical design principles were integrated with the technology to find answers to complex problems. Lastly, rigorous and reflective inquiry was pursued to investigate the innovative learning environments in addition to the definition of design principles.

The eventual goal of design-based research is finding solutions to real life problems by establishing strong links between research and problems. In parallel with this, the current study aims at designing principles for tangible mobile application in the real world. In addition, a noteworthy aspect is iterative design process that allows revealing design principles to guide educational research as well as testing and refining the innovation. Similarly, this is an iterative study because it is based on developing prototypes and making revision in the design and development processes. One of the key characteristic of design-based research is involving a strong, intensive and long-term collaboration between researchers and practitioners. In line with this, in the study the researcher engaged with all stakeholders (teachers, experts, and students with SLD) while examining design principles of tangible mobile application (Amiel & Reeves, 2008).

3.2.2 Quantitative Part

In the quantitative part, multiple-probes across participants design was administered under the single subject research design (Gast, Lloyd & Ledford, 2014) in order to examine the effectiveness of tangible mobile application on students' achievement in the 6th grade cell concept. The dependent variable of the study was the achievement scores of the students and the independent variable of the study was the tangible mobile application.

The experimental part of this study is based on single subject design. It should not be considered there is only one participant. This is not a case study but a quantitative design (Gast & Ledford, 2014). Under the single subject design, multiple-probes across participants design was used in the current study. Both multiple-baseline and multiple-probes design allow the same intervention to be tested on different conditions such as different settings, participant, material, and teaching method. These designs are flexible in terms of pace and planning of procedure. In addition, they are robust against internal validity threats. Furthermore, these designs can be implemented easily to examine effectiveness of a broad range of interventions. Moreover, there is no need to withdrawal of a successful intervention to indicate experimental control. There are three types of both designs: 1) across behaviors, 2) across conditions, 3) across participants. The design of current study is across participants design.

Differently from multiple-baseline design, multiple-probes design is not required continuous baseline measurements. When a plan for the continuous measurement of all targets before the intervention is required by multiple baseline designs, the plan for multiple probe designs should be to collect data occasionally before putting the intervention in practice. The accuracy and the practicality of the two mentioned designs are influenced by this difference (Gast et al., 2014). In this study, the multiple probes design was employed due to its practicality to examine academic performance. In this context, baseline data were collected intermittently.

Analysis of Practical by Researchers and Practitioners in Collaboration	**Development of Solutions Informed by Existing Design Principles and Technological Innovations**	**Iterative Cycles of Testing and Refinement of Solutions in Practice**	**Reflection to Produce "Design Principles" and Enhance Solution Implementation**

Stage 1
✓ Need analysis
✓ Learner analysis
✓ Content analysis
	Stage 2
	✓ Developing Prototypes
	  ✓ Paper-based
	  ✓ Mobile device-based		

	Stage 2.1 ✓ Obtaining special education expert's, science education expert's, and teachers' views on both prototypes ✓ Applying mobile device-based prototype to a student with SLD and obtaining student's views on mobile device-based prototype	Stage 3 ✓ Developing low fidelity prototype (version 1)	
		Stage 3.1 ✓ Obtaining special education experts', science education expert's, and teachers' views on version 1 ✓ Applying version 1 to students with SLD and obtaining students' views on version 1	
		Stage 4 ✓ Developing high fidelity prototype (version 2)	
		Stage 4.1 ✓ Obtaining special education experts' views on version 2 ✓ Applying version 2 to students with SLD and obtaining students' views on version 2	Stage 5 ✓ Developing final version ✓ Determining finalized design principles
			Stage 6 ✓ Administrating multiple-probe across participants design research
			Stage 7 ✓ Holding a pilot study with a special education teacher and a student with SLD in 6th grade and a main study with a psychologist and a student with SLD in 6th grade ✓ Obtaining the reflections of special education teacher and psychologist after using the tangible mobile application on students with SLD

Figure 3.1 Research design based on Reeves's (2000) Development Research Model

Table 3.1 Participants, instruments and data analysis techniques of the study

Stages	Participants	Instruments	Data Analysis
1	Science education expert (n=1) Special education expert (n=2)	Semi-structured interviews Sample of application	Content Analysis
2	Development		
2.1	Special education expert (n=1) Science education expert (n=1) and teachers (n=5) Student with SLD (n=1) Parents of student (n=1)	Semi-structured interviews Focus group interview Demographic questionnaire Prototypes Observation Notes	Content Analysis
3	Development		
3.1	Special education experts (n=2) Science education expert (n=1) and teachers (n=6) Students with SLD (n=2) Parents of student (n=1) Teacher of student (n=1)	Semi-structured interviews Focus group interview Demographic questionnaire Version1 Observation Notes	Content Analysis
4	Development		
4.1	Special education experts (n=2) Student with SLD (n=1) Teacher of student (n=1)	Semi-structured interviews Observation Notes	Content Analysis
5	Development		
6	Students with SLD (n=3) Teachers of student (n=3)	Final Version Observation Notes	Graphical Analysis and Descriptive Analysis
7	Special education teacher (n=1) Psychologist (n=1) Students with SLD (n=2)	Semi-structured interviews Observation Notes	Content Analysis

In stage 1, need analysis, learner analysis, and content analysis were performed. Preliminary design principles of designing and developing a tangible mobile application for students with SLD were identified based on analyses. To give an idea about application and concretize tangible objects, a sample was developed by the researcher. In order to conduct need, learner and content analysis, semi-structured interviews were administered to a science education expert and two special education experts. The design principles were used from the beginning to the end of the study between each stage with an iterative manner throughout the whole process.

In stage 2, paper-based and mobile device-based prototypes were developed taking the principles determined in the first stage into account. Mobile device-based prototype included a tutorial and practice for one learning object from the 6^{th} grade cell concept.

In stage 2.1, a semi-structured interview with one special education expert and a focus group interview with one science education expert and five science teachers were conducted according to four design categories: 1) educational content, 2) visual design, 3) tangible object use, and 4) interaction to obtain their views on paper-based and mobile device-based prototypes. At the same time, mobile device-based prototype was applied to a student with SLD and she was observed. Demographic information about this student was gathered from her parents by a demographic questionnaire.

In stage 3, low fidelity prototype was developed as version 1 based on preliminary design principles and feedback taken stage 2.1.

In stage 3.1, semi-structured interviews with two special education experts and focus group interview with one science education expert and six science teachers conducted according to four design categories: 1) educational content, 2) visual design, 3) tangible object use, and 4) interaction to obtain their views on version 1. Version 1 was applied to two students with SLD and they were observed. In addition, students' demographics data were collected. Semi-structured interviews were administered to students with SLD.

In stage 4, high fidelity prototype was developed as version 2 based on preliminary design principles and feedback taken this stage.

In stage 4.1, semi-structured interviews with special education experts were conducted to obtain their views on version 2. Version 2 was applied to a student with SLD. The student was observed and video-recorded as well. Semi-structured interview was administered to the student with SLD.

In stage 5, final version was developed based on preliminary design principles and feedback taken in stage 4.1. Final design principles of designing and developing a tangible mobile application for students with SLD were identified based on previous stages.

In stage 6, multiple-probe across participants design was administered under the single subject research design as the final implementation in order to examine the effectiveness of the tangible mobile application on the students' achievement in 6^{th} grade cell concept.

In stage 7, an implementation was conducted in order to examine the reflections of special education teachers after using the tangible mobile application on students with SLD. After a pilot study was held with a special education teacher and a student with SLD in 6^{th} grade, the main study was held with a psychologist and a student with SLD in 6^{th} grade. They were video-recorded. Semi-structured interviews were administered to a special education teacher and a psychologist.

3.3 Participants

In this study, purposeful sampling was used. According to Patton (1990), purposeful sampling allows for in depth study by investigating information rich cases that can elicit answers for research questions.

In stage 1, the science education expert (n=1) and the special education experts (n=2) were included in the study in order to conduct need, learner and content analysis.

In stage 2.1, the science education expert (n=1), the teachers (n=5), special education experts (n=1) and the student with SLD as target audience (n=1) participated to convey their opinions in the focus group interview and semi-structured interviews. The components of tangible mobile application (pretest, tutorials, and practices), learning objectives, and educational scenario were presented to science education expert and teachers, and special education experts. They were also informed about how to interact with the application and use it. Observations were conducted to explore participants' use of tangible objects by prototype. The student was purposefully sampled according to two criteria as follows: 1) attending 6^{th} -8^{th} grades and 2) diagnosed with specific learning disability. In addition, student's demographics data was collected from the parents or teachers. YCD Special Education and Rehabilitation Center (250 students) and YI Special Education and Rehabilitation Center (380 students) was selected because of the number of students. Information about the participants was presented in Table 3.2, Table 3.3, Table 3.4, and Table 3.5.

In the stages of 3.1 and 4.1, science education expert (n=1) and teachers (n=6) (only in stage 3.1), special education experts (n=2) and students with SLD (n=2 for stage 3.1 and n=1 for stage 4.1) were interviewed to find out the ideas of the participants on the application developed. Students with SLD were observed during the time they used version 1 and version 2. In addition, they were also video- recorded. Selection procedures of the students were the same with stage 2.1.

In stage 6, for multiple baseline across participants' design, 6^{th} and 8^{th} grade students with SLD (n=3) were selected as subjects. Selection procedures of the students were the same with stage 2.1.

In stage 7, a special education teacher (n=1), a physiologist (n=1) and students with SLD (n=2) were selected as subjects. Selection procedures of the students were the same with stage 2.1. The special education teacher and the physiologist were interviewed to find out their experience and ideas on the use of tangible mobile application. They were also video- recorded.

Table 3.2 Information about science education expert and teachers

Code	Degree	Gender	Experience
SE1	Ph. D.	Female	13 Years
ST1	B.S.	Male	1 Year
ST2	B.S.	Female	1.5 Years
ST3	B.S.	Female	1 Year
ST4	B.S.	Female	1 Year
ST5	B.S.	Female	1 Year
ST6	M.S.	Female	5 Years

Table 3.3 Information about special education experts

Code	Gender	Experience	Institution	Title
SP1	Male	20 Years	State Univ.	Assoc. Prof.
SP2	Female	20 Years	State Univ.	Assoc. Prof.
SP3	Female	20 Years	State Univ.	Assoc. Prof.

Table 3.4 Information about students

Code	Gender	Age	Grade	Disability Type	Disability Rate	Special Education Center	School Type	Study Stage
DC	Female	12	6	Specific Learning Disability	N/A	-	Public	2.1 3.1
BK	Male	12	7	Specific Learning Disability	20	YI Special Education Center	Public	3.1 4.1
NV	Female	12	7	Specific Learning Disability	20	YI Special Education Center	Public	6
AC	Male	12	7	Specific Learning Disability	25	YI Special Education Center	Public	6
EY	Female	13	7	Specific Learning Disability	30	YI Special Education Center	Public	6
FV	Female	11	6	Specific Learning Disability	N/A	YI Special Education Center	Public	7
MYP	Male	11	6	Specific Learning Disability	25	YCD Special Education Center	Public	7

Table 3.5 Information about the special education teacher and the psychologist

Code	Gender	Occupation	Age	Experience	Institution
P1	Female	Psychologist	26	2 Years	YCD Special Education Center
SET1	Male	Special education teacher	29	8 Years	YI Special Education Center

3.4 Instruments

3.4.1 Semi-structured interviews with special education experts

In stage 1, to conduct need, learner and content analysis, a semi-structured interview was administered. The interview aimed to seek if there was a need for this application, and if it was appropriate for students with SLD. It also aimed to decide which content and grade would best fit to utilize such an application.

In stage 2.1, a semi-structured interview was administered to obtain special education experts' views after paper-based and mobile devices based prototypes were presented to them according to four design categories: 1) educational content, 2) visual design, 3) tangible object use, and 4) interaction. The semi-structured interview form consisted of 27 questions. The interview questions were formed after a thorough overview of the limited related literature and focused on demographics (n=3), educational content (n=7), visual design (n=10), tangible object use (n=3), interaction (n=4) (Appendix A).

In stage 3.1, semi-structured interviews were administered to obtain special education experts' views after low fidelity version 1 was presented to them. The semi-structured interview form consisted of 29 questions. The form differed from the one in the stage 2.1 in terms of investigating what kind of changes would come up (Appendix B).

In stage 4.1, semi-structured interviews were administered to obtain special education experts' views after high fidelity version 2 was presented to them. The semi-structured interview form consisted of 25 questions. The form differed from the one in the stage 3.1 in terms of investigating what kind of changes would come up (Appendix C).

3.4.2 A semi-structured interview with science education expert and focus group interviews with science education expert and teachers

In stage 1, a semi-structured interview was conducted and the application was checked to see if it was the most appropriate one for each set of content (unit-subject-learning object) in each grade level.

In stage 2.1, a focus group interview was administered to obtain science education expert's and the teachers' views after paper-based and the mobile application were presented to them based on four design categories: 1) educational content, 2) visual design, 3) tangible object use, and 4) interaction. The interview form consisted of 29 questions. The interview questions were formed after a thorough overview of the limited related literature and focused on demographics (n=3), educational content (n=11), visual design (n=8), tangible object use (n=3), and interaction (n=4) (Appendix D).

In stage 3.1, a focus group interview was administered to obtain science education expert and the teachers' views after version 1 was presented to them on four design categories: 1) educational content, 2) visual design, 3) tangible object use, and 4) interaction. The interview form consisted of 31 questions. The form differed from the one in the stage 2.1 in terms of investigating what kind of changes would come up. The interview questions were formed after a thorough overview of the limited related literature (Appendix E).

3.4.3 Semi-structured interviews with students

In stages 2.1, 3.1, 4.1 semi-structured interviews were administered to students with SLD as target audience after using the tangible mobile application on four design categories and there was a specific section to find out their overall ideas about the application. It focused on which parts the students liked or did not like (positive and negative aspects of the tangible mobile application). In stage 2.1, it consisted of 12 questions. The questions focused on general opinion (n=2), educational content (n=4), visual design (n=2), tangible object use (n=1), interaction (n=3) (Appendix F). In stage 3.1 and 4.1, in addition to these questions, one question was added to educational content part and one question was added to interaction part (Appendix G).

3.4.4 Semi-structured interviews with special education teacher/ psychologist

A semi-structured interview was administered to obtain the special education teacher and psychologist's experience and views about the tangible mobile application with their students after using the application on three categories: 1) the process for starting use, 2) the process for use, and 3) future use. The semi-structured interview form consisted of eight questions.

The questions focused on the process for starting use (n=2), the process for use (n=3), future use (n=3) (Appendix H).

3.4.5 Demographic questionnaire

In stages *2.1, 3.1, and 4.1, 6*, the demographic form was applied to their parents or teachers in order to collect detailed information about students participating in the study. Form included both multiple choices and open-ended questions. It consisted of 19 questions (Appendix I).

3.4.6 Observation notes

In stages 2.1, 3.1, 4.1, and 7, the researcher took observation notes while students were using the tangible mobile application. Observation notes included the difficulties faced, weakness and strengths, negative/positive sides of the application, responses of the students in terms of four categories. It consisted of four observation items (Appendix J).

In stage 6, the researcher took observation notes while students were using the tangible mobile application for the baseline, intervention and follow-up sessions by an observation checklist. It consisted of 11 items. The checklist focuses on being willing to use the application/ being satisfied with the use of application (n=4), sustaining attention while using the application (n=3), using the application and objects easily / correctly (n=4) (Appendix K).

3.4.7 Pretest-posttest

The pretest-posttest that includes criteria-based 22 questions in the tangible mobile application was presented in the multiple-probe across participants design. The pretest-posttest was prepared by the researcher considering the experts' views. The questions were presented students randomly for each session and students were never informed about the correct answers (Appendix L).

3.5 Setting and materials

This part of study was carried out in a regular special education classroom. There were table(s), chairs, and shelves in the classrooms. The researcher and students sit around a table (Figure 3.2). The video camera was placed to an appropriate point in order to keep records without any distraction. Technical features of the tablet were presented (Appendix O).

Figure 3.2 Sessions

3.5.1 Description of the tangible mobile application

The tangible mobile application was developed with the aim of improving achievement of students with SLD in 6th grade cell concept. Android version can be downloaded from markets.

3.5.2 Parts of the tangible mobile application

The Learning Objective: Students will be able to compare animal and plant cells in terms of basic components and functions (6th grade Cell concept)

Scope of the Learning Objective: For the basic components of the cell, only the cell membrane, cytoplasm, and nucleus are given. Without giving detailed structures of cell organelles, students were only mentioned about the names and the main functions.

Concepts: This study aims to equip students with SLD with the following concepts: “The cell, similarities and differences between plant and animal cells, name and function of the organelles, and basic components of the cell”.

Target Audience: Target group consists of students with SLD selected from 6th-8th grade.

The tangible mobile application includes a pretest-posttest, a trial screen, a tutorial and practice parts. Tangible objects are employed in all of these parts.

Firstly, there is a login (a nickname which selected by the researcher) screen in the application. Next, the pretest (Appendix L) that includes criteria-based 22 questions in the tangible mobile application is presented. A trial screen was provided for the students to enable them get familiar with tangible objects as well as being able to use it easily. One of the main parts of the application is the “tutorial part”, which starts with an introduction and followed by an experimentation that is provided through a magnifying glass and a microscope. The next step consists of definitions and explanations about each concept. Each learning unit in the tutorial part is followed by a related practice. The posttest –the last part- is the same with pretest (Appendix L).

Figure 3.3 Screenshots of the tangible mobile application

3.5.3 Tangible Objects

18 tangible models (objects) were designed and developed. In addition to holistic models of animal and plant cells, one microscope, one magnifying glass, six models that included the nucleus, the cytoplasm and the cell membrane of animal and plant cells and the cell wall were designed and developed. The remaining eight of them were the models of the organelles.

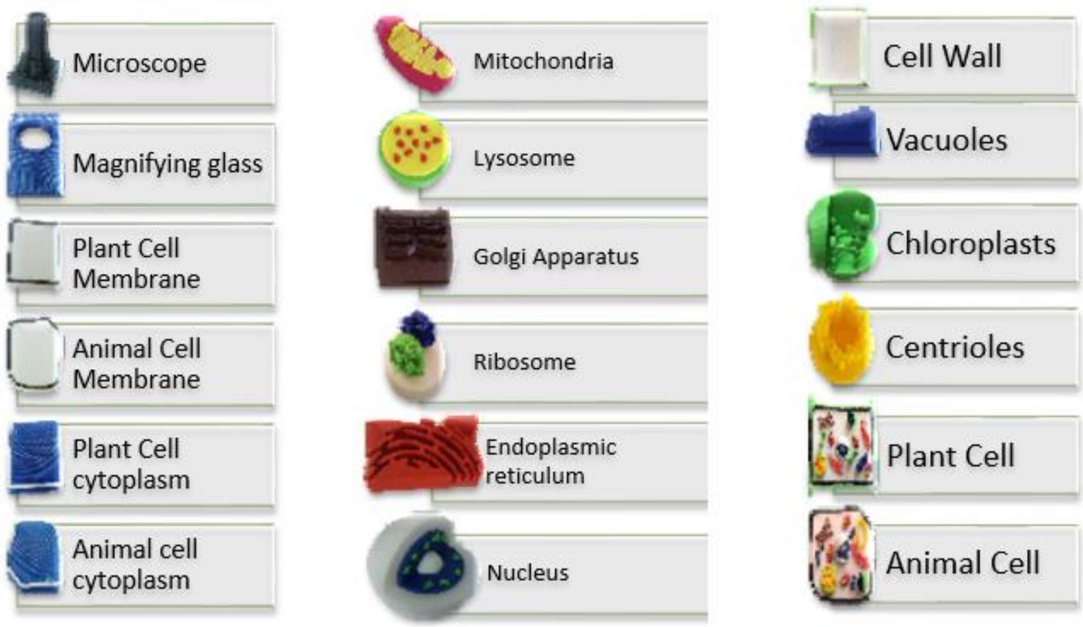

Figure 3.4 Screenshots of tangible models

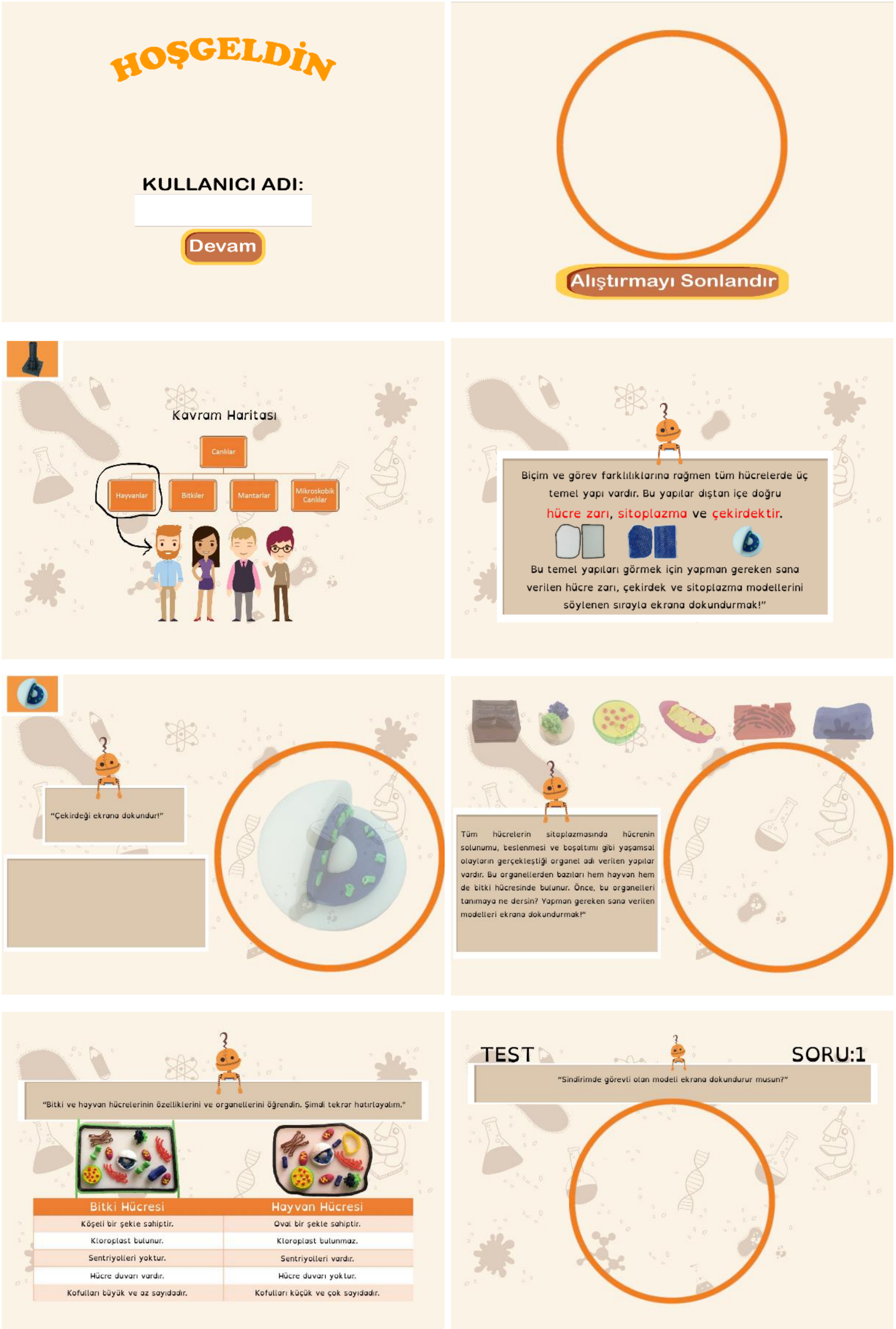

Figure 3.5 Screenshots of Tangible Mobile Application

3.5.4 Technical part of tangible mobile application

The application was developed with Adobe Animate CC. It works via Air Player. It works on Android Tablet. Technical features of the tablet were presented (Appendix O). It will be able to be downloaded from Android Market. Tangible models were designed in 3D CAD programs. During the development of the tangible objects, the researcher received feedback from the science education expert (SE1) and made improvements in color, shape, and the size. Prints were taken by using a 3D printer. A slot was designed for each model in order to place conductive plate and stylus tips. Application works based on the touch sensing principle, which could be used with stylus tips easily. When designing the user interface and illustrating the 2D images a professional help has been received by a professional illustrator. In addition to this, professional support was also received when recording the voices used in the application. All these recording were performed in a professional studio to maintain clarity in the sounds. As a result of all these steps, the application was coded by the researcher.

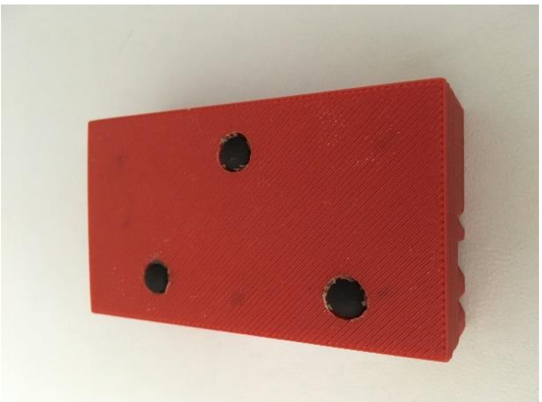

Figure 3.6 The bottom of a tangible object

Database: A local database was created by using SQLite. The database of tangible mobile application was developed in a way to log all the correct attempts, incorrect attempts and the time spent on each activity.

3.6 Procedures

In all stages, all participants were informed about the aim of the study, and they voluntarily participated in the study. Institutional review board approval was taken from METU Ethics Division (Appendix M). Semi-structured interviews were conducted one-to-one and recorded by permission. For student participation, parents were informed about the aim of the study and given consent form (Appendix N). Also, videos recorded by permission of parents. The names of participants were coded and kept private.

3.6.1 Procedures of Qualitative Part

In stage 1, in order to give an idea about application and concretize tangible objects, a sample was developed by the researcher. In order to conduct need, learner and content analysis, semi-structured interviews were administered to a science education expert and two special education experts. The interviews with special education experts took approximately 30 minutes and the interview with the science education expert took 20 minutes.

In stage 2.1, after the participant special education expert, and science education expert and teachers used the prototype, semi-structured interview with special education expert and a focus group interview with a science education expert and five teachers were conducted to obtain their views on paper-based and mobile device-based prototypes. At the same time, mobile device-based prototype was applied to a student with SLD and she was observed. In addition, students' demographics data were collected. The interview with the special education expert took approximately 30 minutes and the focus group interview with the science education expert and teachers took 60 minutes and the interview with the student with SLD took 5 minutes. The interview was kept short time not to bother the student.

In stage 3.1, semi-structured interviews with the special education experts and a focus group interview with a science education expert and six teachers were conducted to obtain their views on version 1. This version was applied to students with SLD. They were observed and video-recorded as well. The video camera was placed to an appropriate point in order to keep records without any distraction. Also, the students' demographics data were collected. Semi-structured interviews were administered to students with SLD. The interviews were kept short time not to bother students. The interview with special education experts took approximately 30 minutes and the focus group interview with the science education expert and teachers took 20 minutes and the interviews with students with SLD took 5 minutes. Data collection procedure for stage 4.1 was the same with stage 3.1.

In stage 4.1, semi-structured interviews with the special education experts were conducted to obtain their views on version 2. This version was applied to a student with SLD. He was observed and video-recorded as well. The video camera was placed to an appropriate point in order to keep records without any distraction. Also, the student's demographics data was collected. A semi-structured interview was administered to the student with SLD. The interview was kept short time not to bother students. The interview with the special education experts took approximately 20 minutes and the interviews with the student with SLD took 5 minutes.

An implementation was conducted in order to examine the reflections of special education teachers after using the tangible mobile application on students with SLD. After a pilot study was held with a special education teacher and a student with SLD in 6th grade, the main study was held with a psychologist and a student with SLD in 6th grade. Teachers or students were not given any training or using manual before the implementations. The researcher gave tablets and objects to teachers. The researcher mentioned teachers that they should grasp the objects and then touched to the tablet screen. The video camera was placed to an appropriate point in order to keep records without any distraction. After the each implementation, a semi-structured interview conducted with the special education teacher and psychologist. The pilot study took approximately 40 minutes while the main study took 30 minutes.

3.6.2 Procedures of Quantitave Part (Single Subject Study)

All experiment processes were conducted by researcher. All sessions were observed and recorded by a video camera.

Baseline: Before starting baseline sessions, parental consent forms were taken from parents and the researcher gathered students' information from the parents or teachers via demographic form as previously stated. For each baseline session, a pretest (Appendix L) was presented including criteria-based 22 questions in the tangible mobile application. At least three baseline data were collected for each student until stability was ensured.

Intervention: Intervention was presented for one learning objects. *Probes* were conducted at the end of each intervention. Probes included practice about each learning object. Each intervention session took approximately 30 minutes while each probe session took approximately 10 minutes. Throughout the experimental period, there were no studies conducted at home and at special education center about the cell concept. Intervention and probes were continued until three students met 100% criteria (which means answering 100% or almost 22 questions correctly for three consecutive probe sessions).

Follow-up sessions: After the intervention, maintenance data were collected by using a posttest. Follow-up sessions were conducted every several days. The posttest was the same with the pretest (Appendix L). Maintenance data were collected using the same procedures with the baseline and intervention sessions.

3.7 Data Analysis

In the qualitative part, content analysis was employed. The main aim in content analysis is to reach the concepts and relationships that can explain the collected data (Yıldırım & Şimşek, 2013). Creswell (2013) emphasized that in qualitative research, data analysis and data collection steps are carried out together. Therefore, data collection and analysis conducted concurrently because one stage outcome is an input for the next stage. For example, the results of stage 2.1 are input for stage 3 due to providing feedback in design process. Collected data were analyzed by following basic qualitative research analysis steps (Creswell, 2013, p.319):

- Organize and prepare the data for analysis
- Read or look at all the data
- Start coding all of the data
- Use the coding process to generate a description of the setting or people as well as categories or themes for analysis.
- Advance how the description and themes will be represented in the qualitative narrative.
- Making an interpretation in qualitative research of the findings or results.

Researcher followed above-mentioned steps in data analysis process. Firstly, all data coming from semi-stuctured interviews, focus group interviews, and observation notes were transcribed to Microsoft Word. Secondly, researcher rechecked and read all transcription to give meaning them. Thirdly, researcher organized the transcribed data by predetermined categories which were educational content, visual design, tangible object use, and interaction. Afterwards, researcher coded the data which is one of the main process of content analysis. Inter coder reliability was employed in this step which means two or more coders agreement on codes are used for the same part of the transcribed data (Creswell, 2013). Hence, a research assistant who conducted qualitative research participated to current study as inter coder. He is a Ph.D. candidate from the Computer Education and Instructional Technology department. He was informed about all stages of the study and given one of the information rich interview. Miles and Huberman's (1994) formula was used in the study in order to calculate inter coder reliability score. This score was found by dividing the number of agreements by the sum of the total number of agreements and disagreements. Inter coder reliability score was calculated as .81 which is accepted as good score by Miles and Huberman (1994). After that, researcher made interpratations. The data were described and direct quotations were given in order to reflect the views of the stakeholders dramatically. In the quantitative part, the data about the effectiveness of the tangible mobile application were analyzed by graphical analysis.

3.7.1 Qualitative part: validity and reliability

External validity

Thick description: Merriam (1995) emphasized that clearly presenting the results in sufficient detail can show other researchers how similar to their own research for more transferability. Because the researcher gives details about participant and research settings of the study (Creswell, 2007). In the study, enough detail was provided for all stages by the researcher to increase transferability to other research situations.

Purposeful sampling: Purposeful sampling aims to reveal both the events and phenomena typically encountered. The variability and diversity of the event or situation being investigated allows the reader to understand the variability and diversity that may exist in their research. In addition, it makes an important contribution in comparison with the research results (Yıldırım & Şimşek, 2013). Characteristics indicating variability of events and phenomena were used in this study in order to increase transferability.

Internal validity

Triangulation: Creswell (2012) defines triangulation as finding evidence from different people (teachers, students, experts), different data types (observations, interviews), and different data collection methods (documents and interviews) to make research more accurate and trustworthy. In addition, Creswell (2007) emphasized that triangulation is to verify the evidence from different sources to illuminate a theme. In this study, the data were gathered from different stakeholders by using different data collection tools.

Peer/colleague examination: It is defined as asking peer/colleague to examine the data and to comment on the plausibility of the emerging findings in Merriam (1995, p.55). In addition, Creswell (2012) stated that an external audit can review the research from a different perspective. In this study, all suggestions given by consultants in data collection and analysis process were considered.

Reliability

Triangulation: As Merriam (1995) indicated that using multiple data sources in data collection can provide reliability as well as internal validity. In this study, different data collection tools were used in data collection process.

Audit Trail: Merriam (1988) highlighted that data collection and data analysis processes should be explained in a way to help another researcher to follow steps and conduct a similar study. In data collection and analysis parts, details were given to help researchers and practitioners who want to replicate this study.

Peer/colleague examination: As Merriam (1995) stated that peer/colleague examination provides a second look at if the initial results are consistent with the data collected. In addition, Yıldırım and Şimşek (2013) emphasized that in the analysis of the data, another peer confirms the results obtained. In this way, it can be confirmed that the results obtained are based on the data rather than the researcher's own view. In the present study, a peer who is in educational technology field was asked to examine the data for coherent results. Data collection and data analysis steps were reviewed by the peer carefully.

3.7.2 Quantitative part: experimental validity

History: "Events occurring concurrently with the intervention could cause the observed effect." (Kratochwill et al., 2010, p.9). In this study, in order to control history effect, the treatment was conducted in summer period. Thus, there was no extra lesson about cell unit at school or special education center or person (teacher). In addition, the researcher controlled that the participants did not study the cell unit out of the special education center.

Maturation: “Maturation refers to changes in behavior due to the passage of time.” (Gast, 2014, p. 99). Maturation is not likely a threat for intervention for short time studies (4-6 weeks) (Gast, 2014). In this study, maturation was controlled because it was a short time study. In addition, the treatment was applied in summer time and students did not take any course which covered the cell concept.

Testing: “Exposure to a test can affect scores on subsequent exposures to that test, an occurrence that can be confused with an intervention effect.” (Kratochwill et al., 2010, p.10). Baseline data were collected intermittently in the multiple probes design, for baseline testing is unlikely a threat. For probe, the questions were presented to students randomly for each session and students were never informed about the correct answers to control testing threat.

CHAPTER 4

RESULTS

In this chapter, firstly, preliminary design principles of designing and developing a tangible mobile application for students with SLD are presented. Development processes of paper-based/mobile device-based prototypes, low fidelity prototype (version 1) and high fidelity prototype (version 2) are explained respectively. After explaining all development processes, the views of special education experts, the science teachers/expert and the students with SLD on both prototypes are analyzed in a detailed manner. In addition, observation data about participants' use of the tangible mobile application is presented. After these stages, the finalized design principles are determined.

Effectiveness result of the tangible mobile application on the students' achievement in 6^{th} grade cell concept is presented. In addition, usability issues about the tangible mobile application by students and the reflections of special education teachers after using the tangible mobile application on students with SLD, is given.

4.1 Research Question 1: What are the design principles of a tangible mobile application for students with SLD?

4.1.1 Stage 1

In this stage, preliminary design principles of designing and developing a tangible mobile application for students with SLD were identified based on analyses. In order to conduct need, learner and content analysis, interviews were administered to a science education expert (SE1) and two special education experts (SP1 and SP2). To give an idea about the application and concretize tangible objects, a sample (the content was parts of digestive system) was developed by the researcher. The principles determined in this stage were taken into consideration for throughout the whole process. Preliminary design principles were determined in terms of four categories: 1) educational content, 2) visual design, 3) tangible object use, and 4) interaction are given.

Principles that seem to complete one another are explained together in the remaining parts of the study. For example, Principle 4 and Principle 5 are explained together since priorities given within one principle is supported by the ideas given in the other principle in terms of appealing to multiple senses as well as keeping reading and writing activities less. This method was incorporated in the principles where there are complementary ideas, as it could be seen in the principles of "educational content, visual design, tangible object use and interaction".

Educational content principles

Principle 1: "Educational content should especially be selected among abstract learning objects."

All the experts, who were interviewed, emphasized the importance of choosing educational content from abstract learning objects. During the conversations, two of them shared stories of students whom they have observed experiencing specific learning disabilities during classroom visits in various contexts. In their experiences, they all observed students to deal with difficulties especially when trying to learn an abstract concept. This reflection was also found to be in parallel with SE1, who has been involved in teaching contexts that focus on science education. In line with the experts from the field of special education, SE1 also asserted expressions that imply the importance of teaching abstract concepts by means of technology. In addition, SP1 and SP2 emphasized that designers need to focus on teaching abstract concepts for both the science courses and life science courses. Following excerpt given by SP1 was echoed almost by all the participants:

> *"…It is very difficult for everyone to visualize concepts in our minds given in 2D formats in the science and life science books. This almost becomes impossible when we are teaching for the students with specific learning disabilities … Let's talk about how to teach the concept of "Plateau".*

Plateau looks like the lowland. There is a difference between them. Plateau is a highland area. Even though you put the child in the middle of the lowland, it is difficult for him or her to understand due to the largeness of the highland. In a simple 2D format, this is really difficult for the child to comprehend the idea. However, the students get into a setting in which he or she feels like walking on the plateau by incorporating the educational content through 3D image." (SP1).

"…Hayat bilgisi veya fen bilgisi dersinde kitaplardaki iki boyutlu görüntülerle kafalarında canlandırmalarının zor olduğu, diğer kişilerin bile gerçek anlamda örneğini görmediği ya da hayal edemeyeceği bir şeyi [ÖÖG yaşayan öğrencilerin] kafalarında imaj olarak oluşturabilmek için. Mesela plato kavramı… Plato, ovanın çok benzeridir. Ama arada şöyle bir fark var. Plato, bir dağdaki düzlük bölgedir. Şimdi bunu, çocuk platonun orta yerine koysan bile büyüklüğünden dolayı algılaması mümkün değil. Basit bir ikili iki boyutlu bir görüntüde bunu çözmesi zor olabiliyor ama 3 boyutlu görüntüde onun içinde geziyor gibi bir ortam oluştuğunda, o zaman farklı bir sürece girer." (SP1).

As you can see in the excerpt above, 3D technology appears to play an important role in the learning experiences of students. This is also crucial for the students with SLD, who need specific support to make visualizations in their minds. We could infer from the interviews that 3D technologies serve as a means of providing better learning conditions not only for the students but also for the teachers. Although SP1 criticized having lack of educational materials that could relate "abstract learning to concrete learning", SP2 noted that there are some available but limited, produced by the teachers. Both shared their concerns about not having enough technologically supported materials.

"…Technologically supported materials are more functional and better facilitators of learning, which leads to permanent learning, than teacher made materials. In this way, multiple clues could be given in various forms

simultaneously. This also contributes to better learning opportunities. In such a setting, stimulus also becomes more concrete." (SP2).

> *"…Teknolojiyle birlikte oluşan somut materyaller, öğretmen yapımı materyallere göre çok daha işlevsel, çok daha kalıcı, çok daha öğrenmeyi kolaylaştırıcı, çok daha fazla ipucunu aynı anda sunma şansı var. Dolayısıyla uyaranları çok daha somutlaştırma şansım var o yüzden de, olmadığından değil ama daha iyi öğrenmeye sebep olsun diye." (SP2).*

SE1 also confirmed the above-mentioned expressions with the following words: *"We need to create platforms that could be lived and experienced by students. This [tangible technology] not only makes abstract concepts concrete but also enable students to learn actively."* (SE1). *"Öğrencinin biraz daha kendi kendisinin yapmasını sağlayacak bir ortam [gerekli]…Aslında somutlaştırmamış oluyoruz burada [kavranabilir teknoloji ile]. Çünkü bizzat kendisinin yapması gerekir."* (SE1). SE1 also mentioned the difficulties experienced in the science teaching process. She finds it too difficult to teach abstract concepts even for adults who continue the undergraduate program in her faculty. She believes that teachers should be willing to use tangible technologies in a way to support their classes. Only in this way, students could internalize the concepts.

Principle 2: "Learning objectives that are determined for educational content should mainly consist of expository texts."

Principle 2 emerged as a result of the interviews with the two experts from the field of special education. Both of the experts underlined the constraints experienced during reading long texts. Students with SLD show common characteristics with regards to performing reading and writing skills. Course books that contain long and complex sentences put these students into a "vicious circle of difficulties". They highlighted the need for tangible technologies in a way to support students and teachers. They believe that instructional designers should be aware of these barriers encountered by this group of students and develop their materials in line with the needs and capabilities of the students. This may open alternative learning paths for this disadvantaged group of students. Words revealed by SP1 showed the roadblocks that encountered by students with SLD and the ways in which those roadblocks could be overcome:

> *"Students with SLD are expected to be on the same platform with other students. I suggest using the same educational goals and content but presenting it with alternative materials with simplified texts... In this way, we could create equal learning opportunities for this group of students … Let's give the course of environmental pollution as an example for a science course. Rather loading children with long texts, if we gave them an alternative scenario of the city via video or image, they would at least have an idea what pollution and its reasons could be."* (SP1).

> *"Şimdi belirli şekillerde kaynaştırma eğitimi içerisinde devam eden öğrencinin okul müfredatını takip etmesi gerekiyor. Bazı yerlerde müfredat bol içerikli hale dönüşüyor. O bol içeriği çocuk alması gerekiyorsa ve alabilecek özelliklere sahipse o zaman hiç çekinmeden orda bu testini yapabilmelisin… Tabi öğrenip öğrenemeyecekler mi? Belli bir görselleştirme ile yalıtılmış metinlerle doğrudan özü veren metinlerle bu iş yapılabilir mi? Yapılamaz mı? Hemen diğer bir örnek sana, mesela çevre kirliliği konusu. Çevre kirliliği konusundaki o döngü ya da çevre kirliliğini arttıran unsurlarla ilgili olarak bunları yüz tane yüz tane sayacağına karşıdan görünen bir sanayi şehrinin [video veya] görüntüsünü bile çocuğa versen… Şehirlerdeki kirlenmenin ne olduğuyla alakalı ya da nedenleriyle ilgili olarak bir şey söyleme şansına ulaşır o yüzden."* (SP1).

Principle 3: "Educational content should be given appropriately to students' age and disability type."

Experts in the field of special education highlighted "age and disability type" as the factors of that could be taken into consideration when designing materials for the students with SLD. Since each one of these students carry unique characteristics, educational materials and the teaching practice need to be adopted in line with the needs of each child.

> *"Students with SLD may present different difficulties in the learning process. Each child with a disability exhibit different characteristic in relation with one's disability type. This picture becomes clearer in the case of students with SLD. While a child may have difficulty in audio perception, the other may have difficulty in the visual perception. For this reason materials are expected to be designed by considering these factors."* (SP1).

> *"Öğrenme güçlüğü olan çocuklar farklı sorunlar sergileyebiliyorlar. Bunlar, her engel grubu içinde yer alan kişilerin birbirinden farklılıkları çok fazladır ve öğrenme güçlüğünde bu durum çok çok nettir. Yani bir çocuk işitsel olarak algılamada sorun yaşıyorsa diğer bir görsel algıda sorun yaşayabiliyor. Bu nedenle materyalin… O nedenle buranın nasıl diyeyim bu şekilde düzenlemesi gerekiyor." (SP1).*

SP1 confirmed the above-mentioned words through his own lived experience in a project conducted in the United States. In the mentioned experimental study, he had the opportunity to observe and work with students with SLD. He noted the significance he had observed between presenting a concept on paper with lots of texts incorporated into the content and technology supported materials incorporated with lots of visuals and simplified texts. He underlined the value of presenting simplified materials designed in accordance with the specific characteristics of student by using technology. He emphasized the fact that technology works better if these principles are taken as a priority. SP2 more or less mentioned similar ideas for the students by saying *"Design should be differentiated with regards to disability type."* (SP2). *"Engel türü de tabi ki de [dikkate alınmalı]. Yapılacak uyarlamaları belirliyor engel türü."* (SP2). Both of the participants noted that "age" should be taken as one of the factors that determine the content and the approach in all these phases.

Principles 4 and 5: "Reading and writing activities should be kept less in educational content." and "Vocal parts of written texts should be included."

Both of the experts from the field of special education indicated "reading and writing comprehension" as one of main problem areas for the students with SLD. As it was noted by SP1, *"Most of the students with SLD (80-85%) suffer from reading skills."* (SP1). *"[ÖÖG yaşayan] Çocukların %80-%85'i okumada problem yaşıyor."* (SP1). Similar concerns were also revealed by SP2. Reasons behind this problematic area in some of the cases are that students with SLD are unable to "visualize" and "illustrate" the concepts when they are presented only in the text form. This leads them to the before mentioned *"vicious circle"* in which they feel demotivated to participate in the classroom activities. Special education experts (SP1 and SP2) proposed that students with SLD could be helped through the effective use of technology in which skills of listening and visualization are incorporated. In line with this, the following recommendation was given by SP1 for the students with SLD to overcome this constraint:

> *"Visualization [for these students' reading and writing activities] becomes extremely important. If you reveal these activities in the audio and visual forms, it [learning] becomes easier. For example, what can you drink when you are by yourself in a desert? You can drink cactus water. How do we know this? We could remember this from a cartoon we have read in our childhood. No one teaches you what you can do in a desert. When we see it on the paper, we could remember the images and pictures. For this reason these are critical factors in their [students with SLD] learning."* (SP1).
>
> *"Görselleştirme o yüzden inanılmaz derecede önemli hale geliyor. Hem dinlemeye dökerseniz hem de görsel olarak bunu verirseniz bu artar. Mesela birçok şeyde. Mesela ben çocukluğumdan kalma şeylerden bir tanesi. Çölde kaldığında ne içebilirsin. Kaktüs suyu içebilirsin. Bunu nerden biliyoruz. Bir çizgi romandaki görüntüden biliyoruz. Bu kadar basit bir şey. Kimse sana kalkıp bunu öğretmiyor. Ama görsel olarak bu kafanızda kalabiliyor. İşte o nedenle bu çocuklar içerisinde kritik hale gelebiliyor." (SP1).*

Excerpt above illustrated the way that learning occurs in the minds of these children and the impact of audio and visual support mechanisms in the learning process. In line with this interpretation, SP2's words also highlighted the value of technology when teaching for these students:

> *"We put educational technology in practice to enable students with the use of alternative skills. We in a way used the existing reading materials, tailored and adopted them into the educational technology."* (SP2).

> *"…Okuma yazma sonuç olarak metinlerde de var. Oradan okuma yazma kullanaraktan buna ulaşamadıkları için, bu kazanımları elde edemedikleri için biz öğretim teknolojisini devreye soktuk."* (SP2).

As could be seen in the words of SP2 educational technology serves as one of the most important means for supporting these students in the learning process. Similarly, SP1 noted the need of tangible technologies with the following words:

> *"…We have students who suffer from reading skills that include lack of vocabulary, comprehension, reading speed and such. For example, if you give a difficult text for a 7th or 8th grade student who has difficulty in reading comprehension, he or she will perceive as if he or she is tortured. He will not move one-step aside with this strategy. We should always keep in mind this question: "How can I present this material for these* students so that (s)he *can comprehend and follow the* course?"(SP1).

> *"…Okuduğunu anlama konusunda ciddi problemleri olan çocuklarımız var. Bunun kimisi dağarcık sorunu yaşıyor, kimisi algı sorunu yaşıyor, kimisi okuma hızı problemi yaşıyor, kimisi okumadaki bazı yetersizliklerden işte eklemleme vs. probleminden dolayı en sonunda okuma okuduğunu anlama problemi yaşıyor. Orta 3'e gelmiş ve okuduğunu anlama problemi yüksek seviyede olan bir çocuk ya da orta 2' de olan bir çocuk için yazılı materyal vermek o çocuğu öldürmektir. O nedenle sizin yapmanız gereken şey bu materyali ona sunulabilir hale dönüştürmeniz gerekiyor."* (SP1).

Voices of SP1 and SP2 highlighted reading and writing skills as one of the primary areas in which students with SLD experience difficulty. Their words also highlighted the nature of these skills and the way they counterpart each other. In other words, difficulty in reading comprehension leads difficulty in writing. That is why these students need to supported in the skills they have strengths, which is listening. Therefore, presenting materials through the effective use of age and disability type appropriate audio visuals enable students to get involved in the learning process.

Principle 6 and 7: "Student should be given appropriate feedback." and "Students should be reinforced upon giving correct answers."

Feedback and reinforcement could be listed as the most important strategies in the effective teaching process. However, the need for these strategies becomes more important when it is the case for the students with SLD. Therefore, both of the special education experts underlined the impact of giving feedback and reinforcement for these students by emphasizing the way they should be given. In this way, the continuity of the learning process and the motivation for learning could be maintained as well as providing guidance and support. SP1 also noted the following principles:

> *"Words used in feedback should be built on positive and constructive approach rather than judgment and criticism. Expressions that associate with failure should be avoided ... In cases when there seems to be failure, avoid using words that may decrease motivation."* (SP1).
>
> *"…Olumlu dille tamamlanmalı, tekrar etmesi gereken bir şey varsa olumsuz ifadelerden ya da onu başarısız hissettirecek ifadelerden uzak bir şekilde doğru kaynağa yönlendirme ya da doğru bilgiyi sunma şeklinde olmalı… Yani eleştiri yok. Yargı yok."* (SP1).

Both of the experts noted how criticism serves as a roadblock in learning. As it was noted by SP1 with the following words:

> *"Being critical [and negative in feedback] is one of the main mistakes that is done in education not specifically for these students. I have to focus on dealing with one's manner and approach towards learning and I can only achieve this through a positive approach. As long as I am critical towards the child I could never built a connection that leads learning. Otherwise all the channels will be closed."* (SP1).

> *"Evet, eleştirel bir yargıyla çocukların üzerine gidiyoruz. Bu genel eğitimde de yanlış yapılan bir şey, özel eğitimde de yanlış yapılan bir şey. Ben çocuğun öğrenmesi ve öğrenmeye dönük olumlu tutumuyla uğraşmak durumundayım. Ben ona eleştirel dille yaklaştığım sürece o buradan uzaklaşacak. Uzaklaştığı zaman zaten kanallar kapanacak...*" (SP1).

The above statement was echoed many times in the conversations with the experts from the field of special education. It could be seen in their views and experiences that motivating students and getting them ready for the learning process is the most important step that leads the other steps. They admitted that this is not only important for this group of special students but also for other students but it becomes a "stepping stone" in the case of students with SLD. These students need to be motivated and supported more than their peers. We could infer from their messages that the interaction should be based on "motivation".

Experts also highlighted "reinforcement" in line with this interpretation. When students with SLD are not provided with appropriate reinforcement, their learning experience could have a desperate end, which is illustrated with the word: *"learned helplessness".*

> *"One of the main [constraints] we experienced with students with SLD is learned helplessness ... In cases when a child is unsuccessful due to having the experience of learned helplessness, he or she should be given reinforcement to make him or her feel that that one could still be successful in spite of making mistakes ... Students should be supported towards his or her strengths and continue to work on the areas he or she is successful."* (SP1).

“Bilhassa öğrenme güçlüğü olan çocuklarımızda bizim yaşadığımız şeylerden bir tanesi öğrenilmiş çaresizlik gibi kavramlar olabiliyor. Öğrenilmiş çaresizlik yani akademik başarısızlık konusunda öğrenilmiş çaresizlik yaşayan bir çocuğa ne kadar başarılı olduğunu hissettirmek için pekiştireç iyidir. Başardığı şeylerin devamı arttırmak sağlamak için pekiştireç yine iyidir...” (SP1).

SP1’s comments about reinforcement was confirmed by SP2 who asserts that the more reinforcement is given the more appropriate behavior is presented. Reinforcement is expected to have the power of increasing motivation, which forms the basis of the learning process.

Visual design principles

Principle 1, 2 and 3: “Interface design, character selection, 2D and 3D images, animations, and vocal parts should be appropriate to the age and characteristics of the disability type.” and “Interface design, character selection, 2D and 3D images, fonts, animations, and vocal parts should be simple, user-friendly, motivating, and should not be distractive.” and “Written texts, images, animations, and vocal parts should facilitate understanding of the educational content.”

Participants’ views appear to be categorized under the second principle of “visual design”. They indicated “attention disorder“ as one of the main problems encountered by students with SLD. In order to overcome the constraints encountered in relation with this problem they suggested design principles based on visuals they attract their attention. They also underlined the importance of considering the “age and disability type appropriateness” in the design process. This enables students to focus on the material on an extended time span rather than short-term playtime activities. Educational materials based on this design principle are expected to be important to increase motivation. Following principles were mentioned by all the participants: Interface design, characters selection, use of 2D and 3D images, fonts, animations and vocal parts should be simple and user friendly, motivating and should not be distractive. Experts stated that concentration is one of the main challenges students with SLD suffer from in the learning process. That is why visuals that are directly related with the educational content should be used. Otherwise, students should be confused with the unnecessary information.

> *"Students with SLD were diagnosed with the problems of attention disorder and limited attention time span. For this reason, we have to consider the developmental processes in age specific groups and design materials that will appeal their expectations and needs ... This is important in all the design processes ranging from color selection to screen layout of critical components ... It should be noted that students expect to follow a consistent screen layout that will make the learning process easier... Once being familiar with the layout, the student is provided with opportunities to focus only on the educational content and acquire the new information."* (SP1).
> *"Öğrenme güçlüğünde güdülenme odaklanma ve dikkat süresiyle bağlantılı olarak problemler zaten ortaya konulmuş vaziyette. Bunun çocukların belli bir süre o etkinlik üzerinde sıkılmadan kalabilmesini sağlamak için çocukların yaş gruplarına uygun çekici şeyler olması gerekiyor. Renk kullanımında ve yerleştirme konusunda ekran üzerinde çok fazla dağılmadan belli bir yere odaklanabileceği şekilde ve bütün kritik verinin hemen hemen aynı yerde çıktığı bir ekran ara yüzler zinciri olarak düşünürsen bunu, her konuyla alakalı olarak çocuk ana bilginin nerede çıktığını zaten alışacak ve hep oradan takip edecek"* (SP1).

Similarly, SP2 makes additional comments that support the idea of visual design principles by saying:

> *"The more the material is presented in a simple form the more student gets focused on the educational content. For example, characters should be given in a way not to suppress the content. These students have problems of memorization so sentences should be short by giving clear messages."* (SP2).

> *"...Ne kadar sadeleştirirsen o kadar dikkat çekici uyaranlardan arındırırsan içeriğe o kadar çok dikkat çektirirsin. Onun dışında da karakterin öğretilecek*

olan şeyin önüne geçmemesine [dikkat edilmeli]. Kısa cümleler [kurulmasına dikkat edilmeli] çünkü [öğrencilerin] bellekte tutma problemleri var." (SP2).

Their words echoed the importance of following visual design principles that meets the needs of students with SLD in a way to extend the attention time span as well as increasing motivation. All of them underlined the importance of using appropriate and necessary visuals that supports the educational content.

Principle 4: "Fonts should be appropriate for students with specific learning disabilities (such as Helvetica, Arial etc.)."

In addition to the visual design principles mentioned above, participants also indicated *"the use of fonts"* as one of the measures that should be taken into consideration. They believe that special fonts should be used to meet the needs of students with SLD. Following excerpt given by SP2 was mentioned by both of the experts from the field of special education:

> *"Fonts serve as stimulus for the software. Using appropriate font forms attract students' attention."* (SP2).
>
> *"[Fontlar] bu yazılımda uyaran görevini görüyor… Çocuğun oraya daha dikkat etmesi gerektiğini vurguluyor."* (SP2).

Tangible Object Use Principles

Principle 1 and 2: "The size, color, details of tangible objects should be similar to real life objects." and "The size of tangible objects should allow to noticing details."

All the experts' interviews highlighted the impact of tangible objects in the learning process. They also indicated that the design of tangible objects should be developed as it is seen in real life situations. This is especially important in the case of students with SLD, who have the tendency to generalize for the objects they have seen. Therefore, instructional designers are expected to be careful in these processes to make sure that student is exposed to see the object with the same shape and features in every context, whether in a course book and on a tablet. These views were supported with the following words:

> *"For example when you see a pink heart you could directly say that it is a heart… It does not work the same in the mind of a student with SLD … As the instructional designers have to be careful to develop the materials and the objects in line with the real life contexts."* (SP2).

> *"Mesela sen kırmızı bir kalpçik gördüğünde kalp olduğunu biliyorsun. Ama onlar [ÖÖG yaşayan öğrenciler] için öyle olmuyor işte... Dolayısıyla da mümkün olduğu kadar nesnelerin gerçek nesnelere yakın olmasını [dikkate almalısın]."* (SP2).

SE1 also stated that students with SLD have the tendency to remember and visualize the objects in their minds in accordance with how objects are presented in shape and color. Keeping up with the international standards (color, shape, and size) was also mentioned as one of the priorities that should be taken into consideration in this process. Tangible object development process was considered as a "model development process", in which all the steps should align with the real life situations.

> *"…We have to be careful to reveal the exact sizes and shapes of the organelles in the teaching process. Isn't this the purpose of the model development process? Depending on the screen, we may enlarge or minimize the objects. Whatever the size of the expected screen is we should reveal the shape and size in the real life formats. We cannot give shapes that contradict with the real life since it may create problems in students' perceptions."* (SE1).

> *"…Gerçek boyutları birebir yapmak gerekiyor. Yani model oluşturmanın amacı bu değil midir? Bir gerçeği vardır gerçekten siz olabildiğince belli ölçeklerde küçültürsünüz. Aynı bu şey gibi ekranı büyütüyoruz büyütüyoruz, nedir her şey aynı oranda büyüyor her şey aynı oranda küçülüyor. Eğer biri*

daha fazla biri daha az küçülürse o zaman işte bir sıkıntı olur öğrencinin algılaması ile ilgili." (SE1).

Moreover, SE1 also highlighted to apply the same mentality in the coloring process. Following international standards (color, shape, and size) could be seen as a road map in this process.

Two special education experts asserted that objects should be designed in a way to reveal the detailed features. In this way, it looks similar to the one that can be seen in the real life. Students with SLD could also be given the opportunity to recognize the objects through these details. Following excerpt highlighted this need:

> *"Objects should be neither too small nor too big. They should be designed in a way to allow the student hold it easily. When the object is too big it creates a problem in the use of screen. Therefore, objects should be designed in an appropriate shape that allows users to use both the tablet and the tangible objects easily."* (SP1).

> *"Aşırı küçük olursa çocuk bunu [detayları] göremez. Aşırı büyük olursa tablet kullanımıyla ilgili sıkıntı çıkar. Ele oturmayla ilgili sıkıntı çıkar. Kontrolle ilgili sıkıntı çıkacak onun yerine çocukların el büyüklüklerine uygun ama detayları görünebileceği bir büyüklük olması önemli"* (SP1).

In his internship classroom observations, as the mentor of special education teacher candidates SP1 has observed cases in which, students with SLD had difficulty in the use of objects due to size inconsistency.

Principle 3: "Tangible objects should be light and made from health-friendly material."

All the experts also emphasized the use of using "light materials with appropriate size that fits the hand of the child". If the object is too heavy, the child could be injured during when trying to hold the object. This also enables teachers to carry the objects to different classrooms easily. Following words shared by SP1 highlighted the special needs of these students: *"When a child has weakness in his or her* *muscles he or she may feel the need for lighter objects more to spend less energy as well as using hand and eye coordination effectively …" "Çocuğun eğer kas gücünde zayıflık varsa … göz koordinasyonu etkili bir şekilde yapabilmesi için kolunu yormadan yapman gerekiyor."* As well, experts also underlined the importance of using health friendly materials in the production process. It is highly possible that the material could expose students to a poisonous situation when it is taken into lungs with the air:

> *"…Normally these children do not put these objects into their mouths unless they are introduced to feed like candies that look the same with the real one. In such cases, tasting even breathing could be dangerous for children because most of the polymer materials are dangerous for health. For this reason, high quality materials should be used to protect children in the teaching process."* (SE1).

> *"… Bir kere bu yaş grubundaki çocuklar tabi ki ağzına vesaire götürmeyecek ve yani belli bir yaştan bahsediyoruz. Ama yine de bazıları şey olur hani böyle ay ne kadar güzel şeker gibi falan deriz. Mesela böyle bir şekilde belki tatma gibi şeyler belki olabilir, belki olabilir o nedenle sakıncalı olabilir eğer iyi maddeler kullanılmazsa. Bunun haricinde tatmak gerekmiyor tamamen teneffüs yoluyla da kimyasal maddeler vücudumuza geçebilir… Çünkü her polimer madde iyi madde değildir o yüzden bu üç boyutlu yazıcılar polimer maddelerden yapılıyor bildiğim kadarıyla onları o yüzden iyi kaliteli malzemelerden seçmek gerekiyor. Teneffüsle de zarar verdiği için."* (SE1).

Interaction Principles

Principle 1: "Students should be informed about the use of tangible objects and a trial screen should be developed."

Special education experts indicated the value of interaction in the use of tablets and tangible objects. This is a novel and different interaction process for the students with SLD. Therefore, experts noted that guided instruction given by the application an important role in the quality of the interaction process. Through a trial practice, students should be given the chance to get familiar with the tangible system and this new interaction type. SP1's own project experience highlighted this case with the following words:

> *"In one of our projects a software was developed. Nevertheless, the setup of the software was not user friendly. The set up was too difficult that I, as an instructor, was even unable to understand how it works. That is why I did not ask the mentors to use it. I was afraid that they would be confused and demotivated."* (SP1).

> *"Şimdi bizim kendi projemiz için başka bir tane yazılım yapıldı. Fakat yazılımın kurulumunda sağ elinizle sol kulağınızı göstermiyorsunuz. Sağ elinizi bacak aranızdan geçirip sol kulağınızı yakalamaya çalışıyorsunuz. O kadar berbat bir kurulum düzeni yapmışlar ki bana anlatıldı, ben dahi anlamadım ve koçlara kullandırtmadım, vermedim. Kuramayacaklar, karmakarışık olacak. Hiç girmedim…"* (SP1).

Principle 2: "Students should easily interact with the mobile application".

Both of the special education experts asserted that the interaction should be easy. They indicated that written texts should be presented with the audio supported materials. SP2 also warned about the danger that could be encountered as a result of limited and difficulty interaction, which may lead to "learned helpnesses". For this reason, materials should be supported with lots of feedback and reinforcement in addition to simple and clear presentation.

Principle 3 and 4: "The amount of interaction between the application and the student should prevent student from getting bored/distracted." and "Tangible interaction between all sections of the application (tutorials, practice, the pretest, the posttest) and students should be provided."

Special education experts stated that in all the steps (pretest, posttest, practices and such) interaction should be maintained. SP1 indicated that the application may not go beyond being a 2D book unless all the interaction are achieved. SP2 also warned about the short time concentration span of students with SLD and noted that they may fail to focus on the application if they are not involved in the interactive learning processes. Following examples illustrated the scenarios that have been experienced by the one of special education experts:

> *"One of the ways of involving students in the learning process is to give them the opportunity to use their senses through touching, hearing, seeing and such… This is especially important for the students with intellectual disabilities. The design should create a platform for the student to occupy continuously with the material that is paper based or 3D real object… When the child is left alone with a material with "no or limited interaction", it highly probable that he or she will lose concentration and motivation to continue."* (SP1).

> *"Bunun işte verimliliği arttırmanın yollarından bir tanesi dizaynın iyi olması, etkileşimin iyi olması, çocuğun materyalle haşır neşir olmaya devam etmesi... Mesela biz zihinsel engelli çocuklarla çalışırken... Bile... Ona bir şey öğretirken bir karton bile olsa, bir gerçek 3 boyutlu nesne bile olsa çocuğun onu eline almasına, incelemesine onunla bir şekilde temasta kalmasına hatta siz soru sorarken avcunun içerisine koyup ona bakmasına neden olursunuz. Çünkü onu başka bir yere koysanız ona bakmayabilir…"* (SP1).

Experts also warned about the quantity of the interaction. Interaction in the design should be presented in a consistent manner that supports the learning process. SP1 noted that students' attention may be lost when there is too much and inconsistent interaction. Therefore, interaction should be given based on the time needed otherwise it may create barriers for the learning. This was illustrated by SP2 with the following metaphor of the use of antibiotics:

> *"As in the case of taking antibiotics unnecessarily, too much and unnecessary interaction may lead to unhealthy learning contexts that affect students' motivation and involvement in a negative way."* (SP2).

> *"Etkileşim çok fazla olursa bu sefer güdülenmesi tıpkı şey gibi düşün hani bağışıklık sistemi güçlenir gibi antibiyotik alırsın bağışıklık sistemi güçlenir de artık şey olmazsın ya o yüzden hani dolayısıyla da çok fazla böyle haşır neşir olmayıp o etkileşimi tam kıvamında verdik uzun olsa motivasyonlarını kaybederler kısa olsa motivasyonlarını sağlamazdı."* (SP2).

SP2 noted that the amount and nature of interaction should be arranged in a way to encourage student independence in the learning process. Otherwise, there lies a risk behind, which is *"interaction addiction"*. In such a context, interaction serves as an *"end"* rather than *a "means"* for better learning.

Principles 5: "Written and vocal instructions should be given to ease of the use tangible mobile application."

Special education experts emphasized the role of "written and vocal instruction" as a guide for interaction. In this way, these instructions could serve as a guide that let students to maneuver in the learning platform. The instructions should also be based on simplicity principle that makes the processes understandable for the student with SLD. These ideas have been illustrated by SP1 as follows:

> *"Students with SLD already deal with a topic that is difficult for them in the classroom. When the student is introduced with a complex material, this may turn into a puzzle. The possibility to make mistakes increases in the puzzle. When one experiences making mistakes the feeling of being unsuccessful increases. The student should be approved with the rewards as much as possible. The more one is successful and given positive feedback and rewards the higher the motivation gets. This also encourages their study habits. There is chain reaction … if you suppose [this process] as a chain"* (SP1).

> *"Zaten okulda anlamakta zorluk çektikleri materyalle çalışacaklar. Eğer materyalle yazarsa, karışık hale dönüşürse onlar için orada çok bilinmeyenli denklem haline dönüşebilir bu. Çok bilinmeyenli denklemle hata yapma ihtimalleri artar. Hata yaparsa eğer, başarısızlık hissini körüklemiş olursun. Mümkün olduğunca öğrenciyi, özel öğretim prensibinden birisidir bu.*

Öğrenciyi mümkün olduğunca başarılı tecrübelerle onaylarsınız. Ne kadar çok başarı o kadar güzel feedback [geri bildirim] ona dönük olarak sağlam pekiştireçler arkasından yeni uygulamalara dönük yüksek motivasyonu getirir ve bu da çalışma becerilerini arttırmaya dönük bir şeydir. Böyle bir zincir var... Basit bir zincirle düşünürsen." (SP1).

Principle 6: "Tangible objects and their images in the application should be similar."

Special education experts asserted that pictures and visuals used on the tablet should be the same with the tangible objects developed. This will support their visual perception and matching skills. SP2 highlighted this interpretation as follows:

"Students with SLD should make generalizations. The more generalizations are similar to real ones, the more difficult students with SLD could make distinctions. At the same time, the more students with SLD make distinctions between the objects, the more they could learn them completely." (SP2).

"... [ÖÖG yaşayan öğrencilerin] bunu [öğretilecek kavramı] genellemesi gerekli. Kavram öğretiminde genelleme ne kadar çok gerçeğine benzer ise ayırt etmesi o kadar güçtür... Ayırt ettiğin zaman da tam öğrenmiş sayılırsın." (SP2).

Principle 7: "Students should be shown an image which tangible object should be touched on the tablet screen."

Special education experts underlined the importance of showing visual illustrations of tangible objects. In this way, students with SLD could be given the opportunity to associate the concept mentioned audial with the picture of the concept given on the tablet. This is also important in the introductory phase, in which visual object is introduced as a clue for the learning process. SP1 noted that value of using visual clues in the learning process as follows:

> *"Clues serve as important instruments in the learning process. When there is no clue, the task could be more difficult for the child… By giving a clue, you could start a chain process which leads one to another…"* (SP1).

> *"…İpucu dediğimiz şey öğrenmeler için önemli. Siz ipucu oluşturmadığınız zaman bu çocuğun ne yapacağıyla ilgili karar verme süreci daha da zorlaşacak… İpucuyla çocuk doğru cevabı verdiği anda, ya da doğru cevaba yöneldiği anda sizin uygun zinciriniz başlar. İşte o zinciri başlatabilmek için ipucu kritiktir."* (SP1).

Principle 8: "It should be clear where to touch the tangible objects on the screen."

Screen layout should be arranged and organized in a coherent way. Tutorial section, practice sections, and such other section that will be used in the layout should be given consistently in all applications. In other words, all these instructional details should be given in the same places with the format. In this way, students with SLD will not spend time and energy to understand the system instead focus on the learning content and material. Following expressions were given by SP1:

> *"… [Student] should not be distracted … Let's give the use of telephone as an example … There are 3 [stylus] tips in the technology of your [intended application] in which the child is expected to touch the object on to the screen. What would you do if the child left one of the tips out of the screen?"*(SP1).

> *"[Öğrencinin] bir yerlere dağılmaması için. Şöyle bir şey var mesela telefon üzerinde alalım. Senin kullandığın teknolojide 3 nokta vardı. 3 noktayı getirip koyman gerekiyordu bu çocuk şunu şöyle yapacak, hop telefonun dışında bırakacak bir tane noktayı. O zaman ne yapacaksın?"* (SP1).

SP1 continues his comments by saying that the below mentioned constraint could create a chain reaction which one leads to another in a way that serves as a barrier for the learning process.

Preliminary design principles for the tangible mobile application for students with SLD determined by investigating special education experts', and science education expert's and teachers' opinions. Final design principles are listed below in terms of four categories:

Educational content principles

Educational content represents the instructional content on the determined learning objects presented in the tutorial and practice parts in the tangible mobile application.

1. Educational content should especially be selected among abstract learning objects.
2. Learning objectives that are determined for educational content should mainly consist of expository texts.
3. Educational content should be given appropriately to students' age and disability type.
4. Reading and writing activities should be kept less in educational content.
5. Vocal parts of written texts should be included.
6. Student should be given appropriate feedback.
7. Students should be reinforced upon giving correct answers.

Visual design principles

Visual design includes interface design, character selection, 2D and 3D images, font selection, animations, written texts, and also vocal parts.

1. Interface design, character selection, 2D and 3D images, animations, and vocal parts should be appropriate to the age and characteristics of the disability type.
2. Interface design, character selection, 2D and 3D images, fonts, animations, and vocal parts should be simple, user-friendly, motivating, and should not be distractive.
3. Written texts, images, animations, and vocal parts should facilitate understanding of the educational content.

4. Fonts should be appropriate for students with specific learning disabilities (such as Helvetica, Arial etc.).

Tangible object use principles

Tangible objects are designed and developed close to real objects to provide physical engagement and multisensory interaction. Students interact with these designed objects by grasping them and touching on to the tablet screen.

1. The size, color, details of tangible objects should be similar to real life objects.
2. The size of tangible objects should allow to noticing details.
3. Tangible objects should be light and made from health-friendly material.

Interaction principles

Interaction represents student interacting with the educational content. Also, the tangible objects provide interaction between the student and the content. Due to the fact that it is a new way of interaction for students, the use of tangible objects should be tested before the application. Moreover, necessary guidance should be provided in application which object to touch or where to touch it.

1. Students should be informed about the use of tangible objects and a trial screen should be developed.
2. Students should easily interact with the mobile application.
3. The amount of interaction between the application and the student should prevent student from getting bored/distracted.
4. Tangible interaction between all sections of the application (tutorials, practice, the pretest, and the posttest) and students should be provided.
5. Written and vocal instructions should be given to ease of the use tangible mobile application.
6. Tangible objects and their images in the application should be similar.
7. Students should be shown an image which tangible object should be touched on the tablet screen.

8. It should be clear where to touch the tangible objects on the screen.

4.1.2 Stage 2

Paper-based and mobile device-based prototypes were developed taking into account the principles determined in the first stage. According to the analyses that were made in the stage 1, with the feedback of two special education experts (SP1 and SP2), content was selected from 6^{th} grade science and technology course and the learning object was selected which was difficult to concretize. In addition, it contained expository text. One science education expert (SE1) confirmed the appropriateness of the learning object in terms of these criteria. In this way, the most appropriate learning object was determined for tangible mobile application.

After determination of the content, paper-based prototype (educational scenario of whole application) (APPENDIX P) was designed. Firstly, views of two special education experts (SP1 and SP2) were taken about educational scenario. They said that each learning unit in the tutorial part should be followed by a related practice. The educational scenario was revised by adding practices. After that, the views of the science education expert (SE1) were taken. She suggested that some parts of the content should be modified. After taking all these views into consideration, the educational scenario was finalized. The mobile device-based prototype included tutorial and practice parts, which was for part of one learning object from the 6^{th} grade cell concept, was designed and developed (Figure 4.1).

Parts of tangible mobile application (pretest, tutorials, and practices), how to use application, learning objective, educational scenario, and interaction were presented to science education expert (SE1)/teachers (ST1, ST2, ST3, ST4, and ST5) and special education experts (SP1 and SP2). Paper-based prototype (educational scenario of whole application) and mobile device-based prototype were presented to experts and teachers taking four design categories of: 1) educational content, 2) visual design, 3) tangible object use, and 4) interaction into consideration.

Prototypes of Tangible Mobile Application

The paper-based prototype refers to educational scenario of the whole application (Appendix P). The tangible mobile application with tangible models (objects), which are explained in the stages of introduction, tutorial, and practices parts were developed. Screenshots of the mobile devices based prototype are presented below (Figure 4.1).

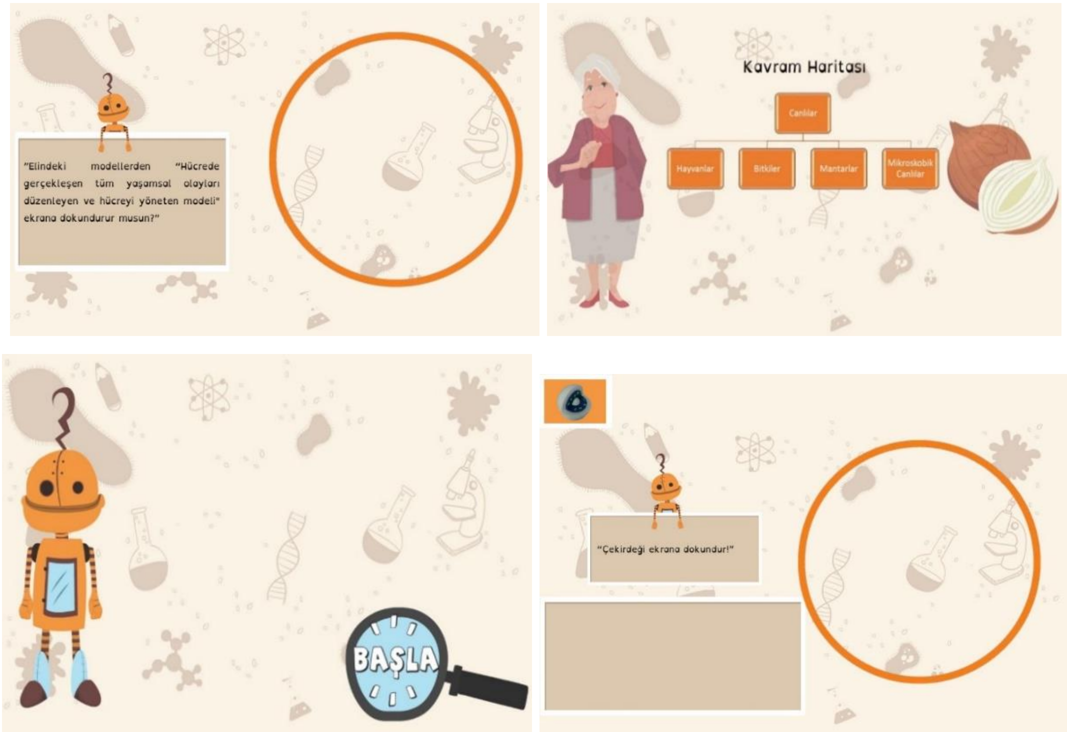

Figure 4.1 Screenshots of the mobile device based prototype

4.1.3 Stage 2.1

In stage 2.1, a semi-structured interview with one special education expert (SP1) and a focus group interview with one science education expert (SE1) and five science teachers (ST1, ST2, ST3, ST4, and ST5) were conducted. Interviews were based on using four design categories: 1) educational content, 2) visual design, 3) tangible object use, and 4) interaction to obtain their views on paper-based and mobile device-based prototypes. At the same time, mobile device-based prototypes were applied to the student with SLD (DC). During this process, the researcher also observed the student and took notes while the student (DC) was using the tangible mobile application. Demographics data about the student was also collected. Semi-structured interview was administered with student with SLD (DC) after using the tangible mobile application. In this process, the student was asked simplified questions that align with the four design categories intended. The researcher analyzed the feedback after stage 2.1 in terms of educational content, visual design, tangible object use, and interaction as they could be seen below.

Educational content

Face to face interviews and focus group interviews showed that both experts and teachers shared similar views with regards to educational content. Interviewed special education expert (SP1) and science education expert (SE1)/teachers (ST1, ST2, ST3, ST4, and ST5) agreed on the usefulness of tangible mobile application in terms of special education and science education fields, respectively. Promising features of tangible mobile application are expected to be useful and beneficial for the students with SLD. Following comment was made by the special education expert (SP1) and it illustrates the ways in which a new perspective could be opened in the minds of students:

> *"Educational content of the tangible mobile application has the following qualities which are; dividing the concept into individual pieces and presenting a whole sample provides both unity and uniqueness, enabling the student to compare-contrast, converting objects to 3D, graspable [objects], children's being able to see the objects on the screen and recognizing the objects in detail. Reusable material enables them to use it many times as well. All these qualities make a change in the lives of children and leave positive impact."* (SP1).

> *"Faydalıdır. Tek tek parçalara ayırması, bütün örnek koyması, karşılaştırma sunması, tekrar edilebilir olması, tekrar tekrar kullanılabilir olması, 3 boyutlu hale dönüştürmesi, çocuğun tekrar tekrar eline alıp yoklayabilmesi,*

ekranda görebilmesi, parçacıkların detaylı olarak farkına varabilmesi bunu ciddi şekilde özel eğitim için kullanılabilir hale getiriyor." (SP1).

Above-mentioned features illustrated the richness of the tangible mobile application in terms of appealing to multiple senses. In this way, students with SLD are provided opportunities to learn and internalize a concept by looking, hearing, touching, and interacting. Although the material is expensive, being able to reuse it multiple times provides a platform for learners in which they could internalize the concept. SP1's comments were also supported by the student with SLD (DC), who indicated that she wants to use the application again and use similar applications in other lessons as well. Similar to the special education expert (SP1), the science education expert (SE1) and all teachers (ST1, ST2, ST3, ST4, and ST5) agreed on the usefulness of tangible mobile application in terms of tangibility, concretizing, visuality, similarity to multiple representations and providing opportunities for tactile learners.

The features of tangible mobile application enable the requirements of learning in special education. For example, special education expert (SP1) enlightened:

> *"There's something I've always told my students. Students with special education needs, intellectual disabilities, learning disabilities, autism needs to be given [constant] stimuli. We could categorize these factors as "stimulus richness, stimulus diversity and stimulus frequency". Each of these [tangible objects] serves as a stimulus. Since tangible objects are provided in 3D with colorful format, it is easy to get the attention of the students. As well, the interactive application serves as a rich source of stimuli for children. Using it many times enables the children to expose with frequent stimuli. When children could make connections between the concepts he or she has learnt and the book content learning experience becomes more visible and comprehensible. This opens paths for stimulus diversity."* (SP1).

> *"Benim hep öğrencilerime söylediğim bir şey var. Özel eğitim öğrencisi zihinsel engelli de olsa, öğrenme güçlüğü de olsa otizmli de olsa uyaran zenginliği, uyaran çeşitliliği, uyaran sıklığı… Bunların her biri bir uyaran*

görevi görüyor. Bu çocuk 3D olması, renkli olması, interaktif hale dönüşmesinden dolayı bir kere bir uyaran zenginliği yaşıyor. Tekrar tekrar kullanılabilirliğinden dolayı uyaran sıklığı yaşıyor. Bunu kitap bilgisiyle birleştirdiği zaman uyaran çeşitliliğine haline dönüşüyor." (SP1).

As it was seen in the above-mentioned quotation, tangible application was seen to be as a means for providing "stimulus richness, stimulus diversity, and stimulus frequency" for students with SLD. Therefore, educational content was found to be successful in ways of following one of the most important learning principles. This is especially evident in the voices of the special education expert (SP1), who found the application useful in terms of providing stimulus richness, diversity, and frequency.

Being consistent with real life can enhance concretizing the concepts and allow students to illustrate them in their minds. In this way, the concepts can be more meaningful for students. Special education expert (SP1) underlined the importance of the application's being in line with real life:

"[He asks the name of the object in his hand]. Endoplasmic reticulum. I have never known the details of it in my life. It was just a drawing. Now it has a meaning for me. I thought the plant cell looks like a computer chip as soon as I saw it. In fact, the computer chip was developed by using the real life as an example. Therefore, the computer chip was a prototype of the plant cell ... I did not before know that plant and animal cells have different structures. Now, I know that there are differences, one of them is rectangular and the other is something else. I heard it before through it is the first time I seen them in this shape that looks real. [He shows the ribosome] That is incredible ... This is awesome." (SP1).

"[Elindeki nesnenin adını soruyor]. Endoplazmik retikulum. Hayatta şunun şu detayı olduğunu bilmiyordum. Sadece karşıdan çizimdi bu. Artık benim için bir anlamı var. Yani şu [bütün bitki hücresi] ben bunu görür görmez bir bilgisayar çipine benzettim, aslında bilgisayar çipi buna benzetildi. Gerçek doğadan çıkmış bir teknoloji örneğini gördük. ...İşte şu ikisinin [bitki ve

hayvan hücreleri] farklı yapıları olduğunu bilmiyordum. Artık farklı yapıda olduğunu biliyorum, birisi dikdörtgen birisinin farklı bir şey olduğunu. Yani öyle söylenmişti ama artık gözümde. [Ribozomu göstererek] inanılmaz bir şey bu. Müthiş bir şey bu." (SP1).

Above-mentioned comments highlighted the value of using tangible technologies in teaching abstract concepts. As an instructor and an expert, he confessed that he has never seen such a real life looking 3D application before that could be used for the students with SLD. So, it was revealed that the rationale behind the application could be seen as functional since it has left a good first impression on the eyes of the expert. Science education expert (SE1) and teachers (ST1, ST2, ST3, ST4, and ST5) agreed that presenting this educational content by a tangible mobile application is appropriate since it is hard to concretize the cell subject. For example, the science education expert (SE1) claimed:

"Students can not exactly make sense of the cell. It is essential to explain the concept of the cell in a 3D way. Also, since students have SLD, they should be supported with visual materials." (SE1).

"Hücreyi tam anlamlandıramıyorlar 3 boyutlu bir şekilde muhakkak dile getirilmesi gerekiyor ki öğrencilerinde görsel olarak, öğrenme zorluğu çeken öğrenciler olduğu için görsel materyallerle de desteklemeleri lazım." (SE1).

Comments of the SE1 align with the comments of SP1 from the basis of revealing difficult abstract concepts through the use of 3D materials. Therefore, the application developed to explain the concept of cell was found to be helpful to open learning paths for the students with SLD. Furthermore, she noted that using realistic and 3D tangible objects instead of using a book or a pasteboard material can bring more advantages when teaching the abstract concepts. Following comments expressed by SE1 highlighted the importance of 3D tangible materials:

"None of us have had the opportunity to observe the organelles so close and realistic. We were only given a simple cell model on a book before. We were

> *expected to assume and recognize the organelles within the cell models… We have used cell models [primitive handmade materials]. Although we can reach the 3D versions, the practice was not that helpful for use to learn the concept of cell ... Now we have a very different developed form of [educational] technology. For example, in a simple handmade material, you could also teach the lysosome. However when you use tangible application you could clearly see the significant differences between the two lysosomes."* (SE1).
>
> *"Bir de hangimiz küçükken gördük ki organelleri bu kadar yakından ve gerçekçi hallerini, hiçbirimiz görmedik. Sadece bize bir hücre modeli veriliyordu ve o hücre modelinin içerisinde hangi organelin olduğunu tanımaya çalışıyorduk. Bizimde orada mesela hücre modellerimiz [basit el yapımı] var. Yani, ama tabi ki bunlar çok farklı bir [eğitim] teknoloji[si], kalkıp da orada 3 boyutlu halini görebilirsin ama aynı zamanda hem öğrenmeni sağlayacak şeyler değildi. Orada da lizozom var burada da ikisi arasında ciddi farklılıklar var…"* (SE1).

SE1 indicated the influence of tangible application in teaching the concepts both in an effective and in a concrete manner. With the use of tangible application, the risks of misunderstanding and misinterpretation when learning an abstract concept could be minimalized and the efficiency in the learning process could be developed at the maximum level. This interpretation was confirmed by one of the science teachers (ST2) with the following words: *"Exactly, [when we were students] we were trying to figure out by looking at the model in the book ..."* (ST2). *"Kitaptaki modele bakarak anlamaya çalışıyorduk."* (ST2).

As a result of using the tangible mobile application, special education expert (SP1), science education expert (SE1) and teachers (ST1, ST2, ST3, ST4, and ST5) found the tangible mobile application useful and helpful to meet the needs of students with SLD. They believe that tangible application might decrease difficulties and struggles encountered by students with SLD in addition to helping them to use different senses in the learning process. Moreover, the tangible mobile application can build a connection between images in their book and the application. This was illustrated by the special education expert (SP1) as follows:

> *"The qualities of incorporating 3D and visual materials through an interactive way this application enables children to be more involved in the learning process. In addition to these unique qualities, the application eliminating reading at the minimum level in a way to encourage children to understand the concept by looking, hearing, and touching. Therefore, children who have difficulties in reading and reading accuracy can learn this [content] by audio-visually supported materials. The application helps the students to connect these [visual representations in the application] with the images in the book… Therefore; it is a life changing opportunity for children with specific learning disabilities."* (SP1).

> *"3 boyutlu, görselleşebilmesi, interaktif olması, okumayı ortadan kaldırıyor olması yani okumakta zorluk çekip okuma kesintileri yaşayacak bir çocuk için bunu dinleyerek ve görsel olarak almak; hem nesne olarak görsel hem tablet üzerinde görsel olarak almak. Bunları kitaptaki görüntüsüyle birleştirmesine yardımcı olacak ve aynı zamanda işitsel algısını kullanacak o nedenle öğrenme güçlüğü olan bir çocuk için nimet."* (SP1).

The science education expert (SE1) pointed out the qualities of tangible mobile application, which were similar to above-mentioned qualities by SP1, as a way of enabling students to learn with the following words:

> *"Since it is realistic, it meets [the needs of students with SLD]. We just need a different way to teach student with specific learning disabilities. They have a strong visual memory. Therefore, you need to include visuals. We looked at them (nucleus etc.) by microscope. We attempted to draw their shapes. Nevertheless, we had difficulty in identifying the organelles when we looked at them. Here, students are able to see at least by concretizing. [With this*

application] one can observe all of them [organelles and the basic components] one by one." (SE1).

> *"Gerçekçi olduğu için [öğrenme güçlüğü olan öğrencilerin ihtiyaçlarıyla] kesinlikle örtüşüyor. ÖÖG yaşayan öğrencilere sadece farklı bir yol gerekiyor öğretebilmek için… Görsel hafızaları onların güçlü ve dolayısıyla görsellik katmak gerekiyor. Çekirdeği filan, bizlerde yaptık, mikroskopta baktık, ardından onların şekillerini çizme girişimlerimiz oldu ama orada bizler baktığımız zaman hangi organellerin hangisi olduğunu anlamlandırmada zorluk çekiyorduk. Burada en azından somutlaştırarak görebiliyor öğrenciler. [Hücreyle ilgili organel ve temel birimlerin] hepsini teker teker gözlemleyebiliyorsunuz."* (SE1).

The importance of incorporating multiple senses from an interactive basis forms the main pillars of the tangible application. As it could be seen from the excerpts above, both SP1 and SE1 underlined the value of the tangible model as a way of cultivating the strengths of the students with SLD rather than focusing on their weaknesses. In this way, they also feel motivated to learn while getting the pleasure of learning a new concept through using their multiple senses.

Special education expert (SP1) expressed that the tutorial and practice parts were appropriate for the target audience in terms of age, developmental characteristics and disability type. Learning and teaching approaches used in the presentation of educational content, methods, and techniques were found to be appropriate for the target audience and objectives. The presentation of content was also found to be appropriate for students with SLD. Reinforcements were also found to be sufficient.

Science education expert (SE1) and teachers (ST1, ST2, ST3, ST4, and ST5) agreed that the tutorial part, and pretest-posttest parts were sufficient and appropriate to teach the concept of cell for students with SLD. Presentation of the educational content was appropriate in terms of moving from outside of the cell into inside of it, presenting basic components in general and then focusing on organelles specifically. According to science education expert (SE1) and teachers (ST1, ST2, ST3, ST4, and

ST5), learning and teaching approaches used in the presentation of educational content, methods, and techniques were appropriate; however, using analogy could be good. By taking this suggestion into consideration, the researcher decided to ask the recommendation of special education expert. Therefore, the issue of whether the use analogy could be used in the application or not was confirmed with view of the special education expert (SP1). As opposed to the suggestion of science education expert and teachers, SP1 warned the threat that could be created when incorporating analogy or developing the application by using the analogy as a base. He pointed out that analogy is not appropriate for the target audience in this study.

The student with SLD (DC) stated that the tutorial and practice parts had a positive effect for her learning. In addition, she noted that tutorial part provided her with the new information while she had the opportunity to make connections with her previous knowledge. However, the experts and teachers noted the need to develop the practice part by concluding with a holistic practice. Therefore, their suggestion was to add a part that summarizes all the sub concepts given within the unit by means of a practice part that enables the student to check what he or she has learnt so far.

All the interviewed experts and teachers acknowledged that the application could increase motivation since they found it enjoyable like a game while teaching a concept in an interactive manner. At the same time, it gets the attention of the students.

The researcher also observed that special education expert (SP1) was able to use the application easily. Likewise, student with SLD (DC) could also use it smoothly. However, the science education expert (SE1) had a problem in touching objects to the screen at the first time when she used the application. She touched the objects on to the tablet screen slightly and then she did not think of removing the object from the tablet to make it function. Afterwards she realized how to touch on to the screen properly, quickly, and easily. The researcher observed during the practice sessions that all the participants found using the application enjoyable and interesting.

Visual design

All interviewed experts and teachers (ST1, ST2, ST3, ST4, and ST5) agreed that user interface design, 2D, 3D images and animations are appropriate. Special education expert (SP1) acknowledged this as follows: *"User interface design is very simple and very usable. It is also designed in a way not to distract the learner's attention."* (SP1). *"[Kullanıcı ara yüzü] çok sade, çok kullanılabilir, çocukların gereksiz yere dikkatini dağıtmayacak şekilde."* (SP1).

Moreover, the student with SLD (DC) stated that she liked the images and the shapes of tangible objects most. It was revealed by the student with SLD (DC) that the images look real.

During the interviews, experts emphasized mostly the importance of color use in tangible applications. Special education expert (SP1) reported that the correct use of color can provide important advantages to learners. This idea is similar to what another science education expert (SE1) proposed as color use could facilitate learning and perception.

It was observed during the use of application that experts, teachers, and the student (DC) liked character, animation, and images. In the application, there was a forest-tree-leaf animation in the first screens. After the animation, there was an experiment that contained the examination/observation on the leaf by using a magnifier and a microscope. All the participants also enjoyed these experiments.

Visual design of the tangible objects was appropriate according to the experts and teachers. Well-designed objects make learning enjoyable. Student with SLD (DC) highlighted the impact of visual design of tangible objects with the following words: *"I liked their [tangible models] shapes and colors."* (DC). "*Şekilleri, resimleri [beğendim]. "* (DC).

In the first piloting sessions, the researcher observed the way how participants got bored with the tone and sound of the robotic voice. Expression that indicates boredom was used by the student with SLD by saying "*off...puff..."* They preferred to read themselves because of the mechanic and slow voice. Vocal instruction given by the robotic speaker was criticized by the participants. All the interviewed experts, teachers, and the student with SLD indicated that they found it boring and slow. The researcher considered all these suggestions and the robotic voice decided to be replaced with a real human voice with clear explanations. The transitions between the explanations are arranged in a smooth and clear way as well as adding the necessary intonation as it is seen in real life class settings. While the experts and teachers gave recommendations for the voice component, they found the written instructions understandable. Therefore, the researcher kept the written instructions as it is.

Robot character was found to be enjoyable, fun, and charming for the application by all participants. In addition, the science education expert (SE1) and teachers (ST1, ST2, ST3, ST4, and ST5) stated that it was compatible with science and technology lesson, the color was appropriate and the character was not distractive.

Tangible object use

The participant special education expert (SP1) and science education expert (SE1) /teachers (ST1, ST2, ST3, ST4, and ST5) agreed that tangible object use could facilitate learning. In addition, they stated that these objects could make content more understandable and can improve learning. The special education expert (SP1) found both the tangible objects and the images of them appropriate for students with SLD.

The researcher observed that when science education expert (SE1)/teachers (ST1, ST2, ST3, ST4, and ST5) used the application, they sometimes had difficulties in using some of the tangible objects such as microscope and plant cell membrane. They suggested that all the objects should work when touched on to the tablet and the consistency and accuracy should maintain afterwards. In this way, effectiveness of the application could be sustained. Apart from this constraint, the experts, teachers, and student with SLD used tangible objects easily in the rest of the activities.

The researcher also observed that all participants were very surprised for the first time they saw the tangible objects. Using the tangible objects was found to be enjoyable for all the participants. They were curios and enthusiastic to touch on to the screen as well as examining the objects within the application. They tried to figure out what the objects were, the function and the role of them within the whole system. In addition to these positive reflections, all the participants found the colors of objects were very attractive. The feedback of experts and teachers about tangible object use was also echoed in the feedback of the student with SLD (DC):

> *"We can see their [basic components and organelles] shapes. The shapes are attractive and full of amusing sides like a toy. For sure it is better to learn in this way: Seeing and touching instead of listening to a lecture."* (DC).
>
> *"Şekillerini zaten görmüş olduk, daha güzel, eğlenceli, oyuncak gibi. Evet, anlatmaktansa öğrenmek daha iyi, görmek, dokunmak…"*(DC).

Science education expert (SE1) /teachers (ST1, ST2, ST3, ST4, and ST5) are more focused on similarity of the objects with the real ones. In this context, experts criticized that the cell wall was not clear in the existing form. In addition to this criticism, experts also noted that the cytoplasm should be similar to egg whites. In addition, science education expert (SE1) and teachers (ST1, ST2, ST3, ST4, and ST5) suggested that the chloroplast should be horizontal and its granada should be cylindrical.

Interaction

Tangible objects developed within the scope of this study were based on interaction principle. That is why students with SLD were provided with the opportunity to interact with the application by grasping tangible objects and then touch them on to the tablet screen. The researcher observed during the application process that the student (DC) found this kind of interaction interesting and enjoyable. This was also confirmed with experts' and teachers' feedback as it could be seen below.

In general, experts and teachers who used the application stated that tangible objects were suitable for providing interaction between the student and the application. In addition, they noted that mobile application provided interaction between the student and the educational content.

It was observed that interaction through the use of tangible objects was found to be exciting and interesting for all participants because it was the first time they were using a tangible application. The researcher observed in their first time experiences that grasping the objects and touching them on to the screen was an amazing experience. They all seemed to be amazed with this kind of interaction. The participants' motivation was also observed to be high during the observations. All the participants listened to the instructions, took the feedback given and appreciated the reinforcements given. Based on the observations it could be said that interaction of the student with the tangible mobile application was successful. The student completed the application without having any interruption.

Tangible mobile application was developed based on the principle of "taking the individual characteristics of the students". Since students with SLD have concentration and focus problems, the tangible application was developed in line with the needs of these students. In this process, cultivating curiosity in learning process was taken into consideration and the idea interaction was aimed to be maintained through supporting students' ability to interact in all these parts. Therefore, allowing students to discover the tangible mobile application may play a key role for providing interaction. Special education expert (SP1) stated the importance of providing interaction between the student and the application:

> *"If the children have learning disabilities but not severe behavior disorders, let them explore… If children have mental disabilities or autism or behavior disorder, I would say be careful with small parts etc., he/she may throw them in the mouth and so on. For instance, a small child wants to do something, Children want to test with their mouth, [objects] may stuck in the child's throat and something happens. However, I think it is not possible for a child*

with learning disabilities. Besides, colors and shapes etc. of [tangible objects] attracts students and it is a good opportunity to explore." (SP1).

> *"Bu çocuk öğrenme güçlüğüyse ve şiddetli davranış bozukluğu yoksa bırakın keşfetsin. Yani bu bir zihinsel engelli ya otizmli bir çocuk olsa ya da davranış problemleri olan bir çocuk olsa, "Aa şu küçük parçalarına vesairelerine dikkat edin", derdim. Ağzına atar, bilmem ne yapar, bir şey olur o tür şeyler. Mesela küçük çocuk şey yapmak ister, test etmek ister. Ağzıyla bakmak ister, orda tık diye boğazına gider bir şey olur, onu şey yapamam ama bir öğrenme güçlüğü olan çocukta bunları düşünmem. Artı bu rengi, şekli bilmem nesi cazibe konusu, keşfetmesi için bir fırsat."* (SP1).

Excerpt above underlined the importance of supporting the interaction through the use of discovery. Although there may be other, risk factors in the cases of students with other severe disability types. Students with SLD may be given the place to discover and use tangible objects securely. In addition, special education experts (SP1) claimed that another factor in ensuring interaction is the real proximity of tangible objects:

> *"I really like this [application]... In OZTEK project, there was a smart clothes application. Real clothes were sewed from the real objects and students placed them on a board. Reality had reached to the top point in this [smart clothes application]. This [application] was very nice [in terms of being real like]. It increases interactivity of children incredibly."* (SP1).

> *"Bu güzel bir şey, ben bunu gerçekten çok sevdim... [ÖZTEK Projesi'nde de] orada akıllı giysiler uygulaması vardı. O da gerçek nesneler, şey, kıyafetler dikilmişti, içine yerleştirilmişti şeyler. Onlarda bir gerçekçilik, şey, çok üst boyuta ermişti, iyi olmuştu. Bu çok güzel oldu, çocukların interaktifliğini çok arttırıyor, inanılmaz arttırıyor."* (SP1).

Special education expert's (SP1) previous experiences and the current experience with regards to the use of the tangible mobile application showed him that real proximity plays a crucial role in the learning process. Therefore, students are given the chance to acquire new information by making transitions and connections with the real life situations.

Students can make practice with tangible objects to use application easily before starting it. Students can gain higher learning benefits by using the application easily and it will be very helpful for students. All interviewed experts and teachers emphasized that there should be a trial screen for the tangible object use to increase interaction. For example, the science education expert (SE1) suggested:

> *"Students should be allowed to try them [tangible objects]. Before they use the application, students should look at all [tangible objects] parts and get a little familiar [with tangible objects]."* (SE1).
>
> *"Uygulama öncesinde incelesinler. Uygulama öncesinde deneyebilsinler. Bence uygulama öncesinde hepsine baksınlar. Biraz şöyle tanıdıklık gelsin."* (SE1).

It could be interpreted from the before mentioned words that a trial screen and a trial use is necessary both to make the students get familiar with the tangible mobile application and to sustain the interaction as much as possible.

Screen placements could serve as a guide for students as well as facilitating interaction between student and the application. Special education expert (SP1) shared his thoughts about a "circle" used as a screen placement to guide students. The way how "circle" functions is beneficial for the students in a way to guide them where to touch and where to focus: *"Using a circle [where touched the object] provides tips about where to focus continuously."* (SP1). *"O dairenin kullanılıyor olması sürekli nereye odaklanacağıyla alakalı ipucu sağlıyor."* (SP1).

As it could be seen in the excerpt above students with SLD need guides or some sorts of markers used in the screens. In this way, they know where to touch and how to proceed in the steps of the learning process. These screen placements provide advantages both in terms of being used as a guideline and as a platform for constant interaction. This also aligns with our principles used in the early stages of this research study.

The science education teachers (ST1, ST2, ST3, ST4, and ST5) and expert (SE1) suggested that students should take feedback whether their attempts were successful or not. Following words were expressed by the science education expert (SE1): "*Feedback should be given even if it is absolutely correct or incorrect.*" (SE1). *"Yanlış da olsa doğru da olsa. Dönütler yer almalı."* (SE1).

Although positive reinforcement and feedback for the correct answer are applicable in the application, feedback should be given to students for incorrect answers. The application should give immediate feedback with the vocal instruction. Therefore, students will be given the initiative to take responsibility for their own learning and be willing to involve in the learning process through constant feedback and interaction. For example, when the student touched the mitochondria instead of the vacuoles, the application would give a vocal feedback by saying "*It is the mitochondria*". In this way, students would be aware of what they have done and the learning process will be supported through guiding towards the targeted concept that needs to be taught.

4.1.4 Stage 3

In this stage, a low fidelity prototype was developed as version 1, based on preliminary design principles and the views of special education expert (SP1), science education expert (SE1) and teachers (ST1, ST2, ST3, ST4, and ST5) revealed in the stage 2.1. As a result of taking all these views into consideration, the mobile prototype part was improved through making the necessary modifications and additions. After taking feedback of experts and teachers about paper-based prototype, this part was developed based on their feedback. Improved, modified, and added parts are explained below in the Table 4.1.

Table 4.1 Improved, modified, and added parts

Previous Version	Improved, Modified, and Added Version	Source
There was no feedback for incorrect answers.	Appropriate feedback for incorrect answers were added.	SP1, SE1, ST1, ST2, ST3, ST4, and ST5
There was no holistic practice at the end of the tutorial and practice parts.	A holistic practice at the end of the tutorial and practice parts was added.	SP1, SE1, ST1, ST2, ST3, ST4, and ST5
There was robot voice in vocal instructions.	A fluid and faster voice record instead of robot voice in vocal instructions was used.	SP1, SE1, ST1, ST2, ST3, ST4, and ST5, DC, observation
Sometimes tangible objects could not work correctly.	More stable tangible objects were developed.	SE1, ST1, ST2, ST3, ST4, and ST5
A big and thick cell wall object was designed.	A new 3D design and print for the cell wall object was developed.	SE1, ST1, ST2, ST3, ST4, and ST5
The cytoplasm was not similar to egg white.	The cytoplasm was changed similar to egg white.	SE1, ST1, ST2, ST3, ST4, and ST5
The chloroplast was vertical and its granada was not cylindrical	The shape of the chloroplast was made horizontal and its granada was made cylindrical.	SE1, ST1, ST2, ST3, ST4, and ST5

4.1.5 Stage 3.1

In stage 3.1, semi-structured interviews with two special education experts (SP1 and SP2) and a focus group interview with one science education expert (SE1) and six science teachers (ST1, ST2, ST3, ST4, ST5, and ST6) were conducted according to four design categories: 1) educational content, 2) visual design, 3) tangible object use, and 4) interaction to obtain their views on version 1.

In addition, to taking views of the experts and teachers about the modified version of the prototype, the version 1 was also used by two students with SLD (DC and BK) by the help of researcher. They were observed and all these phases were video recorded to be used for the further analysis. In addition, students' demographics data were collected. Semi-structured interviews were administered to students with SLD (DC and BK). Details are given as follows:

Educational content

Improved and modified parts in the educational content were found to be appropriate by all interviewed science education expert (SE1) and teachers (ST1, ST2, ST3, ST4, ST5, and ST6) and the students with SLD (DC and BK). Science teachers found the presentation given within the scope of the educational content satisfying in terms of providing an effective organization of the content for a science lesson. They noted that the concept is suitable not specifically for the students with SLD but for all students. Since topics given a science lesson are not easy to be revealed effectively to the students, science teachers expressed the need felt during the teaching process. Science teachers illustrated this view with the following example taken from the application.

There was a comparison experiment between animal and plant cell in the application. Before the experiment, there was a visual explanation of why we use human cell for animal cell. One science teacher (ST6) underlined that even normal students get confused about why we were taking samples from human for examining the animal cells in the experimental stage. In line with this reflection, the researcher also observed during the application process that student DC liked the experiment. Her expressions and her body language showed that she enjoyed all the phases of the teaching process. Notes taken by the researcher exemplified the way how she was involved in the process. When she touched microscope to the tablet screen, she saw the leaf cell. She was fascinated and excited.

The researcher was careful to take all the necessary teaching strategies into consideration during the development of the prototype. One of the main strategies the researcher took as a priority was to make connections between learners' previous information. This was also appreciated by the participants who used the application. In line with this priority, there was a concept map to remind students classifying of living things from 5^{th} grade. One of the science teachers (ST6) claimed that the concept map in the application was very effective to illustrate this concept.

There were also some minor suggestions made by the participants. Although these recommendations were not fundamental changes that affect the general format and the content, these are only some minor changes in wording. For example, ST6 suggested changing the verb "allow" into verb "provide" as it is more appropriate in the context of removing harmful substances. For the rest of other improved and modified parts, science teachers were appeared to give positive comments.

From another perspective, special education experts' views were also taken into consideration when giving the final revisions for the application. As for the educational content, they seemed to be satisfied with most of the parts. However, there were some minor changes that were put forward. The researcher took these views into consideration to make the necessary changes. Students with SLD are needed to get feedbacks for each of their actions. Both special education experts (SP1 and SP2) agreed that students should be given corrective feedback. One of them (SP2) suggested:

> *"There are two types of feedback, for the correct response and incorrect response. For the correct response, necessarily, before or after well done, bravo, etc., it should be a statement 'this a ...' You are doing great, it's a*

cytoplasm! or bravo, it is a cytoplasm! For the incorrect response, feedback should be like: 'this is not*…, you should touch ...'"* (SP2).

"2 tür dönütümüz var, doğru tepkilerde ve yanlış tepkilerde. Doğru tepkilerde mutlaka, aferin bravo vs.' lerden sonra ya da önce bu bir....... şekilinde açıklama olmalı. Mükemmel gidiyorsun bu bir sitoplazma, ya da bravo bu bir sitoplazma gibi, yanlış tepkilerde ise bu .... değil. ..... dokundur şeklinde dönüt gelmeli." (SP2).

Experts suggested that the wording in giving the feedback should be used in longer sentences such as:

"Do you think this is …? Come on, touch the ..."or "Be careful! touch ... In essence, this should be ultimate goal: Children should understand when they are wrong. They should know what to touch instead of just being told that their answer was incorrect ..." (SP2).

" ..." Sence bu....... mu?. Hadi......... dokundur. Ya da "Dikkat....... dokundur." gibi. İşin özünde şu olmalı sonuçta, yanlış yaptığını anlamalı ve yanlışın yerine ne koyacağını bilmeli." (SP2).

SP2's words given above was echoed in SP1 as well. Their words highlighted the importance of giving corrective feedback to the students during the learning process. In addition to face-to-face interview reflections, the researcher also took observation notes during the application part. The researcher's observation showed that one of the students (BK) was a little tense in the pretest. He spent longer time on some of the questions more than expected. He wanted to think more than the routine timing. This may be seen as a sign of him taking the process seriously and his willingness to complete the application successfully. Similar behaviors were also observed during the posttest as well. Two of the students showed signs of tense behaviors in the posttest, most probably with the same concerns. However, they could not direct attention on the practice in the posttest. The researcher observed that they were willing to do it in a correct way and they wanted to get confirmation after each step whether they are right or wrong. However, this did not stop them to concentrate on the task with full attention. This may be due to their first time experience and being unfamiliar with the task and the application. It should also be noted that this might be related with their characteristics with regards to students with SLD. Observations revealed that from time to time; they smiled and made it clear that they were happy and satisfied about using the tangible mobile application.

Students with SLD were also found to reveal unique and different perspectives in the observation of the follow up activity. Each learning unit in the tutorial part was followed by a related practice. It was observed during the use of application that the students could not make sense about why this activity was given to them and they showed expressions that this was confusing for them. In order to overcome this problem, the researcher explained the students that these questions were used a complementary component that could be used as a reinforcement for the learning process. The more they become familiar with the task and the application the more they felt confident to do the practice. At the same time, they also used expressions how indicated that they appreciated the modifications and improvements done in the updated versions of the tangible mobile application. This also evident in the comments of DC and BK, who became experienced users after each practice.

Visual design

Improved and modified parts in visual design were found appropriate by all interviewed science education expert (SE1), teachers (ST1, ST2, ST3, ST4, ST5, and ST6) and the students with SLD (DC and BK). They found the images which were presented before the concept map were effective. Moreover, vocal instruction was found to be appropriate in this stage.

Improved and modified parts in tangible object use were found partially appropriate by special education experts (SP1 and SP2). For example, one of them (SP2) noted that there is no synchrony between the audio and images on a few screens. SP2 suggested that they should be synchronized.

Moreover, they (SP1 and SP2) discussed that the duration of that image on the screen should be 5 seconds when students touched the microscope in experiments. 10-second duration was found to be too long and confusing. The researcher used these constructive feedback and attempted to make the necessary modifications to improve tangible mobile application.

In addition, the special education experts (SP1 and SP2) reported that the concept map appeared too fast on the screen, which caused the students to have difficulty to follow. They suggested that there should be 2-3 seconds before and after each set of the content. SP2 explained this with the following words: "*When moving from one exercise to another, we should be given more time. We call it instruction with consecutive trials. The important thing here is to take 2-3 seconds in transition. It should be slower*." (SP2). *"…Bir alıştırmadan diğerine geçerken süre ver. Biz buna ardışık denemelerle öğretim deriz ve burada önemli olan geçişlerde 2-3 saniye geçmesidir. Hızlı bir geçiş var bunu yavaşlatalım"* (SP2). This suggestion was used as one of the principles in the design process by the researcher. The modifications and improvements were also done in line with this suggestion. Therefore, before and after each content the researcher made sure that 2-3 seconds were given for the students to enable them to think about the content, perceive it by using various senses and internalize the concept with the carefully planned steps.

The researchers also took the views of students while applying the model. The students' expressions underlined the fun part of the design as a result of the modifications made in the revised version. Therefore, improved and modified parts in visual design were found to be appropriate by students with specific learning disabilities (DC and BK). DC's comments exemplify the ways in which their attention was guided towards learning and interaction through the visual design elements used in the application:

> *"I liked all of images [in the application]. Especially, the tree animation was very nice which was coming at first [screen]. The font facilitated my reading.*

I listened to all voices and read all text at the same time. It was useful." (DC).

"Tüm resimleri beğendim. Özellikle ilk baştaki ağaç animasyonu çok güzeldi. Font okumamı kolaylaştırdı. Aynı anda tüm sesleri dinledim ve tüm yazıları okudum. Yararlıydı." (DC).

Comments of the student revealed the impact of visual design elements in the design process. Students were constantly in need of using their multiple senses through various forms of means. Visual and audio elements were needed to be used effectively to encourage students to get involved in the learning process. As well, other senses such as touching can also be used to let students feel the process as well as taking initiative for his or her own learning. Although it may not be possible to incorporate other senses such as smelling and tasting, the design could be developed in a way to let the student feel those senses. In this way, students with SLD could be provided with a platform of learning in which the abstract experiences could be felt and visualized in their minds. The researcher was aware of the difficulty of realizing this aim though she attempted to do her best to create such an application through taking all these views into consideration.

Tangible object use

Improved and modified parts in tangible object use were found to be appropriate by all interviewed special education experts (SP1 and SP2), science education expert (SE1) /teachers (ST1, ST2, ST3, ST4, ST5, and ST6) and the students with SLD (DC and BK).

Reflections showed that tangible objects were found to be more useful than drawings made by the teachers. One of the science teacher's (ST6) comments highlighted the need for finding alternative methods to overcome the burdens created in the traditional system: "*Tangible objects are very useful to make content understandable. Since normally we just draw these components and organelles on the board…"* (ST6). *"[Kavranabilir nesneler içeriğin anlaşılmasını] kolaylaştırıcıdır. Biz sadece* *tahtaya çizdiğimiz için bence çok başarılı."* (ST6). ST6 noted that in the traditional method we appeal to the sense of "seeing" rather than using all other senses. However, with the help of tangible objects we could actively involve the students in the learning process. They also noted that not only students with SLD but also all the students should be given such opportunities to learn the content better.

In line with the reflections of the experts and the teachers about the tangible object, students also revealed positive comments when they were shown and asked to practice with the revised parts. Improved and modified parts in tangible object use were found to be appropriate by the students with specific learning disabilities (DC and BK) with the following words: *"[Tangible] objects and especially new shapes of the cytoplasm are very nice."* (DC). *"Nesneler özellikle de sitoplazmanın yeni şekli çok güzel."* (DC).

Another suggestion about the tangible object use was made in line with the needs of the students with SLD. SP1 suggested that all of the tangible objects should not be presented to students at the same time in order to prevent any distraction when students use the application. Additionally, tangible objects should be placed in separate boxes and students should take them from the boxes for giving attention and clearer vision of tangible objects. In this way, students with SLD may be guided towards the learning in the order arranged by the teacher rather than leaving the student in a room of toys without having any guided purpose. This also served as one of the design principles by the researcher.

Interaction

Improved and modified parts in interactions were found to be appropriate by all interviewed special education experts (SP1 and SP2), science education expert (SE1) /teachers (ST1, ST2, ST3, ST4, ST5, and ST6) and the students with SLD (DC and BK).

There is a possibility that students may not examine or look at the object for any reason (distraction, hurriedness etc.) during the use of the application. In this context, SP1 suggested that the images should come to screen transparently before the students touch the tangible objects to screen in order to increase interaction. This also served as one of the design principles that could increase interaction in the present study.

Especially at the beginning of the application, students may have missed the instructions or explanations. In order to overcome this problem, students should be given the opportunity to listen again as much as they want. Both special education experts (SP1 and SP2) recommended that students could replay the explanations in tutorial part optionally. Following excerpt taken by SP1 was echoed in the voices of other experts:

> *"These students have the tendency to have day dreams most of the time. We have seen this scenario many times… Even though you provide them the content in the context of technology, you may still find them day dreaming and getting lost in the practice. Therefore, when giving an instruction, we have to make sure that student gets the directions correctly. That is why they should be given the opportunity to listen to the instructions as much as he or she wants. This is our general principle in the learning process with these students."* (SP1).

> *"Çünkü bu çocuklarda zaten yüksek oranda görülen bir şey sis, gündüz düşleri vs. bunlar tarzında. Siz onlarla çalıştığınızı düşündüğünüz zaman, o teknoloji karşısında da olsa odağını kaybedebilir ve oradaki yönergeyi görmeyebilir. Ya da gündüz düşünün arasında kaybolup gidebilir. O nedenle bunun [çocuğun] kaçırdığı yeri tekrar edip başarıya ulaşabilmesi için tekrar aynı noktaya [gelmesi lazım]. Her zaman bizde temel prensip bu."* (SP1).

Above-mentioned statements highlighted the need to give multiple chances to the students to learn in accordance with his or her own learning pace. The researcher made the necessary change to meet his need expressed by the participants and added a replay button in the introduction part of the tutorial application.

The importance of giving feedback was mentioned in the educational content section before. This appeared to be significant as in the case of interaction. All the participants noted the importance of feedback as an instrument for enhancing the interaction process. In line with the views of the teachers, student DC also used expressions that highlighted the value of feedback enhancing the interaction process. Her views showed that giving feedback for both correct and incorrect attempts can increase interaction from the lenses of the students. DC's words could bring us the lenses of students with SLD: *"It [the feedback] told me when I was wrong or right. I liked it."* (DC). *"Doğru veya yanlış olduğumu söylemesini sevdim."* (DC).

There was also trial screen about tangible object use to increase interaction with the tangible mobile application. Based on the observations, especially, BK liked the trial screen very much. The application stated the names of objects when he touched them on the trial screen, the student was very pleased and excited with it. He even touched all of the tangible objects twice. Based on the observations, it was seen that all of the students could use the application easily. Using the application was enjoyable and interesting for them.

The researcher observed in the application process that in some of the objects students may felt demotivated to use due to some limitations. Especially when they used them at the first time, BK look surprised and DC looked bored. The researcher also took the observations as a data to improve the application in the follow up steps and made the necessary modifications. One of the constraints was experienced when students touch the screen with his or her fingers. The screen does not function when the fingers are in contact with the screen. This is one of the barriers that may influence the interaction process in a negative way. The only approach that could be done is to warn the student about the ways in which the screen works.

4.1.6 Stage 4

In this stage, a high fidelity prototype was developed as version 2 based on the views of special education experts (SP1 and SP2), science education expert (SE1) and teachers (ST1, ST2, ST3, ST4, ST5, and SP7). After taking their views stage 3.1 into consideration, Version 1 was improved, modified, and given the updated shape as Version 2. Improved, modified, and added parts are explained in Table 4.2.

Table 4.2 Improved, modified, and added parts

Previous Version	Improved, Modified, and Added Version	Source
Audio and animation have no synchronization at some screen.	Audio and animation were synchronized.	SP1 and SP2
Duration of image on the screen was 10 seconds.	Duration of image on the screen was reduced from 10 seconds to 5 seconds.	SP1 and SP2
There were no corrective and descriptive feedback	Feedback for the correct response and incorrect response were incorporated.	SP1 and SP2
Screen transitions were too fast.	Screen transitions were delayed 2-3 seconds.	SP1 and SP2
All tangible objects have presented to students in one box at the same time.	Tangible objects were presented to students in three different boxes in terms of their features (For instance, common organelles should be in a box).	SP1 and SP2
There was no replay button for the explanations in the tutorial part.	A replay button was added for the explanations in the tutorial part.	SP1 and SP2
There were no transparent images of the objects which were presented on the screen before the students touch the objects.	Transparent images of the objects were presented on the screen before the students touch the objects,	SP1 and SP2

4.1.7 Stage 4.1

In stage 4.1, semi-structured interviews with special education experts (SP2 and SP3) were conducted based on the following four design categories: 1) educational content, 2) visual design, 3) tangible object use, and 4) interaction to obtain their views on version 2. As the final step for the revisions, Version 2 was applied to one student with SLD (BK) and the researcher observed the process. The student's demographics data were also collected. The learning process was video-recorded as well. Semi-structured interview was also conducted with the same student (BK).

Educational content

Improved and modified parts in the educational content were found to be appropriate by special education experts (SP2 and SP3) and the student with SLD (BK).

Both special education experts (SP2 and SP3) claimed that tangible mobile application is useful for special education. For example, SP2 stressed that: *"It is useful. It is necessary for the subjects in the curriculum to be acquired for students with SLD and it is necessary to make adaptations for them."* (SP2). *"Yararlıdır. Çünkü müfredat içinde yer alan konuların özel öğrenme güçlüğü gösteren çocuklar için de kazandırılması gereklidir ve bunun için uyarlamalar yapmak gereklidir."* (SP2).

SP3 noted the unique qualities of the tangible mobile application by saying that she found it useful and appropriate for the students with SLD. The way how audiovisual items are used and the way how the concept are presented enables the student to understand the concept while interacting with the application. She thought that the whole process was based on the idea of "learning by doing". As well, the tangible system gives immediate feedback and reinforcement, which motivates students to be actively involved in the learning process.

Presenting the content to students with SLD clearly can make their learning easy. Regarding educational content, SP3 said:

> *"There is a clear and concise presentation that makes it easier for students to understand. Since language is understandable, clear, fluent, and natural, it facilitates the perception, attention and motivation difficulties of these learners."* (SP3).
>
> *"Öğrencilerin anlamasını kolaylaştıracak şekilde net ve anlaşılır bir sunum var. Dil anlaşılır, net, akıcı ve doğal olduğundan, bu öğrencilerin algı, dikkat ve motivasyon güçlüklerin kolaylaştırabilecektir ve dolayısıyla uygundur."* (SP3).

SP3's above-mentioned statements underlines the importance of clear language use in the application not only as a means of channeling the necessary information but also encouraging students to learn and motivate them. In similar manner, SP2 emphasized the importance of continuity of getting students' attention via the mobile application as well as providing to learn.

At this stage, participants agreed the effectiveness of the organizational structure used within the application in terms of educational content. In line with this idea, SP2 emphasized that the practices were arranged in a way to allow better understanding of the concept.

Observation notes revealed the positive insights and behaviors observed by the researcher. Compared with observation of Version 1, the student was much more involved with the revised form of the mobile application in Version 2. It was noted during the observation that the student could use the application more easily. Using the application was enjoyable and interesting for him. However, in the questions and the practice parts the student sometimes used the tangible objects carelessly. To be more specific, he touched the objects randomly to the tablet screen. This point was also taken into consideration to take the necessary precautions. At this stage, the researcher gave the final shape for the mobile before the experimental phase. Observations notes were used as a means to use the necessary strategies for instructional designers in design processes.

Visual design

Improved and modified parts in tangible object use were found to be appropriate by special education experts (SP2 and SP3) and the students with SLD (BK). SP3 underlined the appropriateness of the visual design used in the revised version with the following words:

> *"The visual design was appropriate because it took the difficulties of attention problems of these students [with specific learning disabilities] into account. This design included elements that enhance the attention and motivation of the students."* (SP3).
>
> *"Tasarım bu öğrencilerin dikkat sağlama güçlükleri dikkate alınarak tasarlandığından uygundur. Bu tasarım[da] öğrencilerin dikkat ve motivasyonunu arttırıcı öğelere yer vermiştir."* (SP3).

In line with the reflections of SP3, SP2 also added: *"The visual design is appropriate because it is simple, guiding, and not distractive."* (SP2). *"Dikkat dağıtmayan, sade ve uygun biçimde yönlendirici olduğundan [görsel] tasarım uygundur."* (SP2).

Experts (SP2 and SP3) emphasized appropriateness of the instructions. For example, SP2 claimed: *"Instructions are short, clear, and appropriate to the age level."* (SP2). *"Yönergeler kısa net ve yaş düzeyine uygundur."* (SP2). Similarly, SP3 stated *"The vocal instructions which are clear and understandable, helps the students for difficulties in following the instructions. In addition, written instructions are free from confusing and distracting items. They are simple."*(SP3). *"Sesli yönergeler öğrencilerin yönerge takibinde yaşadıkları güçlüklere yardımcı olacak şekilde net ve anlaşılır olduğundan uygundur. [Ek olarak] Yazılı yönergeler; basit, karışık ve dikkat dağıtıcı öğelerden arındırılmış şekilde olduğundan uygundur."* (SP3).

In addition, it was observed during the use of application that the student also liked the character, animation, and images were used in the revised version. He enjoyed to conduct magnify and microscope experiments as well. As a result of these positive reflections, the researcher decided to give the application the final shape and continue with the experimental stage and test the effectiveness of the model in the follow up stages.

Tangible object use

The third category which was tested in Version 2 was the tangible object use. In this phase, improved and modified parts in tangible object use were found to be appropriate by all interviewed special education experts (SP2 and SP3) and the student with SLD (BK). It could be interpreted from their views that tangible objects can help students to understand the content easily. Their views were echoed in SP3's in the following quotation:

> *"[By using tangible objects] Faster and easier acquisition can be achieved. There may also be positive developments in fluency, generalization and retention."* (SP3).
>
> *"[Kavranabilir nesneler kullanılarak] daha hızlı ve kolay edinim sağlanabilir. Ayrıca akıcılık, genelleme ve kalıcılık bakımından olumlu gelişmeler olabilir."* (SP3).

In addition, she added: *"Since they [tangible objects] are consistent with general characteristics and needs of these students, they are appropriate."* (SP3). *"Kavranabilir nesneler, bu öğrencilerin genel özellikleri ve ihtiyaçlarıyla tutarlı olduğundan uygundur."* (SP3).

Using the tangible objects was enjoyable for the student. Because the tangible objects were in 3D format, they were attractive for students with SLD. Reflections taken for tangible object use showed that revisions made so far are satisfactory to start the experimental stage.

Interaction

The final category was interaction and participants' reflections were also analyzed to check whether changes made for the application was useful or not. As it was seen in other categories, improved and modified parts in interactions were found to be appropriate by interviewed special education experts (SP2 and SP3) and the student with SLD (BK).

Both of the special education experts and the student who practiced the new version appreciated the way how interaction is maintained in the application. SP3 underlined that interaction must be based on instructions, reinforcement, and feedback between students and the application. More specifically, she exemplified: *"Immediate feedback is important for students in this group [students with SLD], feedback needs to be clear."* (SP3). *"Bu gruptaki öğrenciler için anında geribildirim önemlidir, geribildirimlerin net olması gerekir."* (SP3). Their words noted the ways in which interaction was embedded in all the stages in each task whether implicitly or explicitly. SP2 is one of the participants who has been able to visualize and experience all the stages of the study. Therefore, she was able to make comparisons and comment on the updated versions with comparative methods. Her words showed that revisions made in the latest version is much more effective in terms of enabling students to interact in all the stages of the tangible application.

It was observed that interaction by using tangible objects was very exciting and interesting for the student (BK). It was also noted that the student's motivation was high to complete the application. He listened to the instructions, feedback, and reinforcements. Based on observation, interaction of the student with the tangible mobile application was also found to be successful. However, sometimes he touched his finger(s) on the screen when he touched the tangible objects to the tablet screen. Hence, the interaction was interrupted when his finger(s) touched the screen. However, these minor constraints are not directly answered as a change in the application. This may be due to the individual characteristics of the child as well. All these notes were reported in the present study to enable instructional designers for the design processes in the future studies.

4.1.8 Stage 5

Design principles for the tangible mobile application for students with SLD determined by investigating special education experts', science education expert's and teachers', and students' opinions. Final design principles were determined in terms of four categories: 1) educational content, 2) visual design, 3) tangible object use, and 4) interaction are given. In addition, sources and stages are presented in Table 4.3. In addition, the design principles are listed below.

Table 4.3 Final design principles

EDUCATIONAL CONTENT							
Stage 1		Stage 2.1		Stage 3.1		Stage 4.1	
Source	DP	Source	DP	Source	DP	Source	DP
SP1, SP2, SE1	Educational Content should especially be selected among abstract learning objects.						
SP1, SP2	Learning objectives that are determined for educational content should mainly consist of expository texts.						
SP1, SP2	Educational content should be given appropriately to students' age and disability type.						
SP1, SP2	Reading and writing activities should be kept less in educational content.						
SP1, SP2	Vocal parts of written texts should be included.						
SP1, SP2	Students should be given appropriate feedback.			SP3	Students should be given immediate feedback.		
SP1, SP2	Students should be reinforced upon giving correct answers.						
		SP1, SP2	Each learning unit in the tutorial part should be followed by a related practice.				
		SP1, SE1, ST1, ST2, ST3, ST4, ST5	There should be a holistic practice at the end of application.				
				SP1, SP2	A corrective feedback should be given after an incorrect answer/attempt.		
				SP1, SP2	A descriptive feedback should be given after a correct answer/attempt.		
		Obs.	There should be interactive activities (experiments, animations etc.) in tutorial part.	Obs.	There should be interactive activities (experiments, animations etc.) in tutorial part.	Obs.	There should be interactive activities (experiments, animations etc.) in tutorial part.
VISUAL DESIGN							
Stage 1		Stage 2.1		Stage 3.1		Stage 4.1	
Source	DP	Source	DP	Source	DP	Source	DP
SP1, SP2	Interface design, character selection, 2D and 3D images, animations, and vocal parts should be appropriate to the age and characteristics of the disability type.						
SP1, SP2	Fonts should be appropriate for students with specific learning disabilities (such as Helvetica, Arial etc.).						
SP1, SP2	Interface design, character selection, 2D and 3D images, fonts, animations, and vocal parts should be simple, user-friendly, motivating, and should not be distractive.						
SP1, SP2	Written texts, images, animations, vocal parts should facilitate understanding of the educational content.						
		Obs., SP1, SE1, ST1, ST2, ST3, ST4, ST5, DC	Vocal instructions should be fluid, clear, and at an appropriate pace.				
		SP1	The color of tangible objects should be similar to the course books.				

Table 4.3 (continued)

TANGIBLE OBJECT USE							
Stage 1		Stage 2.1		Stage 3.1		Stage 4.1	
Source	DP	Source	DP	Source	DP	Source	DP
SP1, SP2, SE1	The size, color, details of tangible objects should be similar to real life objects.						
SP1, SP2, SE1	Tangible objects should be light and made from health-friendly material.						
SP1, SP2, SE1	The size of tangible objects should allow to noticing details.						
				Obs.	The thickness of the objects should prevent the student's fingers touching the screen.	Obs.	The thickness of the objects should prevent the student's fingers touching the screen.
				SP1	Tangible objects should be grouped appropriately and presented in separate boxes to the students.		
INTERACTION							
Stage 1		Stage 2.1		Stage 3.1		Stage 4.1	
Source	DP	Source	DP	Source	DP	Source	DP
SP1, SP2	Students should be informed about the use of tangible objects and a trial screen should be developed.						
SP1, SP2	Students should easily interact with the mobile application.	SE1, ST1, ST2, ST3, ST4, ST5	Students should easily interact with the mobile application.	Obs.	Students should easily interact with the mobile application.		
SP1, SP2	The amount of interaction between the application and the student should prevent student from getting bored/distracted.						
SP1, SP2	Tangible interaction between all sections of the application (tutorials, practice, the pretest, the posttest) and students should be provided.						
SP1, SP2	Written and vocal instructions should be given to ease of the use tangible mobile application.						
SP1, SP2	Tangible objects and their images in the application should be similar.						
SP1, SP2	Students should be shown an image which tangible object should be touched on the tablet screen.						
SP1, SP2	It should be clear where to touch the tangible objects on the screen.						
				SP1	The images should come to screen transparently before the students touch the tangible objects to screen.		
				SP1, SP2	There should be 2-3 seconds delay between each set of content.		

Educational content principles

Educational content on the determined learning objects presented in the tutorial and practice parts in the tangible mobile application.

1. Educational content should especially be selected among abstract learning objects.
2. Learning objectives that are determined for educational content should mainly consist of expository texts.
3. Educational content should be given appropriately to students' age and disability type.
4. Reading and writing activities should be kept less in educational content.
5. Vocal parts of written texts should be included.
6. Students should be given immediate feedback.
7. Students should be reinforced upon giving correct answers.
8. Each learning unit in the tutorial part should be followed by a related practice.
9. There should be a holistic practice at the end of application.
10. A corrective feedback should be given after an incorrect answer/attempt.
11. A descriptive feedback should be given after a correct answer/attempt.
12. There should be interactive activities (experiments, animations etc.) in tutorial part.

Visual design principles

Visual Design includes interface design, character selection, 2D and 3D images, font selection, animations, written texts, and also vocal parts.

1. Interface design, character selection, 2D and 3D images, animations, and vocal parts should be appropriate to the age and characteristics of the disability type.
2. Fonts should be appropriate for students with specific learning disabilities *(such as Helvetica, Arial etc.).*

3. Interface design, character selection, 2D and 3D images, fonts, animations, and vocal parts should be simple, user-friendly, motivating, and should not be distractive.
4. Written texts, images, animations, vocal parts should facilitate understanding of the educational content.
5. Vocal instructions should be fluid, clear, and at an appropriate pace.
6. The color of tangible objects should be similar to the course books.

Tangible object use principles

Tangible objects are designed and developed close to real objects to provide physical engagement and multisensory interaction. Students interact with these designed objects by grasping them and touching on to the tablet screen.

1. The size, color, details of tangible objects should be similar to real life objects.
2. Tangible objects should be light and made from health-friendly material.
3. The thickness of the objects should prevent the student's fingers touching the screen.
4. The size of tangible objects should allow to noticing details.
5. Tangible objects should be grouped appropriately and presented in separate boxes to the students.

Interaction principles

Interaction represents student interacting with the educational content. Also, the tangible objects provide interaction between the student and the content. Because the application provides students with a new way of interaction, the use of tangible objects should be tested before the application. Moreover, necessary guidance should be provided in application about which object to touch or where to touch it.

1. Students should be informed about the use of tangible objects and a trial screen should be developed.

2. The amount of interaction between the application and the student should prevent student from getting bored/distracted.
3. Tangible interaction between all sections of the application (tutorials, practice, the pretest, and the posttest) and students should be provided.
4. Written and vocal instructions should be given to ease of the use tangible mobile application.
5. Tangible objects and their images in the application should be similar.
6. Students should be shown an image which tangible object should be touched on the tablet screen.
7. It should be clear where to touch the tangible objects on the screen.
8. The images should come to screen transparently before the students touch the tangible objects to screen.
9. There should be 2-3 seconds delay between each set of content.
10. Students should easily interact with the mobile application.

4.2 Research Question 2: Is the tangible mobile application effective on students' achievement in the 6th grade cell concept?

4.2.1 Stage 6 (Effectiveness)

In quantitative part, multiple-probes across participants design was administered under the single subject research design in order to examine the effectiveness of tangible mobile application on students' achievement in the 6th grade cell concept. The dependent variable of the study is the achievement scores of the students and the independent variable of the study is the tangible mobile application. In this stage, three 7th grade students with SLD were selected as subjects. NV was a 12 years old female and attending 7th grade in a public school and also YI Special Education Center. She had a 20% of disability rate. AC was a 12 years old male and attending 7th grade in a public school and also YI Special Education Center. He had a 25% of disability rate. EY was a 13 years old female and attending 7th grade in a public school and also YI Special Education Center. She had a 30% of disability rate. An achievement test that includes criteria-based 22 questions was given students to determine their knowledge level on the the 6th grade cell concept (Appendix L). The pretest-posttest was prepared by the researcher taking the experts' views into considerations. This test was used in all sessions. Questions were randomized for each session and students were never informed about the correct answers. These were the key features of the test. Thus, students were like solving a different test each time.

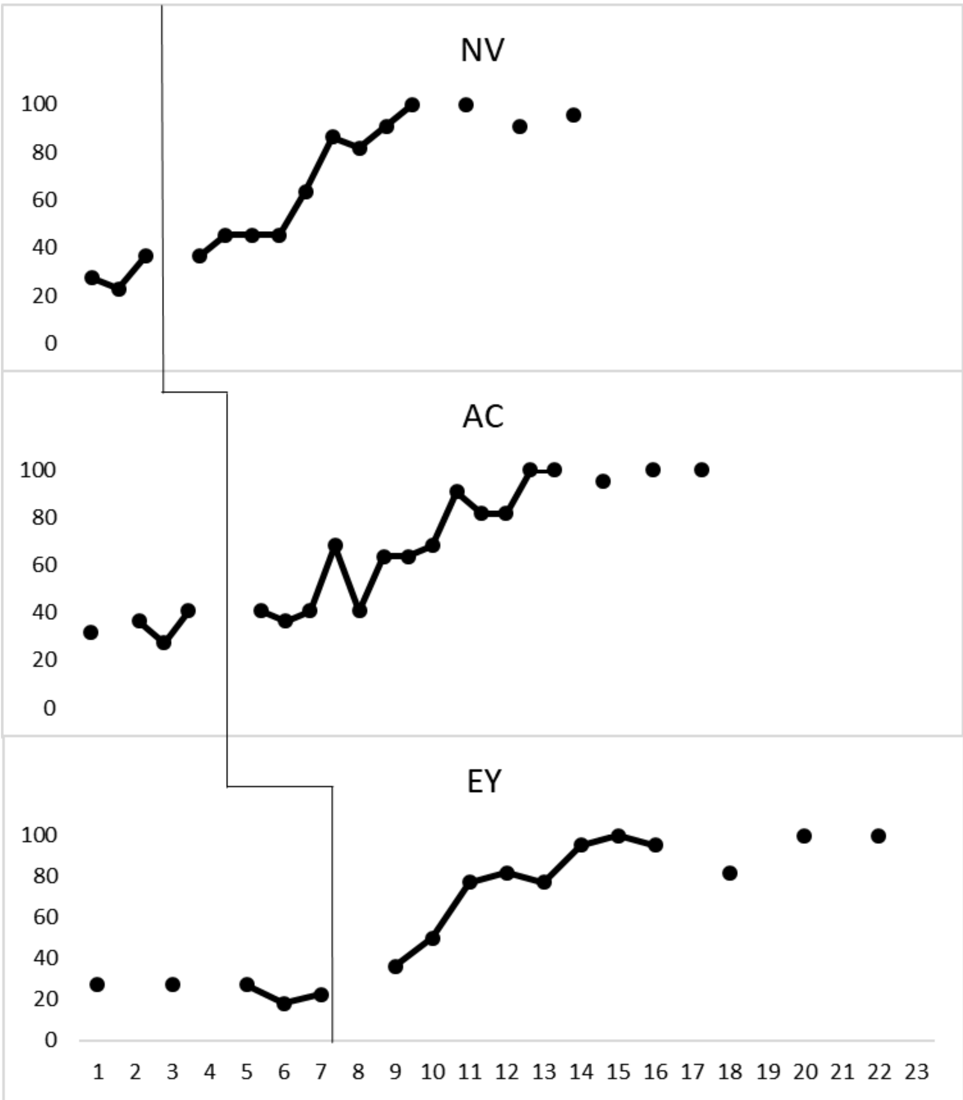

Figure 4.2 Correct answers percentage of participants for baseline, intervention and follow-up sessions

Effectiveness data of NV

In three sessions of baseline, percentage of correct answers were between 20% and 40%. At the end of the first four intervention sessions, percentage of correct answers were still 40% approximately. There was an immediate increment in the number of correct answers at the 5^{th} and 6^{th} intervention sessions. After a slight decrement for the seventh session, she showed improvement again and she answered 100% of questions correctly. At the follow-up sessions, she answered between 90% and 100% of the questions correctly (two incorrect answers out of 22 questions in 2nd session and one incorrect for the 3^{rd} session) (See Figure 4.2). While percentage of correct answers were approximately 30% in baseline sessions, percentage of correct answers were approximately 100% after the intervention. These results suggest that the tangible mobile application was effective.

Effectiveness data of AC

In four sessions of baseline, percentages of correct answers were between 20% and 40%. Until 12^{th} intervention session, there was an increasing trend with slight fluctuations except for the fifth session. He answered 100% of questions correctly at the 12^{th} and 13^{th} sessions. At the first follow-up session, he answered 95% of the questions correctly (one incorrect answers out of 22 questions). At the second and third sessions in the follow-up, he answered 100% of questions correctly (See Figure 4.2). The correlation between the number of correct attempts during 12 intervention sessions and the number of correct answers in probe sessions after interventions is significant, $r(10) = .61$, $p < 0.05$ (0.03). There is a moderate positive correlation between them, so it can be said that when he paid attention to the instruction, the number of his correct answers in probe sessions increased. It means, decreases of his correct answers were not related with application; rather it was related with his behavior disorder. While, percentages of correct answers were approximately 30% in baseline sessions, after the intervention, percentages of correct answers were approximately 100%. These findings indicated that the tangible mobile application was effective.

Effectiveness data of EY

In the fifth sessions of baseline, percentages of correct answers were between 20% and 40%. EY exhibited a gradual increasing trend at intervention sessions. The number of correct answers increased to 100% at the 7th session. At the first follow-up session, she answered 82% of the questions correctly (four incorrect answers out of 22 questions). At the second and third sessions in the follow-up, she answered 100% of questions correctly (See Figure 4.2). While, percentages of correct answers were approximately 30% in baseline sessions, after the intervention, percentages of correct answers were approximately 100%. These results suggest that the tangible mobile application was effective.

Summary of effectiveness findings

Baseline sessions consisted of only probes. Correct answers were between 20% and 40% of all questions for all participants' each probes in baseline sessions. It was not a surprising result. They had studied related subjects at their schools before for almost 10 months but they could not remember at all. As it was mentioned in the previous sections, students with SLD have memory and retention problems. It can be thought that they found the correct answers by chance, because the questions which they answered correctly were not the same in each session. In this context, the relative success of AC in baseline sessions can be explained by chance factor. It can be understood clearly by probe scores of AC in early intervention sessions. To sum up, none of the participants did not know the cell subject.

Intervention and probe sessions continued until participants reached 100% criteria (which means answering 100% or almost 22 questions correctly for three consecutive probe sessions) after baseline sessions. There was a rapid increase in the numbers of correct answers for all probes taken after each intervention sessions. Unlike other students, there were more intervention sessions and some fluctuations in the graph AC (Figure 4.2). There was a significant relationship between AC's correct answers during intervention and probe sessions. Thus, it can be inferred that, decreases were seen when AC did not pay attention to instruction (AC had behavior disorder) and this was also the reason why there were numerous sessions. Moreover, this situation can be seen as an evidence for being able to say that the tangible mobile application can provide learning opportunities for students. The other two participants (NV and EY) completed intervention sessions without having any problems.

After intervention sessions, follow-up sessions were conducted every several days. Similar to baseline sessions, follow-up sessions consisted of only probe sessions. All participants' correct answers were 100% or almost all questions for each follow-up sessions. Eventually, achievements of participants in these sessions showed that they learned the cell concept effectively. Although a period has passed after the intervention, they did not forget what they have learnt so far. Overall, this study provides an empirical evidence about the effectiveness of tangible mobile application for students with SLD.

Usability issues the tangible mobile application by students with specific learning disabilities

Students were observed during the treatment in order to seek usability issues about the tangible mobile application according to three main categories: 1) Being willing to use the application/ Being satisfied with the use of application 2) Sustaining attention while using the application 3) Using the application and objects easily/correctly. The researcher took observation notes while students were using the tangible mobile application for the baseline, intervention, and follow-up sessions by an observation checklist.

All students were willing and glad to use the application. In addition, they displayed their satisfactions by their attitudes and behaviors. Their scores are close to the mean score of 2 (M_{NV}=1.75, M_{AC}=1.66, and M_{EY}=1.92). (See Table 4.4).

Application was successful at getting attention of students. They maintained their eye contacts with application and objects, they followed instructions and they responded with some actions. Their scores are close to the mean score of 2 for this subcategory too (M_{NV}=2.00, M_{AC}=1.77, and M_{EY}=1.77) (See Table 4.4).

None of them seemed to deal with any difficulties. Especially NV and EY did not make any incorrect attempts during intervention sessions (M_{NV}=2.00 and M_{EY}=2.00). Although AC did not have any difficulty, he did some incorrect attempts during the intervention sessions. He also had behavior disorders. However, this was only in the first several sessions. After a while, there was an obvious increment his performance, so his score is not too low for this subcategory, M_{AC}=1.58. (See Table 4.4).

NV was a shy student, so she did not express her emotions and opinions. This might the reason of her low scores about “Being willing to use the application/Being satisfied with the use of application” category. However, she never complained about studying with tangible mobile application, she always tried to learn and answer the questions correctly. Performance of NV in the treatment and means for the other two main categories showed that she was willing to use the application and she kept her attention while using tangible mobile application. In addition, she used tangible mobile application easily and correctly.

AC had behavior disorder besides SLD. His teachers and his father stated that he could get bored quickly from everything. For these reasons, his observation scores were slightly less than other students were. However, his all observation scores were higher than the mean score of 1.5. Thus, it was promising that making him study during an entire session whereas he dislikes studying lesson. After he liked studying with tangible mobile application and started to learn the cell concept, there was an obvious improvement on his performance.

Unlike other students, EY had been noticed to have mature attitudes. As a result, her observation scores were high except for the two items (during the application she used expressions of satisfaction about feedback or used verbal/nonverbal expressions based on the gestures and mimic- during the practice she responded to feedback verbal/nonverbal). These two scores were low maybe because of her shyness, similar to NV. She was satisfied with the use of tangible mobile application. She was very happy to learn the cell concept by using tangible mobile application because she had difficulty in learning the cell concept at her school before.

Table 4.4 Means of observation scores

	NV			AC			EY		
Being willing to use the application/ Being satisfied with the use of application	**B**	**I**	**F**	**B**	**I**	**F**	**B**	**I**	**F**
Before and during the application (s)he submitted a request to study with the tablet or so (s)he said he wanted to study. (At least 1 time)	2	2	2	2	2	2	2	2	2
During the application, (s)he used expressions of satisfaction about feedback or used verbal/ nonverbal expression based on the gestures and mimic (At least 3 times).	2	1	1	1	1	2	2	2	1
*During the application, (s)he used expressions of dissatisfaction about the feedback (At least 3 times).	1	2	2	1	1	2	2	2	2
(S)he requested to continue after application. (At least 1 times)	2	2	2	2	2	2	2	2	2
Mean	1,75	1,75	1,75	1,5	1,5	2	2	2	1,75
General Mean		**1,75**			**1,66**			**1,92**	
Sustaining attention while using the application	**B**	**I**	**F**	**B**	**I**	**F**	**B**	**I**	**F**
(S)he stayed at the interaction with the tablet, (s)he followed the tablets and objects with her/his eyes (Throughout the application).	2	2	2	2	2	2	2	2	2
(S)he followed the tablets while the instructions were presenting (Throughout the application).	2	2	2	2	1	1	2	2	2
During the practice, (s)he responded to feedback verbal/nonverbal (Throughout the application).	2	2	2	2	2	2	2	0	2
Mean	2	2	2	2	1,66	1,66	2	1,33	2
General Mean		**2**			**1,77**			**1,77**	
Using the application and objects easily / correctly	**B**	**I**	**F**	**B**	**I**	**F**	**B**	**I**	**F**
*During the application, (s)he made errors while (s)he was using the application (More than 3 times)	2	2	2	1	1	2	2	2	2
*During the application, (s)he requested assistance intensively (More than 3 times).	2	2	2	2	2	2	2	2	2
*During the application, adults had to intervene frequently (More than 3 times).	2	2	2	1	2	2	2	2	2
*During application, (s)he experienced problems about matching the objects with the presented examples (3 mistakes or more for 14 questions)	2	2	2	1	1	2	2	2	2
Mean	2	2	2	1,3	1,5	2	2	2	2
General Mean		**2**			**1,58**			**2**	

Note: Yes-2, Partially-1, No-0; for negative question* Yes-0, Partially-1, No-2. B: Baseline, I: Intervention, F: Follow up

4.3 Research Question 3: What are the reflections of special education teachers after using the tangible mobile application on students with SLD?

An implementation was conducted in order to examine teachers' use of the tangible mobile application. Tangible mobile application was used by two groups to determine whether it is easy to use or not. After a pilot study had been conducted with a special education teacher (SET1) and a student with SLD (FV) in 6th grade, the main study was held with a psychologist (P1) and a student with SLD (MYP) in 6th grade. It should be noted that teachers or students were given neither any training nor any manual instructions before the implementations. The researcher gave the tablet and the objects to teachers. The researcher said to the teachers that students should grasp the objects and touch on to the tablet screen. The video camera was placed to an appropriate point in order to keep records without any distraction. After both implementations, a semi-structured interview was conducted with the special education teacher and the psychologist. The observations from the video recordings and interviews were analyzed in terms of three categories: 1) the process for starting to use, 2) the process for use, 3) future use.

4.3.1 The process for starting use

First reactions and implications of both the special education teacher (SET1) and the psychologist (P1) were very positive and involved. The researcher also noticed that they were curious to follow up all the coming steps. SET1’s words revealed this curiosity and excitement:

"The shapes [tangible objects] struck my attention. It was nice. So it can be more permanent in children' minds with these shapes [tangible objects] actually. I spent some time to understand [how the system works] and how I can use the objects at the beginning. After that, when I figured out the shapes and design purpose, I thought it would be very useful. In particular, you have placed everything in plant cells and animal cells. They were very nice." (SET1).

"Şekiller çok dikkatimi çekti. Güzel olmuş. Yani bu şekillerle [kavranabilir nesnelerle] daha kalıcı olabilir çocukların aklında. İlkten [sistemin nasıl çalıştığını] anlamaya çalıştım, ondan sonra hani çözünce şekilleri, hangisinin ne amaçla yapıldığını, çok faydalı olacağını düşündüm. Özellikle, bitki hücresi ve hayvan hücresine hepsini yerleştirmişsiniz. O çok güzelmiş." (SET1).

Excerpt given above reveals the initial constraints that could be experienced when using the application. This is a short time period of curiosity and discovery phase that opens paths to the following steps. Therefore, the process for starting use was found to be satisfactory by the participants. Similarly, P1 revealed the following reflections:

"When I first saw it…The subject was actually one of the subjects I did not like very much when I was a student. So, seeing the materials alive and touching them was actually much better than "what we see on A4 size paper" ... It [the tangible application] was so much better. Yes! This was now three-dimensional and I could see what it is. Since [the application] created [this thought], I liked it so much." (P1).

"İlk gördüğümde konu aslında benim de çok sevmediğim konulardan birisiydi öğrenciyken. Yani şey materyalleri canlı görmek ve onlara dokunuyor olmak aslında "gördüğümüz A4'tekinden…" çok daha iyi geldi yani "Evet bu artık

üç boyutlu ve bunun ne olduğunu inceleyebilirimi yarattığı için çok hoşuma gitti." (P1).

Reflections revealed by the teachers above echoed each other and positive first impressions seemed to continue in the other phases as well. First reactions and implication of students were also positive and inquiring. Teacher P1 expressed her student (MYP) experiences as follows:

> *"He started to tamper with saying: 'What are these things in the box?' When I said 'we will learn in a moment', he asked questions like: "When are we going to find out?" and "Will we use all of them?". He was very curious to actually discover what they were."* (P1).

> *"MYP zaten şey yaptı direk kutularda bunlar ne ki?" diye kurcalamaya başladı. "Birazdan öğreneceğiz." dediğim zaman "ne zaman öğreneceğiz?" işte "Bunların hepsini mi kullanacağız?" gibi çok merakla onların ne olduğunu keşfetmeye aslında yöneldi."* (P1).

P1's reflections seem to be in parallel with the reflections of teachers who used the application. We could assume from their words that the application gets the attention of both students with SLD and their teachers. These interpretations revealed in the reflections also seem to be confirmed in the observations as well. The researcher noted during the observation that at the beginning of the application objects attracted attention of student MYP. He was happy to know some of them before. However, he was also curious to get to learn about new objects.

Moreover, all participants perceived the tangible mobile application as easy to use. For example, P1 underlined: *"Actually it was not very difficult. It was already describing a lot."* (P1). *"Ya aslında çok zor değildi zaten tarif ediyordu birçoğunu ilk başlangıçta."* (P1).

In similar manner, SET1 stated:

"Like children, I examined at first. How do we do it, how do we touch it etc… Then I started to learn in line with the reaction we got from the tablet. We also noticed the importance of grasping later on." (SET1).

"Çocuklar gibi ben de ilk başta inceledim. Nasıl yapıyoruz, nasıl dokunduruyoruz filan. Sonra tabletten aldığımız tepkilere göre öğrenmeye başladım. Tutuş şekli de önemliymiş. Onu da fark ettik sonradan." (SET1).

They also stressed that the students perceived the tangible mobile application as easy to use. SET1 stated his student learn how to use tangible application easily with the following reflection:

"My student thought she could not do it at first. Then she kept on trying again. I might have given her a little help; I showed a couple of points … And then she was able to comprehend it practically after a while. When it did not work, she began to rotate. She placed right, it did not work, and she turned upside. She learnt it by trial and error." (SET1).

"Öğrencim başta yapamayacağını düşündü. Sonra tekrar deneme yoluna gitti. Hani biraz da yardımım olmuş olabilir, bir iki bir şey gösterdim. Ama ondan sonra kavradı pratik. Kendi zaten olmayınca çevirmeye başladı düz koydu, olmadı ters çevirdi koydu. Deneme yanılma yoluyla öğrendi." (SET1).

In all the experiences teachers' perceptions about their students and the application use in the first phase was expressed about the ways in which it was easy and user friendly. Teacher P1 shared the following scenario she has observed with her student MYP as follows:

"MYP is very curious for electronic, mechanic, and all of them. Even, I thought 'he will open it and look inside soon' because he took it, looked down and said: 'Now, was it perceive from here [stylus]? How did it understand if there is something black under all of them? etc.' He drew much attention. Because it was a very interesting area for him. Even, they were 3 dimensional…He was one of the students with special learning disabilities.

An A4 paper is not enough for them. It was attention grabbing for him. Did he have difficulty? No, it was not too difficult. Because all he had to do was pull the material [tangible object] from the box and touched to there [tablet screen]... I think it was enjoyable and fun for him." (P1).

"MYP zaten böyle mekanik elektronik vs. ne varsa hepsine çok meraklı bir çocuk. Ben hatta bir ara şey dedim herhalde, "MYP birazdan bunun altını açıp içine bakacaktır." dedim çünkü şey yaptı. Aldı altına baktı "bu şimdi buradan mı hissediyor. Koyuyoruz ama hepsinde siyah bir şey varsa nasıl anlıyor?" vs. MYP'nin çok dikkatini çekti çünkü onun çok ilgisini çeken bir alan zaten bu. Hele ki 3 boyutlu olunca ki, MYP bir de özel öğrenme güçlüğü öğrencilerinden birisi. Bir A4 onlara yetmiyor. Öyle görmek evet gerçekten onun için çok dikkat çekiciydi. Zorlandı mı? Hayır, çok zorlanmadı. Çünkü tek yapması gereken yanındaki kutudan o materyali çekip oraya okutmaktı… O'nun için ama keyifli ve eğlenceliydi diye düşünüyorum." (P1).

Based on the observation since MYP touched each object lightly to the screen and he did not remove the objects most of the time, the feedback was not given immediately at certain times. However, it is necessary to touch the screen by applying some force at the same time to the three stylus tip under the object. Then it should be removed from the screen and put aside. P1 underlined this problem as follows:

"Only, once while touching to [tablet screen]. He said 'It did not touch' and he tried to press the tablet. We talked 'MYP, shall we try again? Because pressing the tablet won't work." However, it was enjoyful to use tangible mobile application for him." (P1).

"Sadece bir ara hani orada okuturken, "Ya okumadı." deyip işte tablete bastırmaya falan çalıştı. "MYP bir çekip bir daha mı koysak bastırmanın bir yararı olmayacak çünkü." falan diye konuştuk…[kavranabilir mobil uygulamayı kullanmak] Öyle O'nun için ama keyifli ve eğlenceliydi diye düşünüyorum." (P1).

Another constraint was revealed by SET1 that was related with the circle given on the screen. There is a circle on the screen for touching area of tangible objects in the whole application. SET1 stated that being a circle of the touching area was misguiding for him and his student. They thought that they should touch the objects which were circle. In addition, at first, they touched on to the tablet screen only the circle ones, not rectangular or square ones. During the observation, it was seen at the process for starting use that they spent short amount of time to figure out how to use the process. The constraint could be related with the students' misperceptions about the use of it. Still the researcher took it as a feedback that needs to be improved for further studies.

P1 underlined trial screen made learn to use easier:

> *"The software already started with something [the trial screen]. It introduced the parts [tangible objects]. So, it was already facilitating for us. In fact, MYP said: "okay, I understood" and we passed them. We did not touch the all of pieces [tangible objects]."* (P1).

> *"Zaten yazılımda şey de [alıştırma ekranı] ile başlıyor. Parçaları tanıtmak üzerine gittiği için o zaten senin için kolaylaştırıcı. Hatta biz hani MYP tamam anladım ben dedi ve biz onu geçtik. Hani bütün parçaları [kavranabilir nesneleri] tanıtmadık."* (P1).

Teacher P1's above-mentioned words aligns with the reflections given by SET1 about the ways in which "trial screen" could set a strong ground for a heathy learning process.

4.3.2 The process for use

Both the special education teacher (SET1) and the psychologist (P1) described the process of use easy most of the time. During the observations about the use of the tangible application, all participants appeared to have fun while using it. In addition, they used easily it and they were satisfied with using this application.

In the application, there was a model on the top-left of screen to remind students which objects they should touch on to tablet screen. Both SET1 and P1 perceived these models as a facilitator to the use of application easily. P1 emphasized this with the following words:

> *"In the beginning we solved something like "Oh yes, there is a picture of them [tangible objects] already there, we wish we had looked at it." The designers could add an instructional note that the pictures of the [tangible objects] will be shown to them. In that case we could be prepared for that info and the coming information."* (P1).

> *"[İlk başta] bir şeyi çözmemiz "Aa evet şurada zaten görselin resmi varmış buna baksaymışız ya keşke." dediğimiz bir süreç oldu. İlk bir onu fark ederken bir şey yaptık. Belki orada hani ya da söyledi de biz MYP ile o an duymamış olabiliriz. "Size zaten resmini göstereceğiz bakın." gibi bir ibare belki vardır ama biz duyamadık MYP ile… [Yoksa] o zaman olursa çok iyi olur."* (P1).

SET1 stated that he and his student used the tangible mobile application easily. SET1 underlined that the tablet application was quite explanatory. SET1 thought the application helps teacher to be more ready and be prepared for class.

Based on observation, seeing and exploring new things made both MYP and P1 satisfied/happy while they were using the tangible mobile application. The researcher had the opportunity to observe their happy and satisfied faces when using the tangible mobile application. In line with the observation notes, P1 and SET1 emphasized that using tangible mobile application can motivate the students with SLD. This was explained by SET1 with the following words:

> *"Child learns by doing. It is an important approach in our system and learning becomes permanent in this way. Approximately 70% of information are permanent with learning by doing."* (SET1).

> *"Çocuk yaparak, yaşayarak öğreniyor. Bu da bizim sistemimizde önemli bir şey, [öğrenme] daha kalıcı [oluyor]. Bilgilerin yani yaklaşık %70'i yaparak, yaşayarak kalıcı oluyor."* (SET1).

In line with the excerpt given above, approach used in the tangible mobile application was based on allowing students to learn by doing practicing. SET1 reported that the interaction facilitates the child's learning and expressed his views as follows:

"Because student is more active in the lesson, (s)he touched [the tangible objects to tablet screen] on her/his own. Therefore, learning is easier." (SET1). *"Öğrenci kendini derste daha aktif olarak şey yaptığı için, kendi basıyor, çekiyor. O yüzden öğrenmesi daha kolay oluyor."* (SET1). Moreover, he added:

> *"The guidance of the tablet [application] was good. When child made a mistake, she did not get upset. It was a guided practice. She tried again. The more she tried the more she learnt …"* (SET1).

> *"Yönlendirmeleri falan iyiydi tabletin. Çocuk da zaten yanlış yaptığında hani şey yapmadı, en azından morali bozulmadı. Yönlendiriyor ne de olsa, bir şekil yeniden denedi, hani sürekli denedikçe de öğrendi diye düşünüyorum."* (SET1).

Likewise, P1 also stated that the interaction was good. The student could understand instructions of the tangible mobile application and gave reaction to it. In addition, she added:

> *"It [tangible objects] was not very micro sized, it was very nice, so the children already saw them very small, and it was much nicer to see it bigger. Moreover, children could grasp. It was very good in terms of these perspectives. Other than that, I think the interaction was nice, so it [the tangible mobile application] was not limited it. The application was successful enough to get the attention of the students."* (P1).

"Çok mikro boyutlar değildi o çok güzeldi. Yani çocuklar zaten bunları çok ufak görüyorken, büyük görmek onu çok daha hoşuna gitti. Bu açıdan çok iyiydi. Çünkü inceleyebileceği bir şey. Onun dışında çok bence etkileşim güzel gidiyor, yani sınırlanmıyor ve onun ilgisini çekebilecek düzeyde olduğunu düşünüyorum." (P1).

Participants all seemed to reveal positive insights when revealing their thoughts about the use of application. In addition to having interaction based qualities, P1 underlined the way how ease of use is maintained within the application with the following words:

"It is practical to hear what the organelles are and what they constitute from the tangible application. It was also nice to be asked and evaluated with the follow up control questions. Therefore, the approach was from the general to the specific… Then it enable the learner to distinguish all these [organelles or parts] from each other. Looking from this perspective, yes it was very nice." (P1).

"Ne olduğunu anlatıp birde bunu kontrol sorusu olarak da sorması güzel ya evet bu söylediğim şeyi anladın mı diye soruyordu çünkü. Başlangıçta yani genelden başlayıp böyle daha özele de inmeye başladığı için birazcık daha evet yani dışı tanıdım, artık içe doğru gidebilirim kolaylığı da sağlıyor. Daha sonra bütün bunları birbirinden ayırt ediyor. Bu açılardan bakınca evet çok güzeldi." (P1).

P1 underlined transparent images of the objects, which were presented on the screen in all the steps helped the students touch the objects and follow the instructions clearly. She also emphasized that the way how transparent images are presented guided learners to pass all these steps effectively.

It was noted during the observation that MYP was happy to do the practices (exercise) correctly. P1 claimed that the tangible mobile application motivated the student and allowed him to continue until the end by arouse his curiosity. P1's views are given as follows:

> *"Eventually, there was a mini test [venn schema] after a lecture was over. He could check it again, whether his answers were correct! [He asked]: "So can we do all these? Is it true? "... In a standard lesson, MYP who constantly asks the question of "Is it over?" ... But now he asked: "Okay, it's over. How many correct answers do I have? What are the mistakes I have done?" ... These questions mean a lot to me. From these questions, I could see the progress one could get in the learning process... I should confess that tangible mobile application opened this perspective."* (P1).

> *"En sonunda gene bir anlatım bittikten sonra mini bir test [venn şeması] vardı. Orda da tekrar "Doğru mu? Değil mi?" diye tekrar bakmış oluyordu. "Yani bütün bunları yapabildik mi? Oldu mu?" vs. Hani MYP normalde " Yaptım işte" deyip geçen bir çocuk. "Yani tamam, bitti. Artık önemli değil, oldu mu ama şimdi" diye sorması bile benim için artı bir şey çünkü onun olup olmadığını bile merak ediyor ve bu onun bana göre "Evet bunu öğrenmeye çalışıyorum." deme şekli."* (P1).

As it could be seen in the excerpt above tangible mobile application could serve as a means to increase an awareness in the minds of the students with SLD. Having higher levels of motivation and being an active participant in the learning process may be the reasons for this change in the attitudes. Although this excerpt is given by only one of the teachers, the rest of the participants used expressions and words that implied this kind of change in the minds of students with SLD. From this perspective, tangible mobile application appears to be interpreted by the participants not only in terms of a learning instrument but also as an instrument that motivates students towards the active learning mentality. In additional to the quality, aforementioned, color use could also facilitate learning and perception. Correct color use can bring serious advantages. Also, the tangible mobile application can build a bridge between images in their book and in the application. For example, P1 validated:

> *"I think the vivid color in the application works for children very well. Besides, the materials were already designed in the colors science books. It does not show orange cytoplasm. As far as possible, colors were selected very close to the science books."* (P1).

> *"Ya ben renklerin canlı olmasının çocuklarda çok işe yaradığını düşünüyorum ve tablet uygulamasında renklerin hepsi canlıydı. Bunun yanı sıra materyaller zaten hemen hemen bütün fen bilgisi kitaplarında o anlatılan renklerde tasarlanmıştı yani. Sitoplazmayı tutup bir turuncu göstermiyor yine bize o materyallerde nasıl anlatılıyorsa yine o renk. Mümkün olduğunca ona çok yakın renkler seçilmiş."* (P1).

During the observation, the guidance of P1 and SET1 was very professional. When the students made a mistake, they guided the student properly without telling them the correct answers explicitly. P1 underlined that the tangible application does not eliminate teacher guidance. It is important. However, maybe for the individual use option can be added. In this way, students can study individually.

Based on the observation it can be mentioned that at the beginning of the tutorial part and at some of long instructions the student showed some signs of boredom. In similar manner, in the posttest part, the student got bored probably because of fatigue. It was also observed that SET1 showed signs of boredom when the student thought too much.

SET1 emphasized that the student sometimes used the tangible objects carelessly. To be more specific she touched the objects randomly on to the tablet screen. The observation findings validated it. For example, the magnifier, microscope, animal cell, and plant cell models must not be touched in the venn scheme exercise. The student touched these objects. Hence, the exercise did not work properly when those objects were touched. The reason for this could be the difficulty of the first session experience.

SET1 emphasized that there were some touching problems while his student was using the tangible mobile application. Based on the observation, SET1's student rotated some of the tangible objects while they were in contact with the tablet. Students should be informed about not to drop the object from their hands, not to rotate the object while it was in the contact with the tablet. At the same time, students should be reassured to remove the objects from the tablet after they touched on it.

Aforementioned, since MYP touched each object lightly on to the screen and he did not remove the objects most of the time, the feedback was not given immediately at certain times. However, the feedback was given after several attempts. Moreover, MYP touched his finger(s) on to the screen when he touched the tangible objects on to the tablet screen. P1 mentioned these problems a couple of times during the interview. She claimed that from time to time they had problems with touching the tangible objects during the process of use.

P1 suggested that a user manual of the tangible mobile application makes it easier:

> *"There were only a few things that stem from the lack of training about how to use materials. It is very simple to solve this problem. The teacher could be given guidance about the ways in which they could use the system. I think these are minor limitations that could be overcome."* (P1).

> *"Bir tek ufak tefek şeyler o da materyalleri nasıl kullanacağımızı dair eğitimin olmamasından kaynaklıymış. Bu çok basit o öğretmene rehberlik, yani öğretmene rehberlik edip onu nasıl kullanacağı anlatıldığında sadece çok hızla aşılacak bir şey… Bunlar çok ufak ve sınırlılığı çok kolay aşılacak şeyler diye düşünüyorum."* (P1).

It could be interpreted from the conversations with the teachers that tangible mobile application appeared to be easy to use as well as providing opportunities for learning the concepts more efficiently. It was seen during the observations that teachers were competent and comfortable to use the tangible mobile system without having a prior training. Although there happened to be times when they had experienced difficulty due to being unfamiliar with the application, they were able to handle these constraints after a few trials.

4.3.3 Future use

Future use was determined to be one of the main themes during the interviews. It was evident both in the conversation and in the observations that both the special education teacher (SET1) and the psychologist (P1) were very positive and willing to use of the tangible mobile applications in their classes.

SET1 stated he wants to use the tangible mobile application for this subject and other subjects such as, Math, Geometry, and Language. He claimed that the tangible mobile application provides students with the platform for learning by doing, permanent learning, and visual learning. Likewise, P1 explained:

> *"I think that tangible mobile application can be used in almost all science [related courses]. I can also adapt it to the course of social sciences. For example, to teach the geographic regions I could use a map of Turkey and then inform students about these regions. As well, I can involve students by asking them to plant the fields... There are many options we could incorporate the interdisciplinary topics…"* (P1).

> *"Fen bilgisi [dersinin] bence hemen hemen hepsinde kullanılabilir. Ben bunu sosyal bilgilere de gayet uyarlayabilirim. Tutup bir Türkiye haritasında 7 bölgeleri de çocuğa verip hadi birleştir de yapıp o bölgeyi tanıtırken o bölgenin üzerine ağaç da diktirtebilirim. Ya da oranın bitki örtüsünü serdirtebilirim. …Onun dışında matematik de dahil olmak üzere bir şekilde kullandırtabilinir…"* (P1).

Both of the teachers highlighted the importance of tangible objects as a means for increasing teaching effectiveness and increasing student motivation to learn. As well, they implied the vision that could be brought through the effective combination of interdisciplinary concepts and perspectives. Therefore, their views indicated the future practice that could be implemented in further studies. They also warned instructional designers that educational materials should not be developed based on standard and monotonous teaching approaches; instead, they should enact multiple-sense of students with the most effective means. Therefore, the applications can facilitate the learning and makes the abstract concept concrete as well.

In addition, P1 suggested the use of tangible applications to the other teachers:

> *"I think because I always say that we are in the era of technology and A4 size paper could no longer serve as an educational material. Even a video could be seen as a monotonous instrument at certain times… Students are exposed to lots of stimulus … I think visualizing and touching the material is something that every teacher should actually use. Therefore, I think it is over or A4 age is over. Teachers now have to realize this. It is easier to teach because it [tangible application] gives students with the opportunities to look at all the pieces [tangible objects], from an in depth perspective..."* (P1).

> "*Yani düşünürüm çünkü hep söylediğim gibi yani artık teknoloji çağındayız ve bir A4 [eğitsel bir materyal olarak] yeterli değil. Yani izlediğimiz bir video bile bazen tek düze olduğu zaman yetmiyor, çocukları karşılamıyor artık. Çünkü çok fazla uyarana maruz kalmaya çok alıştık… Yani materyalleri görselleştirmek ve ona dokunabilmek, her öğretmenin aslında kullanması gereken bir şey diye düşünüyorum. Yani bitti ya A4 çağı bitti bence bunu öğretmenlerin artık fark etmesi gerekiyor… Öğretmek daha kolay oluyor. Çünkü zaten çocuğa materyali veriyorsun ve bak, incele diyebiliyorsun yani…"* (P1).

It could be seen from the above-mentioned excerpt that most of the teachers deal with the challenges of limited educational materials in their classrooms. The views noted the demanding and difficult living conditions that special education teachers live in. It could clearly be seen in their experiences that A4 paper is still seen as an important material that they use. It is understandable to follow all the phases through effective data collection and documentation in which A4 serves a medium of instruction. Use of photocopies also creates additional roadblocks for the students in enabling them to reach colored and lively materials. In sum, special education teachers implied the barriers created in their schools and believe that tangible mobile application will give them chances of teaching better and living better in their classroom settings.

CHAPTER 5

DISCUSSION AND CONCLUSION

The main purpose of this study was to determine design principles of a tangible mobile application for students with SLD and to examine the effectiveness of the tangible mobile application on the students' achievement. In addition, usability issues about tangible mobile application by students and special education teachers were examined. In this chapter, the findings of this study are discussed in line with the research questions: 1) What are the design principles of a tangible mobile application for students with SLD? 2) Is the tangible mobile application effective on students' achievement in the 6th grade cell concept? 3) What are the reflections of special education teachers after using the tangible mobile application on students with SLD?

5.1 Design Principles of the Tangible Mobile Application for Students with SLD

Final design principles were determined after analysis, design, development, and evaluation stages. They are discussed in terms of four categories: 1) educational content, 2) visual design, 3) tangible object use, and 4) interaction.

5.1.1 Educational content principles

"Educational content should especially be selected among abstract learning objects" is the first design principle in educational content category. Since students with SLD have difficulties understanding abstract concepts, it is very important that tangible mobile application help students with SLD to concretize the abstract concepts. Thus, more permanent and meaningful learning can be occurred. In line with this design principle, Falcão and Price (2010) emphasized that students with learning disabilities should be provided concreate examples to understand abstract concepts.

“Learning objectives that are determined for educational content should mainly consist of expository texts” is the second design principle in educational content category. There are a number of expository texts (long informative texts) in course textbook such as science and social studies from the 4th grade. Students with SLD have difficulties in reading. As aforementioned under characteristics of students with SLD title, these students have also problems in selection and use of understanding strategies while reading, remembering, and attention. In this context, content should mainly consist of expository texts. Similarly, O'Connor, Sanchez, Beach, and Bocian (2017) stated that students with learning disabilities struggle with reading and understanding expository texts. Moreover, Mason and Hedin (2011) emphasized that science texts contain facts, new, and complex information becomes a barrier for students with learning disabilities because students are expected to read and understand the expository passage after third grade independently. In line with these, Hall (2004) underlined that comprehension of expository texts in science, social studies, and mathematics is challenging for students with reading disabilities. In addition, Hall (2004) stated that there are consequences of not understanding the texts. Students are not able to learn the content, which results in failure in the exams. In addition, they have low self-efficacy and behavior problems. In order to overcome these problems, effective instructional strategies such as graphic organizers, computer assisted technologies should be used to make expository texts more understandable for students with learning disabilities (Jitendra, Burgess, & Gajria, 2011).

“Educational content should be given appropriately to students’ age and disability type” is the third design principle in educational content category. Since students with SLD have very different characteristics compared to normally developing children and special education teachers or science teachers use this application in classroom setting, it is vital to design educational content in terms of age and disability characteristic. Likewise, Kara (2015) and Antle, Wise and Nielsen (2011) addressed that the educational content should be age-appropriate. In parallel with this, İnal (2011) underlined that content should be presented appropriately to

students' age. Cobb, Mallett, Pridmore, and Benford (2007) suggested that learning activities should be designed carefully taking needs and characteristics of students with disabilities into account. In parallel with this, Garzotto and Bordogna (2010) underlined the fact that students with special needs have unique characteristics. In this context, designers should be careful about the unique profiles of these students. In line with this, Fan, Antle, and Cramer (2016) highlighted that design of a tangible system should be arranged based on characteristics of children with SLD (dyslexia). Antle (2007) also emphasized that design should be aligned with abilities of children taking their age into account.

"Reading and writing activities should be kept less in educational content" is the fourth design principle in educational content category. Students with SLD have difficulties in both reading and writing skills. To overcome these problems, vocal instructions should be added and writing and reading activities should be kept minimum level. This design principle associated with the fifth one. *"Vocal parts of written texts should be included"* is the fifth design principle in educational content category. Since students with SLD are slow readers, vocal instructions may help to focus on the content and to understand it easily. In parallel with this design principle, Falcão and Price (2010) stated that students with learning disabilities should be presented minimum amount of text. Moreover, Fan et al. (2016) mentioned that the basic characteristics of these children are the difficulty of reading and suggested that visuals should be included in the design instead of texts. Furthermore, they emphasized that vocal version of the texts can facilitate the learning process of students with SLD. Falcão (2014) accepted minimum text use as a principle for tangible system. Hence, the activities should not be based on supporting reading and writing skills when the target group is children with intellectual disabilities. Likewise, Marco, Cerezo, Baldassarri, Mazzone, and Read (2009) emphasized that children should be given vocal feedback not only to support them but also to reinforce the visual representation on the tangible system. In addition, Karime, Hossain, Gueaieb, and El Saddik (2009) stated that the tangible interface should be developed based on the notion of minimum or none text use.

"Students should be given immediate feedback" is the sixth design principle in educational content category. If students with SLD cannot receive immediate feedback, they may be confused and surprised about their correct or incorrect attempts. Accordingly, this can break students' concentration. Similarly, Hinske (2009) and Kara (2015) determined immediate feedback as a design principle. Golsteijn et al. (2015) stated that it is very crucial to give immediate feedback in order to motivate students to study more by providing interaction and notifications the result of their attempts. Scarlatos (2006) identified immediate feedback as a principle for students to use the system in a successful way. Similarly, Bouck, Bassette, Taber-Doughty, Flanagan, and Szwed (2009) gave students with mild intellectual disabilities immediate feedback in their smart toy, Pentop. Similar with these, Fan et al. (2016) defined immediate feedback as a crucial design element when designing tangible user interface for children with SLD (Dyslexia) in order to avoid any confusion. In parallel with these, Falcão (2014) emphasized that the clear and immediate feedback is one of the vital design principles for tangible system for students with special needs. Likewise, Hornecker and Buur (2006) suggested immediate feedback both visually and auditory. In parallel with these, Bodén, Dekker, and Viller (2011) underlined that the immediate feedback should be used in order to support students' learning process. In addition, feedback is crucial in ways of monitoring students' progress in tangible learning environments (Walker & Burleson, 2012).

"Students should be reinforced upon giving correct answers" is the seventh design principle in educational content category. This design principle is important because students with SLD should be given reinforcement after every accomplished goal to reinforce correct attempts. Reinforcement can motivate and encourage students. Likewise, Falcão and Price (2010) underlined that students with learning disabilities should be appreciated when they do it correctly. Similarly, Fan et al. (2016) underlined the importance of the rewards, reinforcements for motivating and encouraging students with SLD (dyslexia). Correspondingly, Marco, Cerezo, and

Baldassarri (2013) emphasized that the tasks that students successfully complete should be rewarded.

"Each learning unit in the tutorial part should be followed by a related practice" is the eighth design principle in educational content category. This is important because practices can help to learn each learning unit better. Furthermore, these single-question practices give students the opportunity to succeed. Similar to this design principle, Falcão and Price (2010) stated that the difficulty of tasks should be achievable by students. Likewise, Seo, Arita, Chu, Quek, and Aldriedge (2015) emphasized that children should be asked each learning unit as a recall activity. In line with these, Berkeley, Mastropieri, and Scruggs (2011) underlined that guided practices with corrective feedback should be added for students with learning disabilities. In addition, as a result of their extensive literature review McLeskey and Waldron (2011) stated that guided practices with respond should be presented to students with learning disabilities.

"There should be a holistic practice at the end of application" is the ninth design principle in educational content category. Since a holistic practice allows students with SLD to revise all the content. Moreover, it should be added in order to put the pieces of content together and make them more meaningful. Similarly, Berkeley et al. (2011) emphasized that there should be independent practices for students with learning disabilities to recognize how they understand the subjects. In line with this, related literature underlined the importance of independent practice and how it should be for student with learning disabilities (McLeskey & Waldron, 2011; Misquitta, 2011; Wanzek, Vaughn, Roberts, & Fletcher, 2011).

"A corrective feedback should be given after an incorrect answer/attempt" is the tenth design principle in educational content category. It is important to give students corrective feedback to ensure the correction of mislearned information. The corrective feedback does not give the answer for students. Instead, students are informed that (s)/he is doing wrong. Additionally, students should know what to put in place of the mistake. (For example; "This is not mitochondria. It is a cytoplasm.

Please touch the mitochondria"). Similarly, Antle (2013) recommended that the feedback should not be in a form of giving an answer for a student; instead, it should be given in a supportive way to complete the task.

"A descriptive feedback should be given after a correct answer/attempt" is the eleventh design principle in educational content category. It is important because giving a descriptive feedback does not only indicate success but also explain success (For example; "Congratulations, right answer! This is a cytoplasm"). In line with this, Kara (2015) emphasized that the feedback should include an explanation of the object the child puts. Similarly, Hinske (2009) emphasized that feedback should be comprehensive.

"There should be interactive activities (experiments, animations etc.) in tutorial part" is the twelfth design principle in educational content category. Since students with SLD have attention problems, interactive activities may lead students to be a part of these activities and also may help them to focus on educational content more. Similar to this design principle, Falcão and Price (2010) stated that students with learning disabilities should be provided rich and various materials. In addition, Kara (2015) pointed that educational content should not be static. Some multimedia elements like animation should be added. In addition, İnal (2011) proposed that age-appropriate sounds and visuals should be added to educational game. Similarly, Sitdhisanguan, Chotikakamthorn, Dechaboon, and Out (2012) suggested educational activities involving rich stimuli are necessary to engage the students with autism to the course. Likewise, Garzotto and Bordogna (2010) underlined that in order to make learning experience more fun and motivating for children with special needs, different multimedia elements and interactive activities should be added to the tangible system. Cobb et al. (2007) stated that stimulating and appealing multimedia elements can help attract the attention of students with special needs.

5.1.2 Visual design principles

"Interface design, character selection, 2D and 3D images, animations, and vocal parts should be appropriate to the age and characteristics of the disability type" is

the first design principle in visual design category. Since students with SLD have very different characteristics compared to normally developing children and special education teachers or science teachers use this application in classroom setting, it is vital to design these visual parts in terms of age and disability characteristic. In line with this design principle, İnal (2011) proposed that age-appropriate sounds and visuals should be added to educational game. Similarly, Sitdhisanguan et al. (2012) suggested the visual design elements like color use should be arranged taking the characteristic of children into consideration. Antle (2007) also emphasized that design should be aligned with abilities and limitations of children taking their age into account.

"Fonts should be appropriate for students with specific learning disabilities (such as Helvetica, Arial etc.)." is the second design principle in visual design category. Since students with SLD have difficulties in reading, it is vital to select a font type dyslexia-friendly. That is to say, they cannot read every font easily. Fonts that students can read easily should be selected (Helvetica, Arial etc.). Haro, Santana, and Magaña (2012) developed a tangible reading system for children with Down syndrome. They claimed that the special font use can facilitate learning. In addition, Seo and Woo (2010) emphasized that appropriate fonts for learning disabilities should be chosen. In line with this, Fan et al. (2016) stated that because of the children with SLD (dyslexia)' deficiencies, font type selection is very important. They can experience difficulties with Serif-typeface or tightly spaced font types.

"Interface design, character selection, 2D and 3D images, fonts, animations, and vocal parts should be simple, user-friendly, motivating, and should not be distractive" is the third design principle in visual design category. This is important because students with SLD have attention and motivation problems. A simple, user-friendly, motivating visual design can attract students' attention and can help them to focus on. Similar to this design principle, İnal (2011) accepted a simple, user-friendly and interesting visual design as a design principle. Likewise, Falcao, Meira, and Gomes (2007) emphasized the importance of a simple interface for tangible system

in order prevents any difficulty for users. Similarly, effective and simple interface design is suggested by Hinske (2009).

"Written texts, images, animations, vocal parts should facilitate understanding of the educational content" is the fourth design principle in visual design category. Written texts, images, animations, vocal parts should be in accordance with the content. Students should be able to associate content with these elements. Unnecessary use of these items should be avoided. Likewise, İnal (2011) suggested that visual design elements (texts, images, and animations vb.) should be employed for ensuring better learning. Similarly, Falcão (2014) underlined that when designing a tangible system for students with learning disabilities, texts, images, animations, and sounds should be used taken students' need and abilities into account.

"Vocal instructions should be fluid, clear, and at an appropriate pace" is the fifth design principle in visual design category. This is very important because students mostly prefer to learn by listening to voices instead of reading. Vocal instructions should not be too fast to follow and should not be too slow to get bored students. There should be a clear voice to be understood by the students easily. Similarly, Sitdhisanguan et al. (2012) accepted the appropriate use of voice as a design principle. In line with this, Fan et al. (2016) stated that vocal instructions should be short and clear. Similarly, Falcão (2014) stated that voices should be clear, simple, and loud appropriately as one of the key design element.

"The color of tangible objects should be similar to the course books" is the sixth design principle in visual design category. Since students with SLD make a connection between course book and these objects, learning may be more meaningful. Antle et al. (2011) suggested that the visuals that the learner is familiar with should be used in order to reinforce the link between the learning material and the learner.

5.1.3 Tangible object use principles

"The size, color, details of tangible objects should be similar to real life objects" is the first design principle in tangible object use category. Since the consistency with real life experience provides a real experience for students. Even if they are not in their actual dimensions, their dimensions should be relatively different from each other (For example, the nucleus is the largest object.). Similar to this design principle Kara (2015) emphasized that the size of toys and their images should be similar to real life objects. Similarly, Sitdhisanguan et al. (2012) suggested that tangible objects should be as in the real life. Likewise, Falcão (2014) emphasized that physical objects should be familiar to students. Similarly, Bodén et al. (2011) stated that objects should be selected from real world. In line with these, Hinske (2009) underlined the importance of tangible toys that aligns with the real life.

"Tangible objects should be light and made from health-friendly material" is the second design principle in tangible object use category. This is important because tangible objects should be designed to be used easily by students for a long time. Furthermore, if they are heavy, it becomes difficult to use and may damage the surface of the tablet. In line with this, Soleimani, Green, Herro, Walker (2016) made their tangible final prototype from lightweight material. On the other hand, it should not be made of materials that are harmful to health like plastic etc. Correspondingly, Roberto, Freitas, Simões, and Teichrieb (2013) used a kind of health-friendly plastic in their tangible objects. Similar with these, Hinske (2009) stated that play objects should be safe and healthy for children. Marco et al. (2009) stated that tangible objects should be safe and robust. In addition, Karime et al. (2009) stated that tangible material should be lightweight.

"The thickness of the objects should prevent the student's fingers touching the screen" is the third design principle in tangible object use category. This design principle also can affect the interaction. Students should not touch the screen with finger while they are using the tangible mobile application in order to prevent a wrong detection. The objects should be thick enough for the child to grasp

comfortably. Likewise, Sitdhisanguan et al. (2012) suggested that the objects should be able to graspable easily by students. Similarly, Pandey and Srivastava (2011b) suggested that the tangible objects should fit the size of the palms of children with specific learning disabilities (dyslexia).

"The size of tangible objects should allow to noticing details" is the fourth design principle in tangible object use category. It should not be too big to block the screen, nor should it be so small as to prevent seeing the details. Since students with SLD cannot see and touch the details in the two-dimensional textbooks, the objects should be as the students can easily see and touch the details. This may lead to permanent learning in a way to making remember easily. Similar to this design principle, Tsong, Chong, and Samsudin (2012) suggested that tangible objects size should not be too large or too small. Similarly, Marco et al. (2009) emphasized that the sizes of tangible objects should be suitable.

"Tangible objects should be grouped appropriately and presented in separate boxes to the students" is the sixth design principle in tangible object use category. Since students with SLD have attention problems, not all of tangible objects should be presented to students at the same time in order to prevent any distraction. Tangible objects which have same characteristics should be presented together separately from other grouped objects. In line with line with this design principle, Kara (2015) stated that since it causes distraction on students' attention, too many objects should not be included in smart toy. Likewise, Tsong et al. (2012) emphasized that the number of both physical and digital objects should be limited to seven objects for each learning unit.

5.1.4 Interaction principles

"Students should be informed about the use of tangible objects and a trial screen should be developed" is the first design principle in interaction category. Since students have not used this application before, they should do trial as many times as they want to gain familiarity with the system. In this way, they can easily use the application. Similar to this design principle, Kara (2015) stated that a help screen

should be developed before the play. Similarly, Sitdhisanguan et al. (2012) provided a how to use the tangible user interface part before all the sessions with students with autism. Antle et al. (2011) emphasized that students should be showed how to use the tangible system. Falcão and Price (2009b) emphasized that students should be given the necessary time to understand how to use the system. Likewise, Seo et al. (2015) stated that children should be given enough time for familiarizing with the tangible system also experiencing the tangible objects (touch, smell etc.).

"The amount of interaction between the application and the student should prevent student from getting bored/distracted" is the second design principle in interaction category. The reason of this, too much interaction may distract students with SLD's attention while too little interaction may get bored the students. Similarly, Sitdhisanguan et al. (2012) emphasized the characteristic of students with autism should be take into consideration for determining the details about interaction.

"Tangible interaction between all sections of the application (tutorials, practice, the pretest, the posttest) and students should be provided" is the third design principle in interaction category. Tangible objects should be used in all the sections of the application in order to increase interaction between the application and the students. In support of this principle, Hornecker and Buur (2006) emphasize the value of using multiple senses by using physical objects in the use of tangible objects. As well, the rich learning environments should enable students to learn through constant interaction. In similar way, Hengeveld, Voort, van Balkom, Hummels, and de Moor (2007) stated that interaction should be tangible because there are many advantages of it (multiple senses, more natural, active and personal interaction etc.).

"Written and vocal instructions should be given to ease of the use tangible mobile application" is the fourth design principle in interaction category. This is important because students with SLD may give up using the application if they cannot easily use it. In addition, aforementioned, they have difficulties in reading. Vocal instructions may enable ease of use. Likewise, Keay-Bright (2008) stated, the instruction should encompass simple, short, clear sentences for children with

learning difficulties in order to explain children how to use each educational activity. Falcão and Price (2009b) suggested that instructions should be provided to ease the interaction.

"Tangible objects and their images in the interactive application should be similar" is the fifth design principle in interaction category. This principle is important because the consistency between the tangible objects and their images will enable them to better connect with each other. Similarly, Kara (2015) suggested smart toys and their images should be the same. Likewise, Sitdhisanguan et al. (2012) indicated that the same objects should be presented both the digitally and physically to provide higher engagement with the educational content. Fan et al. (2016) mentioned that interaction can be strengthen by associating the digital and physical objects version of the student. Likewise, Antle (2007) stated that appearances of objects in digital and physical forms should be related.

"Students should be shown an image which tangible object should be touched on the tablet screen" is the sixth design principle in interaction category. Since in the tutorial part, students cannot know which object to be touched on the screen, they should be guided by the application in order to prevent any confusion. Similarly, Tsong et al. (2012) empathized that the tangible objects should not be use haphazardly by students for avoiding any problem.

"It should be clear where to touch the tangible objects on the screen" is the seventh design principle in interaction category. Since students have problems with direction, guidance should be given on where to touch the object on the screen. Touching place and its shape should be consistent throughout the application in order to prevent any confusion. Stanton et al. (2001) emphasized that they used colorful rectangles in their tangible interface –Magic Carpet- for students to let them know where to stand. Suárez, Marco, Baldassarri, and Cerezo (2011) suggested that visual feedback should be added to tangible system so that children could recognize where the objects are clearly.

"The images should come to screen transparently before the students touch the tangible objects to screen" is the eighth design principle in interaction category. This principle is important because there is a possibility that students may not examine or look at the object for any reason (distraction, hurriedness etc.) during use of the application. In order to overcome this possibility, the transparent images of the tangible object should come to screen. It also provides a clue for children. Similarly, Marshall (2007) underlined that children may have distraction from the content or details of the objects when children focus on educational activity with physical objects.

"There should be 2-3 seconds delay between each set of content" is the ninth design principle in interaction category. During the instruction, there are a variety of advantages in waiting for 2-3 seconds (constant time delay) in the presentation of the stimuli and the questions to students. Firstly, it helps the students to associate the contents and to distinguish them. In addition to this, it ensures that each learning occurs as individual experiences without interfering with each other, thus it prevents confusions. As the learning pace and the response rates of the students are different from each other, the waiting period of 2-3 seconds is accepted as an adequate response time when the learning is controlled. Tekin-İftar and Kırcaali-İftar (2013) stated that using constant time delay is a common instructional method in special education.

"Students should easily interact with the mobile application" is the tenth design principle in interaction category. In addition, all tangible objects should work when touched once and be stable. This design principle important because mobile application can easily be used by students in order to prevent distracting their attention or motivation. Similar to this design principle, Antle et al. (2011) addressed that it should be easy to use. Students should focus to learn content and should not try to learn to use. In addition, the authors suggested that simple actions should be used in the system for an easy interaction. Likewise, Kara (2015) stated that smart toy should be easy to use. In the same vein, Cobb et al. (2007) accepted easy to use of the tangible system as a design principle. Similarly, Pandey and Srivastava

(2011a) emphasized that the interaction should not be complicated but simple in tangible systems for children with SLD (dyslexia). Falcão and Price (2009b) emphasized that children should interact with the tangible system in an easy way. In addition, Karime et al. (2009) stated that the tangible interface system should assume that children have little or no technical skills. Hinske (2009) underlined that users can interact with the system easily without thinking a lot.

5.2 Effectiveness

One of the purpose of this study was to examine the effectiveness of tangible mobile application on students' achievement in the 6th grade cell concept. The results indicated that the tangible mobile application was effective on students' achievement in the 6th grade cell concept.

This study brought a perspective on how tangible objects enable students with SLD could help them to learn the "cell concept" effectively. Experimental phases followed in the study showed that students could learn the intended subject matter with the effective means provided via tangible mobile application. There has been scarcity of empirical evidence that aligns with the purpose of the present study. However, several studies highlight the effectiveness provided through the use of tangible system. From this perspective, the result of the current study supports the earlier empirical research studies, which revealed effectiveness of the tangible application for students with special needs. Cramer et al. (2016) investigated the effectiveness PhonoBlocks that was a tangible software system in terms of a dynamic color-coding scheme on students with dyslexia in 3rd- 7th grades. They mainly focused on teaching the spelling of the words that includes in one or double consonants and end with –le (cuddle, stable, topple etc.). It was a comparative study and five of students were randomly assigned to Vowel Color Based on Design Principle Group (V-DP) and the rest assigned to Vowel Color Based on Identity (V-ID). As a result, even though there was no significant difference between two groups, improvements were observed for both groups. Likewise, Fan, Antle, Hoskyn, and Cramer (2017) investigated the effectiveness of PhonoBlocks on trained words, new words, and on both. Eight students with specific learning disabilities (Dyslexia) aged between 7-8 years old participated in the experiment for one month. A pretest-posttest design was employed in the study. Findings of the study showed that PhonoBlocks was effective on trained words, new words, and on both. Similar to Cramer et al.'s (2016) and Fan et al.'s (2017) studies, this current study aimed to teach cell concept to students with specific learning disabilities. Likewise, there was a noteworthy increasement in the percentage of correct answers of students. Pandey and Srivastava (2011b) developed a tangible user interface with color and sound cues named as Tiblo to help remember and follow sequential instructions in reading stories or words for students with dyslexia, aged between 8 and 12 years. Rapid ethnography to investigate emotional and psychical aspects and contextual enquiry were employed in their study. As a result, it was found that students were involved more in classroom activities. Improvement in retention skills has also been seen. In line with this, in the current study, all participants gave correct answers to almost all questions for each follow-up sessions. Eventually, achievements of participants in these sessions showed that they learned the cell concept effectively.

Similarly, Sitdhisanguan et al. (2012) investigated the effectiveness of the tangible user interface (TUI) for children with autism on color recognition. The aim of the study was to compare the learning efficacy of touch-based system, TUI and the conventional color stick methods. 20 male children who are 3-5 years old participated to the experiment for four weeks. Eight children were assigned to TUI group, four children were assigned to touch-based system and the rest were assigned to the conventional color stick methods group. A pretest-posttest was conducted for each group. Results of the mentioned study showed that TUI appeared to be more effective for children with autism. Derived from the findings of the current study, it could be interpreted that the tangible interactive system provides more effective learning opportunities for students who could not learn the cell concept at school. This may also create alternative learning platforms for teachers to enable students with disabilities with better tools of support.

Likewise, Bouck et al. (2009) investigated effectiveness of the tangible system (Pentop) for children with mild intellectual disabilities on multiplication. Multiple probe design was used in the mentioned study. Three Hispanic middle school students who were 12 years old participated to the study for four weeks. The results of the study indicated that the percentage of correct answers of three students increased after using the tangible system. Similarly, in the current study multiple-probes across participants design was administered. Both Bouck et al.'s (2009) study and the current study showed that the percentages of correct answer increased for three participants. In this respect, Bouck et al.'s (2009) study seems to align with the current study findings in terms of serving as a facilitator for learning tailored specifically for the student with disabilities.

The current study seems to be effective in terms of providing better learning opportunities for students with SLD with the use of multiple senses. Although the current study focuses on asking students concentrate on a topic related to cell concept, this has been given through the means of skills such as observation, touching and hearing. The results of the current study seem to align with the results in the related scholarship from the basis of using multiple senses. In support of this interpretation, Garzotto and Bordogna's (2010) study could be given. In the mentioned study a tangible technology, Talking Paper was developed to help students with severe disabilities in a real school setting. They combined tangible paper based materials with different multimedia sources (sounds, animations etc.) and created interactive activities. A qualitative pilot study with two students, who had severe disabilities, was pursued to evaluate whether there may be some improvement in children' linguistic, cognitive and motor skills in school context during the three-month time span. Improvements were seen at children' linguistic skills compared to the traditional educational activities in the mentioned study.

5.2.1 Usability issues about the tangible mobile application by students with SLD

Usability issues about the tangible mobile application by students with specific learning disabilities were examined through observation. In the light of observations, it can be deduced that the tangible mobile application ensures students' willingness to use. As well, the researcher also observed that the mobile tangible application was easy to use as well as enabling students' constant attention.

The results of this study indicated that application was successful for getting children' attentions. They maintained their eye contacts with application and objects, they followed instructions and they responded with some actions. Similarly, Keay-Bright (2008) revealed that teachers emphasized concentration of students with severe learning disabilities and autism increased during the use of the tangible system. In traditional setting, they have low engagement and motivation. In parallel with this, Hengeveld et al. (2009) revealed that children using the tangible system paid much more attention when compared with his/her regular classroom setting. Moreover, Cramer et al. (2016) found that tangible software system grasped attention of children. Likewise, Marco et al. (2013) stated that the children focused on the tangible learning materials all the time. In the same way, Haro et al. (2012) revealed that the student with Down syndrome continued his attention throughout the session without asking any reinforcement, assistance or intervene. In addition, in Parkes, Raffle, and Ishii's (2008) study teachers stated that even the student with ADHD could maintain his/her attention all the time while using the tangible object. In line with these, Cobb et al. (2007) underlined the reflections of teachers who stated that the tangible tool have a potential for improving visual attention of students with profound disabilities.

The findings also showed that all children were willing and glad to use the application. Since it is a new way of interaction for students, they seemed to study the concept willingly. To be more specific, the tangible mobile application provides students with physical engagement and multi-sensory interaction, which was very helpful when considering their learning difficulties. Generally, they seemed to enjoy using the application. Correspondingly, Pandey and Srivastava (2011b) revealed that students with dyslexia interested in using Tiblo. Jadan-Guerrero, Jaen, Carpio, and Guerrero (2015) also found that students with Down syndrome liked tangible kit for literacy. Moreover, Keay-Bright (2008) underlined that children used the tangible system in a passionate way. Likewise, Marco et al. (2013) revealed that the children had higher level of engagement and fun when they were using the tangible system. In the same vein, Cobb et al. (2007) stated that the children with severe disabilities liked to use their interactive tangible system. In line with these, Fan et al. (2017) found that most of the children like using the tangible system and they wanted to use it again. Parallel to this, Haro et al. (2012) revealed that the child with Down syndrome liked using the tangible system and wanted to continue using it. Suárez et al. (2011) also found that children preferred tangible system rather than the tactile system.

Furthermore, the present study revealed that all students used the application and the tangible objects easily. None of them confronted with any difficulties. Similarly, Antle et al. (2011) observed that children can easily understand how to use the tangible system. In the learning process, they used the tangible system easily. Besides, Keay-Bright (2008) stated that students with special needs quickly learned how to use the system. This has been interpreted as an unexpected outcome in the mentioned study. In line with these, Fan et al. (2017) revealed that the children reported that the tangible system was easy to use. Parallel with this, Cobb et al. (2007) revealed that children with moderate disabilities used system without an adult assistance.

5.3 Reflections of Special Education Teachers after Using the Tangible Mobile Application on Students with SLD

The findings of the current study indicated that first reactions and implications of the teachers and the students with SLD were very positive and inquiring. They were curious to follow up all the coming steps. The process for starting use was found to be satisfactory by the participants. Correspondingly, Haro et al. (2012) found that students with Down syndrome used tangible interface curiously and they were interested a lot. In addition, Haro et al. (2012) also stated that impressions of teachers were very positive and they were interested to use the tangible system. Similarly, Bodén et al. (2011) stated that the students were curious and interested to explore and learn at first for tangible system. As well, their interview results showed that teachers also enthusiastic about the tangible system. In similar manner, Jadan-Guerrero et al. (2015) emphasized that the teachers found tangible system interesting and enjoyable. In line with these, Pandey and Srivastava (2011b) revealed that children with SLD engaged with the tangible objects as soon as objects were presented to them. In addition, the children were excited and curious to use the tangible mobile application. Likewise, Marco et al. (2009) emphasized that the initial impression of the students was inquiring and full of joy. Even the students wanted to use the tangible system more.

The results also showed that the teachers and the students with SLD perceived the tangible mobile application as easy to use. It was easy and user friendly for all the participants. Furthermore, all the participants were able to use tangible mobile applications easily. However, they encountered few difficulties only at the first trial. The reason for the first time difficulty could be related to teachers' inexperience and unfamiliarity with the system. In support of this interpretation, Jadan-Guerrero et al. (2015) revealed the importance of letting teachers use the tangible system before the students so that they could also help their students. Correspondingly, Haro et al. (2012) emphasized that the use of tangible interface was easier than using mouse for these students. Although there was not a major usability issue, touching problems have been observed in students with SLD. In order to overcome this problem, a small introductory text with images or a video can be prepared. Thus, teachers can learn these little points and can guide their students correctly. Similarly, Marco et al. (2009) revealed that students could use the tangible toys with a little practice. In line with these, Bodén et al. (2011) stated that initially the students misplaced the tangible objects however, they learned it rapidly.

Furthermore, the current study revealed that all participants enjoyed using the tangible system. All the participants appeared to have fun while using it. Likewise, Jadan-Guerrero et al. (2015) stated that children using the tangible system had enjoyable time. Similarly, Falcão and Price (2009a) stated that the teachers who work in special education field were very enthusiastic to use the tangible objects. Bouck et al. (2009) revealed that students with mild disabilities enjoyed using the tangible tool. Similarly, Sitdhisanguan et al. (2012) stated that the students using the tangible system were very enthusiastic and enjoyed.

The findings of the study presented that all the participants were motivated while they were using of the application. Similarly, Starcic, Cotic, and Zajc (2013) stated that the teachers observed that their students using tangible system enjoyed. Likewise, in Jadán-Guerrero, Guerrero, López, Cáliz, and Bravo's (2015) study the increase in the motivation of the teachers and students was observed using the tangible system. Similarly, Jadán-Guerrero et al. (2015) stated that since the tangible system motives students, it is useful for their learning process. In line with these, Cobb et al. (2007) stated that the teachers accepted the tangible tool as a motivation source for learning.

The results revealed that all participants liked the tangible interaction. The teachers thought that it can facilitate students' learning. Furthermore, Jadan-Guerrero et al. (2015) revealed that the teachers felt motivated with the tangible interaction. In addition, the teachers defined tangible interaction as enjoyable and interesting for students. Similarly, Jadán-Guerrero et al. (2015) emphasized that the teachers thought that tangible interaction is complimentary since it combines the digital interaction with the physical interaction. Likewise, Haro et al. (2012) stated that the student with Down syndrome found the tangible system interesting and different because of the interaction style is new. Hengeveld et al. (2009) revealed that owing to the tangible materials and interaction, students could easily grasp literacy skills.

Moreover, the teachers stated that the tangible mobile application can help students to learn permanently because of multi-sensory interaction. In line with this, Jadan-Guerrero et al. (2015) stated that tangible system can facilitate the learning of the students was the general impression of the teachers. Bouck et al. (2009) revealed that the teachers and the students thought that the tangible system was useful to learn multiplication. Similar with these, Jadán-Guerrero et al. (2015) stated that the teachers thought that the tangible system was beneficial for improving literacy skills.

Finally, the teachers wanted to use such materials in the future. They were very positive and willing to use of the tangible mobile applications in their classes. In addition, they can use it in other subjects and lessons. Similarly, Haro et al. (2012) revealed that teachers wanted use the tangible interface in the future. It is likely that such applications will facilitate learning, especially in the context of abstract concepts.

5.4 Suggestions for Instructional Designers and Practitioners

It is thought that the findings of this study may be enlightening for instructional designers to design and develop tangible mobile applications for students with SLD and practitioners (special education teachers, psychologists, counselors etc.) to use it. Instructional Designers could use the guideline (Figure 5.1) to develop similar studies. In addition, practitioners could use the guideline (Figure 5.2) to use this kind of applications.

5.4.1 Suggestions for Instructional Designers

As it could be seen in Figure 5.1, from top to bottom, the model consists of seven fundamental design and development steps and the three improvement steps. In the first step, “the educational subject” was determined. Next, “the educational scenario” was developed while also determining what kinds of tangible objects will be used as well as the features of the objects. The third step is “the development of the tangible objects” and working on the design and the nature of the objects. In the fourth step, paper-based and mobile device-based first prototype was developed, following the sub-steps of “visual design, sound, educational content and coding”. Fifth step was developing the “low fidelity prototype” and the sixth step was developing the “high fidelity prototype”. Seventh step was the final version of the model. It should also be noted that after step four, each step was followed by improvements and the researcher made the necessary changes in line with views of experts, teachers and students as well the observations documented during the implementation.

The right hand columns point the feedback taken from the stakeholders during the design and development phases. Special education experts' views were taken into consideration in all the steps until the final version while science education experts' views were taken in first five steps until the step of "high fidelity prototype". Students' views were also collected. In addition, students used in the steps of developing the first prototype and working on the "low and high fidelity prototypes". As it can be seen on the left hand column, students were asked to use the application and all the steps were observed and documented from fourth step onwards.

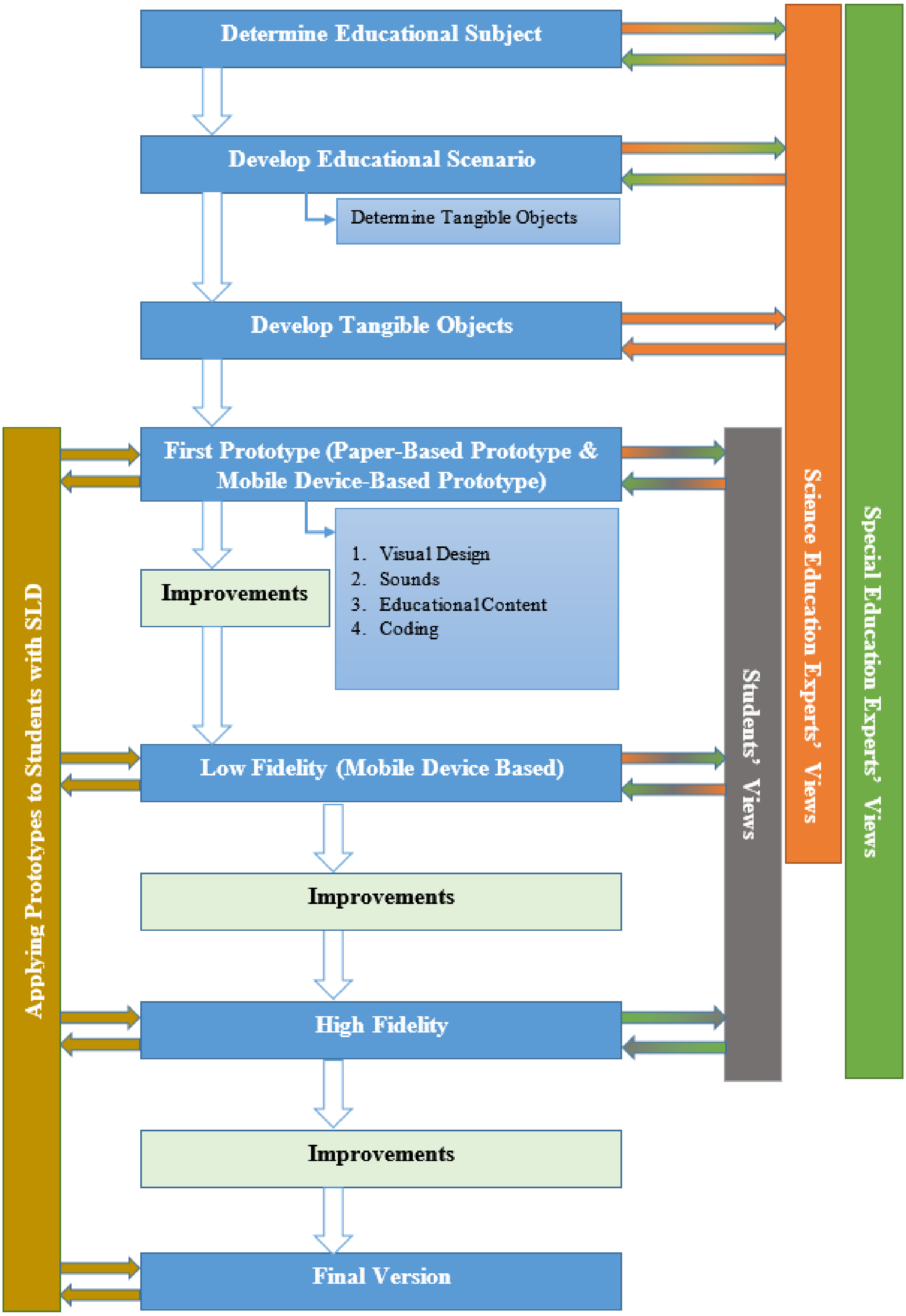

Figure 5.1 Design guidelines for developing tangible mobile application for students with SLD

5.4.2 Suggestions for Practitioners

As it could be seen in Figure 5.2, from top to bottom, the model consists of seven fundamental practice steps. In the first step, the practitioner should remove if there is any distracting stimulus from the learning environment. Next, (s)he should tell the purpose of the application to the student. The third step is "introducing tangible mobile application to students briefly". After introduction step, the practitioner should enter the student's name to login screen and start the implementation. In the fifth step, (s)he should present the boxes which contains tangible objects in accordance with the sections in application. In the sixth step, the practitioner should tell the student about the models on the top-left of screen and the touching area. If the student distracted during using of application, then the practitioner should ensure the attention of student to focus on the application. If no, (s)he should continue and then terminate the session. Because of unique characteristic of the students with SLD, practitioners can adapt the steps in terms of students' progress.

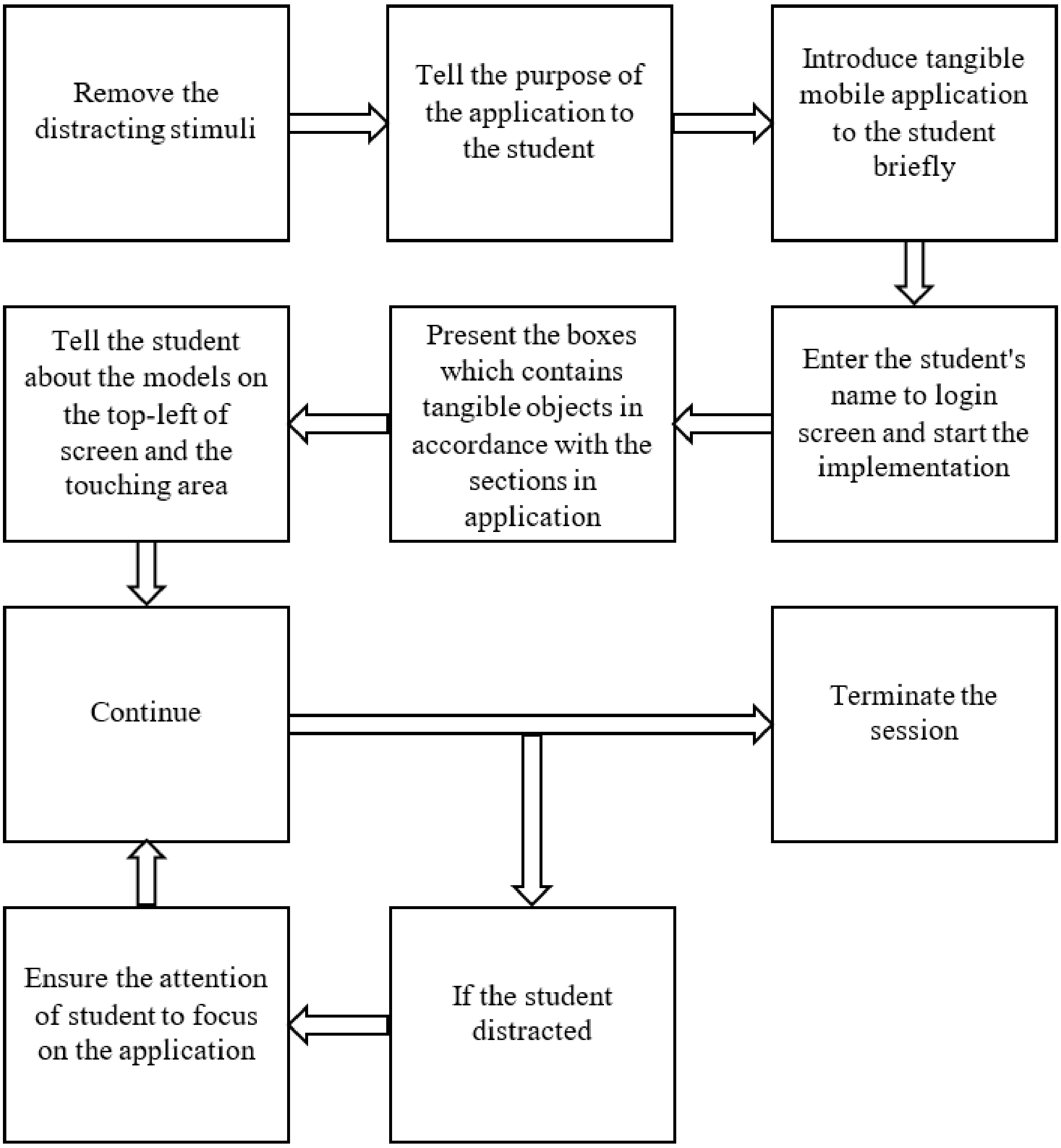

Figure 5.2 User manual of tangible mobile application for practitioners

5.5 Suggestions for Future Research

In the present study, design principles for tangible mobile application for students with SLD were determined by investigating special education experts'/science education expert's, special education/science education teachers' and students' opinions. In addition, the effectiveness of tangible mobile application for students with SLD was revealed. Lastly, usability issues about the tangible mobile application by students with specific learning disabilities and the reflections of special education teachers after using the tangible mobile application on students with SLD were analyzed.

Even tough, this study presents an enlightening perspective about design principles, effectiveness and usability issues about the tangible mobile application by students with specific learning disabilities and the reflections of special education teachers after using the tangible mobile application on students with SLD, there is still a need for future research in following areas:

1. Longitudinal studies about effectiveness could be investigated.
2. Even though the target audience of this study was students with SLD, using tangible mobile application in general education settings could be investigated.
3. Studies could be done with different disability types (students with mild intellectual disabilities, students with attention deficit and hyperactivity disorder etc.)
4. Studies could be done with different age groups.
5. Studies could be done with students who are coming from different socio economic status.
6. Studies could be conducted about usage of tangible mobile application with parents.
7. Studies could be conducted about usage of tangible mobile application in mainstream classes.

8. Gender studies could be investigated about usage of tangible mobile application.
9. Determined design principles could be used in future studies.
10. Studies could be conducted for different courses (social studies, math etc.).
11. Studies could be conducted for home-setting, regular classroom-setting.
12. Even tough tablet was used in this study; calibratability to all multi-touch surfaces could be provided in future studies. For example, studies about tangible application use with smartboard in classroom setting could be investigated.
13. Usability studies could be conducted.

5.6 Conclusion

Tangible objects used with multi touch tablets have a potential to enrich learning experience of students with specific learning disabilities. Providing multi-sensory interaction, physical engagement, accessibility, and collaboration can open a new learning way for students with SLD. It can be ensured by well-designed tangible applications undoubtedly. The main purpose of this study was to determine design principles of a tangible mobile application for students with SLD and to examine the effectiveness of the tangible mobile application on the students' achievement.

Taking the views of stakeholders such as teachers, experts, and students into consideration is very crucial in designing principles. In the current study, special education/science education experts', teachers', and students' opinions about the tangible mobile application for students with SLD were carefully investigated. Design principles for tangible mobile application for students with SLD were determined by investigating special education experts'/science education expert's, teachers', and students' opinions. In addition, a single subject research design was performed in order to investigate the effectiveness of the tangible mobile application on students' achievement in 6th grade cell concept. Usability issues about tangible mobile application by students and the reflections of special education teachers after using the tangible mobile application on students with SLD were examined by using observation and implementation. Overall, the result of the study showed that: 1) 33 design principles of tangible mobile application in four categories –educational content, visual design, tangible object use and interaction- were determined for students with SLD. 2) Tangible mobile application was effective. 3) Students with SLD were willing to use tangible mobile application, they liked it and they used it easily. 4) Teachers thought that tangible mobile application is easy to use and useful for both teachers and students.

Although this study provides design principles, an empirical evidence about effectiveness and usability issues about tangible mobile application by students and the reflections of special education teachers after using the tangible mobile application on students with SLD, still several studies are necessary. In addition, due to the fact that it is a new way of interaction for students, novelty effect problem may be discussed. Researcher is aware of this threat and longitudinal studies are necessary. The findings of the study is also expected to bring unique insights for teachers, administers and parents in addition to researchers and designers.

5.7 Limitations

Some limitations of this study are explained:

- As the nature of qualitative study and single subject research design, purposeful sampling was employed and a limited number of participants participated in the study. This might be a limitation.
- Intervention was administrated to teach one learning object from the 6th grade cell concept. It may have an effect external validity and generalizability of the results.
- It was a short-term study. Longitudinal studies could be developed in further studies.

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APPENDIX A

SPECIAL EDUCATION EXPERT INTERVIEW QUESTIONS (TURKISH)

1. Cinsiyetiniz
2. Hizmet Yılınız
3. Eğitim Durumunuz

EĞİTSEL İÇERİK

1. Kavranabilir uygulamalar özel öğrenme güçlüğü yaşayan öğrencilerin ihtiyaçları göz önüne alındığında özel eğitim açısından faydalı mıdır?
2. Geliştirilen bu uygulama özel öğrenme güçlüğü yaşayan öğrencilerin ihtiyaçlarıyla örtüşmekte midir?
3. Eğitsel içeriğin sunumundan önce gelen test ekranının yeterli midir? Uygulamaya uyum sağlamaları için yeterli midir?
4. Eğitsel içeriğin sunumunda kullanılan öğrenme-öğretme yaklaşımı, yöntem ve teknikler hedef kitleye ve kazanımlara uygun mudur?
5. Eğitsel içerikte sunulan konu anlatımı hedef kitleye uygun mudur?
6. Eğitsel içerikte sunulan alıştırmalar yeterli midir?
7. Kavranabilir uygulamanın özel öğrenme güçlüğü yaşayan öğrencilere eğitsel açıdan daha faydalı olması için neler yapılabilir?
    a. İçeriğin kapsamı özel öğrenme güçlüğü yaşayan öğrencilere uygun mudur? (yaş, gelişimsel özellik, engel türü)
    b. İçeriğin sunumu özel öğrenme güçlüğü yaşayan öğrencilere uygun mudur?
    c. İçeriğin sunumundaki dil özel öğrenme güçlüğü yaşayan öğrencilere uygun mudur?
    d. Yazılı yönergeler özel öğrenme güçlüğü yaşayan öğrencilere uygun mudur?

e. Uygulamada sunulan dönütler yeterli midir?
f. Uygulamada sunulan ipuçları yeterli midir?
g. Uygulamada kullanılan pekiştireçler yeterli midir?
h. Uygulama dikkat ve motivasyonu sağlama açısından uygun mudur?

GÖRSEL TASARIM

1. Test ekranının tasarımı özel öğrenme güçlüğü yaşayan öğrencilere uygun mudur?
2. Ön test-son test ekranının tasarımı özel öğrenme güçlüğü yaşayan öğrencilere uygun mudur?
3. Genel ekran tasarımı (kullanıcı arayüzü) özel öğrenme güçlüğü yaşayan öğrencilere uygun mudur?
4. İçeriğin sunulmasında kullanılan 2 boyutlu görseller özel öğrenme güçlüğü yaşayan öğrencilere uygun mudur?
5. İçeriğin sunulmasında kullanılan 3 boyutlu görseller özel öğrenme güçlüğü yaşayan öğrencilere uygun mudur?
6. Animasyonlar özel öğrenme güçlüğü yaşayan öğrencilere uygun mudur?
7. Kullanılan renkler görseller özel öğrenme güçlüğü yaşayan öğrencilere uygun mudur?
8. Yazılı yönergelerin görsel sunumu (disleksi yaşayan öğrenciler için özel font kullanılması) özel öğrenme güçlüğü yaşayan öğrencilere uygun mudur?
9. Sesli yönergeler özel öğrenme güçlüğü yaşayan öğrencilere uygun mudur?
10. Uygulamada kullanılan karakter özel öğrenme güçlüğü yaşayan öğrencilere uygun mudur?

KAVRANABİLİR NESNELER

1. Kavranabilir modeller özel öğrenme güçlüğü yaşayan öğrencilerin eğitsel içeriği anlamasını kolaylaştırıcı nitelikte midir?
2. Kavranabilir materyaller özel öğrenme güçlüğü yaşayan öğrencilere uygun mudur?

3. Modellerin görsel tasarımı özel öğrenme güçlüğü yaşayan öğrencilere uygun mudur? (Hafiflik, renk vb.)

ETKİLEŞİM

1. Öğrencilerin mobil uygulama ile etkileşimi nasıl olmalıdır?
2. Öğrencilerin kavranabilir modellerle etkileşimi nasıl olmalıdır?
3. Modeller özel öğrenme güçlüğü yaşayan öğrencilerle uygulama arasındaki etkileşimi sağlama açısından uygun mudur?
4. Mobil uygulama özel öğrenme güçlüğü yaşayan öğrencilerle uygulama arasındaki etkileşimi sağlama açısından uygun mudur?

APPENDIX B

SPECIAL EDUCATION EXPERT INTERVIEW QUESTIONS 2 (TURKISH)

1. Cinsiyetiniz
2. Hizmet Yılınız
3. Eğitim Durumunuz

EĞİTSEL İÇERİK

1. İlk prototiple karşılaştırdığınızda eğitsel içerik açısından gördüğünüz farklar nelerdir?
2. Geliştirilen bu uygulama özel öğrenme güçlüğü yaşayan öğrencilerin ihtiyaçlarıyla örtüşmekte midir?
3. Eğitsel içeriğin sunumundan önce gelen test (deneme) ekranı yeterli midir? Uygulamaya uyum sağlamaları için yeterli midir?
4. Ön test-son test özel öğrenme güçlüğü yaşayan öğrenciler için uygun mudur?
5. Eğitsel içeriğin sunumunda kullanılan öğrenme-öğretme yaklaşımı, yöntem ve teknikler hedef kitleye ve kazanımlara uygun mudur?
6. Eğitsel içerikte sunulan konu anlatımı hedef kitleye uygun mudur?
7. Eğitsel içerikte sunulan alıştırmalar yeterli midir? [Son kısma bütüncül bir alıştırma eklenmiştir]
8. Kavranabilir uygulamanın özel öğrenme güçlüğü yaşayan öğrencilere eğitsel açıdan daha faydalı olması için neler yapılabilir?
   a. İçeriğin kapsamı özel öğrenme güçlüğü yaşayan öğrencilere uygun mudur? (yaş, gelişimsel özellik, engel türü)
   b. İçeriğin sunumu özel öğrenme güçlüğü yaşayan öğrencilere uygun mudur?
   c. İçeriğin sunumundaki dil özel öğrenme güçlüğü yaşayan öğrencilere uygun mudur?

d. Sesli yönergeler özel öğrenme güçlüğü yaşayan öğrencilere uygun mudur?
e. Yazılı yönergeler özel öğrenme güçlüğü yaşayan öğrencilere uygun mudur?
f. Uygulamada sunulan dönütler yeterli midir?
g. Uygulamada sunulan ipuçları yeterli midir?
h. Uygulamada kullanılan pekiştireçler yeterli midir?
i. Uygulama dikkat ve motivasyonu sağlama açısından uygun mudur?

GÖRSEL TASARIM

1. İlk prototiple karşılaştırdığınızda görsel tasarım açısından gördüğünüz farklar nelerdir?
2. Test ekranının tasarımı özel öğrenme güçlüğü yaşayan öğrencilere uygun mudur?
3. Ön test-son test ekranının tasarımı özel öğrenme güçlüğü yaşayan öğrencilere uygun mudur?
4. Genel ekran tasarımı (kullanıcı arayüzü) özel öğrenme güçlüğü yaşayan öğrencilere uygun mudur?
5. İçeriğin sunulmasında kullanılan 2 boyutlu görseller özel öğrenme güçlüğü yaşayan öğrencilere uygun mudur?
6. İçeriğin sunulmasında kullanılan 3 boyutlu görseller özel öğrenme güçlüğü yaşayan öğrencilere uygun mudur?
7. Animasyonlar özel öğrenme güçlüğü yaşayan öğrencilere uygun mudur?
8. Kullanılan renkler, görseller özel öğrenme güçlüğü yaşayan öğrencilere uygun mudur?
9. Yazılı yönergelerin görsel sunumu (disleksi yaşayan öğrenciler için özel font kullanılması) özel öğrenme güçlüğü yaşayan öğrencilere uygun mudur?
10. Sesli yönergeler özel öğrenme güçlüğü yaşayan öğrencilere uygun mudur?
11. Uygulamada kullanılan karakter özel öğrenme güçlüğü yaşayan öğrencilere uygun mudur?

KAVRANABİLİR NESNELER

1. İlk prototiple karşılaştırdığınızda kavranabilir nesnelerin kullanımı açısından gördüğünüz farklar nelerdir?

2. Kavranabilir modeller özel öğrenme güçlüğü yaşayan öğrencilerin eğitsel içeriği anlamasını kolaylaştırıcı nitelikte midir?
3. Kavranabilir materyaller özel öğrenme güçlüğü yaşayan öğrencilere uygun mudur?
4. Modellerin görsel tasarımı özel öğrenme güçlüğü yaşayan öğrencilere uygun mudur? (Hafiflik, renk vb.)

ETKİLEŞİM

1. İlk prototiple karşılaştırdığınızda etkileşim açısından gördüğünüz farklar nelerdir?
2. Modeller özel öğrenme güçlüğü yaşayan öğrencilerle uygulama arasındaki etkileşimi sağlama açısından uygun mudur?
3. Mobil uygulama özel öğrenme güçlüğü yaşayan öğrencilerle uygulama arasındaki etkileşimi sağlama açısından uygun mudur?

Eklemek istedikleriniz:

APPENDIX C

SPECIAL EDUCATION EXPERT INTERVIEW QUESTIONS 3 (TURKISH)

1. Cinsiyetiniz
2. Hizmet Yılınız
3. Eğitim Durumunuz

EĞİTSEL İÇERİK

1. Kavranabilir uygulamalar özel öğrenme güçlüğü yaşayan öğrencilerin ihtiyaçları göz önüne alındığında özel eğitim açısından faydalı mıdır? Neden?
2. Geliştirilen bu uygulama özel öğrenme güçlüğü yaşayan öğrencilerin ihtiyaçlarıyla örtüşmekte midir? Neden?
3. Eğitsel içeriğin sunumundan önce gelen alıştırma ekranının yeterliliğini değerlendirir misiniz?
4. Eğitsel içeriğin sunumunda kullanılan öğrenme-öğretme yaklaşımı, yöntem ve tekniklerin hedef kitle ve kazanımlarla hangi ölçüde uyuştuğunu düşünüyorsunuz? Neden?
5. Eğitsel içerikte sunulan konu anlatımının hedef kitleye uygunluğunu değerlendirir misiniz?
6. Eğitsel içerikte sunulan alıştırmaların hedef kitleye uygunluğunu değerlendirir misiniz?
7. Kavranabilir uygulamanın özel öğrenme güçlüğü yaşayan öğrencilere eğitsel açıdan daha faydalı olması için neler yapılabilir? Neden?
    a. İçeriğin kapsamı özel öğrenme güçlüğü yaşayan öğrencilere uygun mudur? (yaş, gelişimsel özellik, engel türü) Neden?
    b. İçeriğin sunumu özel öğrenme güçlüğü yaşayan öğrencilere uygun mudur? Neden?

c. İçeriğin sunumundaki dil özel öğrenme güçlüğü yaşayan öğrencilere uygun mudur? Neden?
d. Sesli yönergeler özel öğrenme güçlüğü yaşayan öğrencilere uygun mudur? Neden?
e. Yazılı yönergeler özel öğrenme güçlüğü yaşayan öğrencilere uygun mudur? Neden?
f. Uygulamada sunulan dönütler yeterli midir? Neden?
g. Uygulamada sunulan ipuçları yeterli midir? Neden?
h. Uygulamada kullanılan pekiştireçler yeterli midir? Neden?
i. Uygulama dikkat ve motivasyonu sağlama açısından uygun mudur? Neden?

GÖRSEL TASARIM

1. Alıştırma ekranının tasarımı özel öğrenme güçlüğü yaşayan öğrencilere uygun mudur? Neden?
2. Ön test-son test ekranının tasarımı özel öğrenme güçlüğü yaşayan öğrencilere uygun mudur? Neden?
3. Genel ekran tasarımı (kullanıcı arayüzü) özel öğrenme güçlüğü yaşayan öğrencilere uygun mudur? Neden?
4. İçeriğin sunulmasında kullanılan 2 boyutlu görseller özel öğrenme güçlüğü yaşayan öğrencilere uygun mudur? Neden?
5. İçeriğin sunulmasında kullanılan 3 boyutlu görseller özel öğrenme güçlüğü yaşayan öğrencilere uygun mudur? Neden?
6. Kullanılan renkler görseller özel öğrenme güçlüğü yaşayan öğrencilere uygun mudur? Neden?
7. Yazılı yönergelerin görsel sunumu (disleksi yaşayan öğrenciler için özel font kullanılması) özel öğrenme güçlüğü yaşayan öğrencilere uygun mudur? Neden?
8. Uygulamada kullanılan karakter özel öğrenme güçlüğü yaşayan öğrencilere uygun mudur? Neden?

KAVRANABİLİR NESNELER

1. Kavranabilir modeller özel öğrenme güçlüğü yaşayan öğrencilerin eğitsel içeriği anlamasını kolaylaştırıcı nitelikte midir? Neden?
2. Kavranabilir materyaller özel öğrenme güçlüğü yaşayan öğrencilere uygun mudur? Neden?
3. Modellerin görsel tasarımı özel öğrenme güçlüğü yaşayan öğrencilere uygun mudur? (Hafiflik, renk vb.) Neden?

ETKİLEŞİM

1. Öğrencilerin mobil uygulama ile etkileşimi nasıl olmalıdır? Neden?
    a. (Etkileşimi açıklamak gerekirse (öğrenci-uygulama arasındaki iletişim, sistemin öğrencinin davranışlarına verdiği dönüt, düzeltme, pekiştireçler, kullanılan butonlar vb.)
2. Öğrencilerin kavranabilir modellerle etkileşimi nasıl olmalıdır? Neden?
    a. (Etkileşimi açıklamak gerekirse (öğrenci-uygulama arasındaki iletişim, sistemin öğrencinin davranışlarına verdiği dönüt, düzeltme, pekiştireçler, kullanılan butonlar vb.)

3. Modeller özel öğrenme güçlüğü yaşayan öğrencilerle uygulama arasındaki etkileşimi sağlama açısından uygun mudur? Neden?
    a. (Etkileşimi açıklamak gerekirse (öğrenci-uygulama arasındaki iletişim, sistemin öğrencinin davranışlarına verdiği dönüt, düzeltme, pekiştireçler, kullanılan butonlar vb.)

4. Mobil uygulamanın özellikleri özel öğrenme güçlüğü yaşayan öğrencilerle uygulama arasındaki etkileşimi sağlama açısından uygun mudur? Neden?

    a. (Etkileşimi açıklamak gerekirse (öğrenci-uygulama arasındaki iletişim, sistemin öğrencinin davranışlarına verdiği dönüt, düzeltme, pekiştireçler, kullanılan butonlar vb.)

APPENDIX D

SCIENCE EDUCATION EXPERT AND SCIENCE TEACHER INTERVIEW QUESTIONS (TURKISH)

1. Cinsiyetiniz
2. Hizmet Yılınız
3. Eğitim Durumunuz

Eğitsel İçerik

1. Kavranabilir uygulamalar fen ve teknoloji dersi açısından faydalı mıdır?
2. Bu eğitsel içeriğin kavranabilir uygulama yoluyla sunulması uygun mudur?
3. Geliştirilen bu uygulama fen ve teknoloji dersi için öğrencilerin -özellikle de özel öğrenme güçlüğü yaşayan öğrencilerin- ihtiyaçlarıyla örtüşmekte midir?
4. Eğitsel içerikte sunulan konu anlatımı yeterli midir?
5. Eğitsel içerikte sunulan alıştırmalar yeterli midir?
6. İçeriğin sunumu kazanımın elde edilmesi için yeterli midir?
7. Konu anlatımı kazanıma yönelik midir?
8. Alıştırmalar kazanıma yönelik midir?
9. Hazırlanan ön test-son test kazanıma yönelik midir?
10. İçeriğin sıralanması ve sunulması uygun mudur?
11. Uygulamada kullanılan öğrenme-öğretme yaklaşımı, yöntem ve teknikler kazanıma uygun mudur?

Görsel Tasarım

1. İçeriğin daha etkin sunulabilmesi için görsel tasarımda nelere dikkat edilmelidir?
2. Ön test-son test ekranının tasarımı içeriğin sunumu açısından uygun mudur?
3. Genel ekran tasarımı (kullanıcı arayüzü) içeriğin sunumu açısından uygun mudur?

4. Uygulamada kullanılan 2 boyutlu görseller içeriğin sunumu açısından uygun mudur?
5. Uygulamada kullanılan 3 boyutlu görseller özel öğrenme güçlüğü yaşayan öğrencilere uygun mudur?
6. Yazılı yönergelerin görsel sunumu içeriğin sunumu açısından uygun mudur?
7. Sesli yönergeler uygun mudur?
8. Uygulamada kullanılan karakter fen ve teknoloji dersiyle uyumlu mudur?

Kavranabilir Nesneler

1. Kavranabilir modeller eğitsel içerikle uyumlu mudur?
2. Kavranabilir modeller eğitsel içeriği anlamayı kolaylaştırıcı nitelikte midir?
3. Modellerin görsel tasarımı ve kullanımı içeriğin sunumu açısından uygun mudur?

Etkileşim

1. Öğrencilerin mobil uygulama ile etkileşimi nasıl olmalıdır?
2. Öğrencilerin kavranabilir modellerle etkileşimi nasıl olmalıdır?
3. Modeller öğrencilerle içerik arasındaki etkileşimi sağlama açısından uygun mudur?
4. Mobil uygulama öğrencilerle içerik arasındaki etkileşimi sağlama açısından uygun mudur?

Uygulama ile ilgili önerileriniz nelerdir?

APPENDIX E

SCIENCE EDUCATION EXPERT AND SCIENCE TEACHER INTERVIEW QUESTIONS 2 (TURKISH)

1. Cinsiyetiniz
2. Hizmet Yılınız
3. Eğitim Durumunuz

Eğitsel İçerik

1. İlk prototiple karşılaştığınızda eğitsel içerik açısından gördüğünüz farklar nelerdir?
2. Deneme ekranı öğrencinin uygulamayı alışması için yeterli midir?
3. Hazırlanan ön test-son test kazanıma yönelik midir?
4. Eğitsel içerikte sunulan konu anlatımı yeterli midir?
5. Eğitsel içerikte sunulan alıştırmalar yeterli midir?
6. İçeriğin sunumu kazanımın elde edilmesi için yeterli midir?
7. Konu anlatımı kazanıma yönelik midir?
8. Alıştırmalar kazanıma yönelik midir? (Bir önceki aşamada, önerileriniz doğrultusunda sona eklenen bütüncül alıştırma konusundaki görüşleriniz?)
9. İçeriğin sıralanması ve sunulması uygun mudur?
10. Uygulamada kullanılan öğrenme-öğretme yaklaşımı, yöntem ve teknikler kazanıma uygun mudur?

Görsel Tasarım

1. İlk prototiple karşılaştığınızda görsel açısından gördüğünüz farklar nelerdir?
2. Deneme ekranının tasarımı içeriğin sunumu açısından uygun mudur?
3. Ön test-son test ekranının tasarımı içeriğin sunumu açısından uygun mudur?
4. Genel ekran tasarımı (kullanıcı arayüzü) içeriğin sunumu açısından uygun mudur?

5. Uygulamada kullanılan 2 boyutlu görseller içeriğin sunumu açısından uygun mudur?
6. Uygulamada kullanılan 3 boyutlu görseller özel öğrenme güçlüğü yaşayan öğrencilere uygun mudur?
7. Uygulamada kullanılan animasyonlar içeriğin sunumu açısından uygun mudur?
8. Yazılı yönergelerin görsel sunumu içeriğin sunumu açısından uygun mudur?
9. Sesli yönergeler uygun mudur?

Kavranabilir Nesneler

1. İlk prototiple karşılaştırdığınızda kavranabilir nesnelerin kullanımı açısından gördüğünüz farklar nelerdir?
2. Kavranabilir modeller eğitsel içerikle uyumlu mudur?
3. Kavranabilir modeller eğitsel içeriği anlamayı kolaylaştırıcı nitelikte midir?
4. Modellerin görsel tasarımı ve kullanımı içeriğin sunumu açısından uygun mudur?

Etkileşim

1. İlk prototiple karşılaştığınızda etkileşim gördüğünüz farklar nelerdir?
2. Deneme ekranının etkileşime nasıl bir etkisi vardır?
3. Öğrencilerin kavranabilir modellerle etkileşimi nasıl olmalıdır?
4. Modeller öğrencilerle içerik arasındaki etkileşimi sağlama açısından uygun mudur?
5. Mobil uygulama öğrencilerle içerik arasındaki etkileşimi sağlama açısından uygun mudur?

Uygulama ile ilgili önerileriniz nelerdir?

APPENDIX F

STUDENT WITH SLD INTERVIEW QUESTIONS (TURKISH)

1. Uygulamanın beğendin yönleri nelerdir? Tekrar kullanmak ister misin? Başka konu veya başka derslerde de kullanmak ister misin?

2. Uygulamanın beğenmediğin yönleri nelerdir? (sıkılma, uygulamayı kullanırken zorlanma vb.)

Eğitsel İçerik

1. Uygulamadaki konu anlatımının öğrenmene etkisi nasıldı?
2. Alıştırmaların konuyu öğrenmene etkisi nasıldı?
3. Başlangıçtaki alıştırmanın uygulamayı nasıl kullanacağını anlamana etkisi nasıldı?
4. Uygulamadaki seslerin konuyu anlamana etkisi nasıldı?

Görsel Tasarım

1. Uygulamadaki resimleri ve robot karakteri hakkında ne düşünüyorsun?
2. Fontun okumana nasıl etkisi oldu?

Kavranabilir Nesne Kullanımı- Etkileşim

1. Uygulamadaki kavranabilir materyalleri hakkında ne düşünüyorsun? Konuyu anlamana etkisi nasıldı?

2. Önceki uygulamaya göre değişen yönler nelerdir?

3. Doğru ve yanlış yaptığında verilen dönütlerin öğrenmene etkisi nasıldı?

4. Yönergeler nasıldı? (Ne yapman gerektiğini söyleyen sesler, yazılar)

APPENDIX G

STUDENT WITH SLD INTERVIEW QUESTIONS 2 (TURKISH)

1. Uygulamanın beğendin yönleri nelerdir? Tekrar kullanmak ister misin? Başka konu veya başka derslerde de kullanmak ister misin?

2. Uygulamanın beğenmediğin yönleri nelerdir? (sıkılma, uygulamayı kullanırken zorlanma vb.)

Eğitsel İçerik

1. Uygulamadaki konu anlatımının öğrenmene etkisi nasıldı?
2. Alıştırmaların konuyu öğrenmene etkisi nasıldı?
3. Başlangıçtaki alıştırmanın uygulamayı nasıl kullanacağını anlamana etkisi nasıldı?
4. Uygulamadaki seslerin konuyu anlamana etkisi nasıldı?
5. En sondaki soruların öğrenmene etkisi nasıldı?

Görsel Tasarım

1. Uygulamadaki resimler ve robot karakteri hakkında ne düşünüyorsun?
2. Fontun okumana nasıl etkisi oldu?

Kavranabilir Nesne Kullanımı- Etkileşim

1. Uygulamadaki kavranabilir materyalleri hakkında ne düşünüyorsun? Konuyu anlamana etkisi nasıldı?
2. Önceki uygulamaya göre değişen yönler nelerdir?
3. Doğru ve yanlış yaptığında verilen dönütlerin öğrenmene etkisi nasıldı?
4. Yönergeler nasıldı? (Ne yapman gerektiğini söyleyen sesler, yazılar)
5. Etkileşim unsurları (daire, model resmi üstte olması, dairenin içindeki görseller, tekrar dinle butonu) nasıldı?

APPENDIX H

SPECIAL EDUCATION TEACHER INTERVIEW QUESTIONS (TURKISH)

1 - Kullanmaya başlama süreci

- Uygulamayı ilk gördüğünüzde ne düşündünüz?
  Prompt: Sizin ve öğrencinizin ilk tepkisi/yaklaşımı
- Bu eğitsel uygulamanın "**kullanımını öğrenme sürecini**" siz ve öğrenciniz açısından anlatır mısınız?
- Prompt: Sadece başlangıç aşamasını anlatınız. Kolaylaştırıcı Etkenler (Alıştırma Ekranı), Zorluklar

2- Kullanma süreci

- Öğrenme süreci sonrasında eğitsel uygulamayı kullanma süreci siz ve öğrenciniz açısından nasıldı?
- Prompt: Kolaylaştırıcı Etkenler (Dokundurma Çemberi, Modeller), Zorluklar/ beğenmediğiniz yönler (öğrencinin ve sizin)
- Uygulamayı kullanmak siz ve öğrenciniz açısından motive edici miydi? Ne açılardan?
- Uygulamayı kullanırken sağladığı etkileşim açısından nasıl değerlendirirsiniz?

Etkileşimi açıklamak gerekirse (öğrenci-uygulama arasındaki iletişim, sistemin öğrencinin davranışlarına verdiği dönüt, düzeltme, pekiştireçler, kullanılan butonlar vb.)

3- Kullanım sonrası

- Bu uygulama elinizde olsa daha sonra kullanmayı düşünür müsünüz? Neden? Sizce diğer özel eğitim öğretmenleri bu uygulamayı kullanırlar mı? Neden?

- Uygulamanın öğrenme/öğretme sürecine katkısı hakkında ne düşünüyorsunuz?

Prompt: öğrenmeyi kolaylaştırma, öög yaşayan öğrencilerin özelliklerine uygunluk, ihtiyaçlarına hitap etme (okumayı azaltma, sesli yönergeler, görseller, dokunma duyusuna da hitap etme vb.)

- Kavranabilir uygulamaları kendi derslerinizde kullanmayı düşünür müsünüz? [Fen ve teknolojiden farklı bir derste de olabilir] Neden? Hangi ders/konu/beceri/kazanım?
- Geliştirilmesi gereken noktalar/öneriler?

  Prompt:

  - Uygulamanın siz ve öğrenciniz açısından kullanım zorlukları/dezavantajları
  - Tasarım (genel ekran tasarımı, 2 boyutlu, 3 boyutlu görseller, robot karakteri, animasyonlar, kullanılan renkler, kavranabilir modeller) açısından
  - İçerik (eğitsel senaryo, içeriğin sunumu, kapsamı, kullanılan dil, sesli yazılı yönergeler, dönütler, pekiştireçler) açısından
  - Kullanım kolaylığı açısından

APPENDIX I

DEMOGRAPHIC QUESTIONNAIRE (TURKISH)

1- Adı Soyadı:
2- Cinsiyeti: □ K □ E
3- Sınıfı:
4- Doğum Tarihi:
5- Engel Yüzdesi:
6- Okulu: □ Özel □ Devlet
7- Öğrencinin özel öğrenme güçlüğü tanısı kim tarafından ve ne zaman konuldu? (Lütfen yazınız):

8- Devam ettiği özel eğitim merkezi:

9- Hangi tarihten beri özel eğitim merkezine devam ediyor?

10- Öğrencinin okul dışındaki eğitimi ile kim(ler) ilgileniyor?

□ Anne □ Baba □ Abi/Abla □ Özel Öğretmen □ Özel Eğitim/Danışmanlık Merkezi □ Diğer

11- Tableti var mı?/Daha önce tablet kullandı mı?

12- Okuma düzeyi nedir? (Dakikada okuduğu kelime sayısı)

13- İstek ve güdülenmişlik düzeyleri nasıldır?

14- Öğrencinin tercih ettiği/sevdiği etkinlik/yiyecek?

15- Akademik başarısı nasıldır? (Not ortalaması vb…)

16- Özel ihtiyaçları nelerdir?

17- Üstün/güçlü yönleri nelerdir?

18- Geliştirilmesi gereken yönleri nelerdir?

19- Sizin eklemek istedikleriniz:

APPENDIX J

OBSERVATION NOTES (TURKISH)

Öğrencinin Kodu:____

Gözlem Tarihi   :___/___/_______

Öğrencinin Genel Olarak Kullanımda Yaşadığı Deneyimler/ Zorluklar (Eğitsel İçerik, Görsel Tasarım, Kavranabilir Nesne Kullanımı ve Etkileşim):

Uygulamanın Zayıf Yanları:

Uygulamanın Güçlü Yanları:

Eklemek İstedikleriniz:

APPENDIX K

OBSERVATION FORM (TURKISH)

	Evet	Kısmen	Hayır
Uygulamayı kullanmaya istekli olması/Uygulamayı kullanmaktan memnun olması			
1. Uygulama öncesinde ve sırasında tabletle çalışmak için talepte bulundu veya benzeri çalışma istediğini ifade etti. (en az 1 kez)			
2. Uygulama esnasında gelen dönütler hakkında memnuniyet belirten ifadeler veya hoşnutluk bildiren sözel sözel olmayan jest veya mimiğe dayalı ifadeler kullandı.(en az 3 kez)			
3. Uygulama esnasında gelen dönütler hakkında memnuniyetsizlik belirten ifadeler kullandı (en az 3 kez)			
4. Uygulama sonrasında devam etmek için talebi oldu.(en az 1 kez)			
Uygulamayı kullanırken dikkatini sürdürmesi			
1. Uygulama esnasında tabletle etkileşimde kaldı, gözleriyle tableti ve materyalleri takip etti. (uygulama boyunca)			
2. Yönergeler sunulurken tableti takip etti(uygulama boyunca)			
3. Uygulama esnasında gelen dönütlere sözel ya da sözel olmayan şekilde tepki/yanıt verdi (uygulama boyunca)			
Uygulamayı ve kavranabilir modelleri zorlanmadan/hatasız kullanması			
1. Uygulama esnasında kavranabilir nesneleri kullanırken sık hata yaptı.(3 ten fazla)			
2. Uygulama esnasında yoğun biçimde yardım talebinde bulundu.(3 ten fazla)			
3. Uygulama esnasında yetişkin müdahalesi sıklıkla gerekti.(3 ten fazla)			
4. Uygulama esnasında nesnelerle uygulamada sunulan örneği eşlemede sorunlar yaşadı/ sık hata yaptı.(14 soruda 3 hata ve üzeri)			

APPENDIX L

PRETEST-POSTTEST (TURKISH)

Sorular rastgele hem yazılı hem sözlü olarak ekrana gelecektir.

1. Hücreyi dış ortamdan ayırarak ona şekil ve dayanıklılık veren modeli ekrana dokundurur musun?
2. Hücrede gerçekleşen tüm yaşamsal olayları düzenleyen ve hücreyi yöneten modeli ekrana dokundurur musun?
3. Çekirdek ile hücre zarı arasını dolduran, yumurta akı kıvamında, yarı akışkan, içinde hücrede görev alan çeşitli organellerin bulunduğu yapının modelini ekrana dokundurur musun?
4. Salgı maddeleri üreten ve salgıları, kesecikler şeklinde paketleyen modeli ekrana dokundurur musun?
5. Protein sentezleme ile görevli olan modeli ekrana dokundurur musun?
6. Sindirimde görevli olan modeli ekrana dokundurur musun?
7. Enerji üreten modeli ekrana dokundurur musun?
8. Hücrede maddelerin taşınmasını sağlayan modeli ekrana dokundurur musun?
9. Hücreye zarar verebilecek ya da fazla olan maddeleri depo eden, bitki hücresinde az sayıda ve büyük; hayvan hücresinde ise çok sayıda ve küçük olan modeli ekrana dokundurur musun?
10. Bitki hücrelerinde bulunan ve hücre zarını çevreleyen dayanıklı, sağlam ve cansız yapı modelini ekrana dokundurur musun?
11. Bitki hücresinde bulunan, hayvan hücresinde bulunmayan, bitkinin besin ve oksijen üretmesini sağlayan modeli ekrana dokundur musun?
12. Hayvan hücresinde çiftler hâlinde bulunurken bitki hücresinde bulunmayan ve hücrenin bölünmesinde görevli olan modeli ekrana dokundur musun?

Şimdi eline hayvan ve bitki hücresi modellerini al, söylenen özellik hangi hücreye ait ise o hücreyi ekrana dokundur.

1. Köşeli bir şekle sahiptir.
2. Oval bir şekle sahiptir.
3. Kloroplast bulunur.
4. Kloroplast bulunmaz.
5. Sentriyolleri yoktur.
6. Sentriyolleri vardır.
7. Hücre duvarı vardır.
8. Hücre duvarı yoktur.
9. Kofulları büyük ve az sayıdadır.
10. Kofulları küçük ve çok sayıdadır.

APPENDIX M

ETHICS COMMITTEE OF MIDDLE EAST TECHNICAL UNIVERSITY RESEARCH CENTER FOR APPLIED ETHICS APPROVAL FORM (TURKISH)

UYGULAMALI ETİK ARAŞTIRMA MERKEZİ
APPLIED ETHICS RESEARCH CENTER

ORTA DOĞU TEKNİK ÜNİVERSİTESİ
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17 MAYIS 2016

Sayı: 28620816 /242

Konu: Etik Onay

Gönderilen: Prof.Dr. Kürşat ÇAĞILTAY
Eğitim Fakültesi

Gönderen: Prof. Dr. Canan SÜMER
İnsan Araştırmaları Etik Kurulu Başkanı

İlgi: Etik Onayı

Sayın Prof.Dr. Kürşat ÇAĞILTAY'ın danışmanlığını yaptığı Elif Polat HOPCAN' ın "Özel Öğrenme Güçlüğü Yaşayan Öğrenciler İçin Kavranabilir Mobil Bir Uygulama Tasarlanması, Geliştirilmesi ve Uygulamanın Değerlendirmesi" başlıklı araştırması İnsan Araştırmaları Etik Kurulu tarafından uygun görülerek gerekli onay **2016-EGT-094** protokol numarası ile **01.06.2016-01.01.2017** tarihleri arasında geçerli olmak üzere verilmiştir.

Bilgilerinize saygılarımla sunarım.

Prof. Dr. Canan SÜMER
İnsan Araştırmaları Etik Kurulu Başkanı

Prof. Dr. Meliha ALTUNIŞIK
İAEK Üyesi

Prof. Dr. Ayhan SOL
İAEK Üyesi

Prof. Dr. Mehmet UTKU
İAEK Üyesi

Prof. Dr. Ayhan Gürbüz DEMİR
İAEK Üyesi

Yrd .Doç .Dr. Pınar KAYGAN
İAEK Üyesi

Yrd. Doç. Dr. Emre SELÇUK
İAEK Üyesi

APPENDIX N

PARENTAL CONSENT FORM (TURKISH)

Sayın Veli,

Çalışmayı yürüten Elif Polat Hopcan, Orta Doğu Teknik Üniversitesi, Bilgisayar ve Öğretim Teknolojileri Eğitimi Bölümünde doktora öğrencisidir. Bu doktora tez çalışması Orta Doğu Teknik Üniversitesi öğretim üyesi Prof. Dr. Kürşat Çağıltay danışmanlığında yürütülmektedir. Çalışmanın amacı özel öğrenme güçlüğü yaşayan öğrenciler için geliştirilen kavranabilir eğitsel tablet uygulamasının etkisini araştırmaktır.

Çocuğunuz ile fen ve teknoloji dersine ilişkin oturum başı yaklaşık 1 saatlik bir uygulama yapılacaktır. Çalışma çocuğunuz için psikolojik veya fiziksel bir risk taşımamaktadır. Çalışmaya katılım tamamen gönüllüdür. Çalışma sırasında izninizin olması durumunda bilimsel değerlendirme amaçlı görüntü kaydı alınacaktır. Çalışmada gizlilik esas olacak, çocuğunuzun ismi hiçbir yerde rapor edilmeyecektir. Çocuğunuz çalışmaya katılmama veya katıldıktan sonra herhangi bir anda çalışmayı bırakma hakkına da sahiptir. Elif Polat Hopcan çalışma süresince kendisine soracağınız tüm sorulara cevap verecektir.

Çalışmaya ya da çocuğunuzun katılımına yönelik daha fazla bilgi için başvurulacak kişi Elif Polat Hopcan'dır. Telefon: ……… E-posta Adresi: polatelif88@gmail.com

İlginiz için teşekkürler,

Elif Polat Hopcan

Yukarıda açıklamasını okuduğum çalışmaya, oğlumun / kızımın katılımına izin veriyorum.

Velinin:

Adı Soyadı: ____________________ İmzası: ________________ Tarih:_________

APPENDIX O

EQUIPMENTS USED IN THE STUDY

Samsung Tab S2 Tablet

CPU Speed: 1.9GHz, 1.3GHz

CPU Type: Octa-Core

Size (Main Display): 9.7"

Resolution (Main Display): 2048 x 1536 (QXGA)

Operating System: Android 6

Weight (g): 392

APPENDIX P

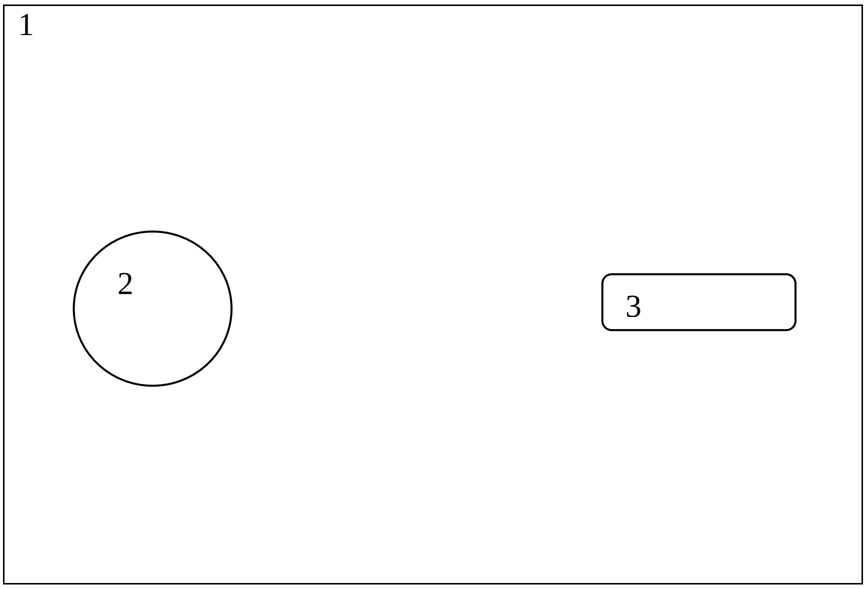
EDUCATIONAL SCENARIO (TURKISH)

Kazanım:

6.1.1.1. Hayvan ve bitki hücrelerini, temel kısımları ve görevleri açısından karşılaştırır.
a. Hücrenin temel kısımları için sadece hücre zarı, sitoplazma ve çekirdek verilir.
b. Hücre organellerinin ayrıntılı yapıları verilmeden sadece isim ve görevlerine değinilir.

Kurgu:

Ekran 1



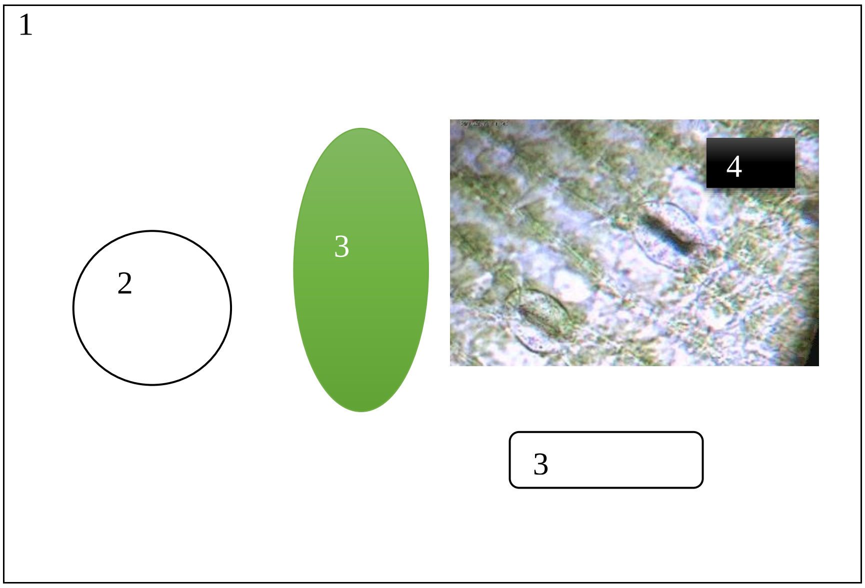
1. Arka plan: Sade bir arka plan görüntüsü.

2. Karakter alanı: Robot

3. Başla Butonu: Robot'un konuşması bitince ekrana gelecek olan "başla" butonu.

1. Ekran, Ekran 1 düzeninde açılır. Robot ekrana gelir. **Sesli yönerge:** "Merhaba ben Robot, hücre içinde bir yolculuğa çıkmaya hazır mısın? Haydi, başlayalım" der.
2. Ekran 1'de belirtilen Başla Butonu ekrana gelir. Öğrenci Başla butonuna tıklayınca Ekran 2 gelir.

Ekran 2



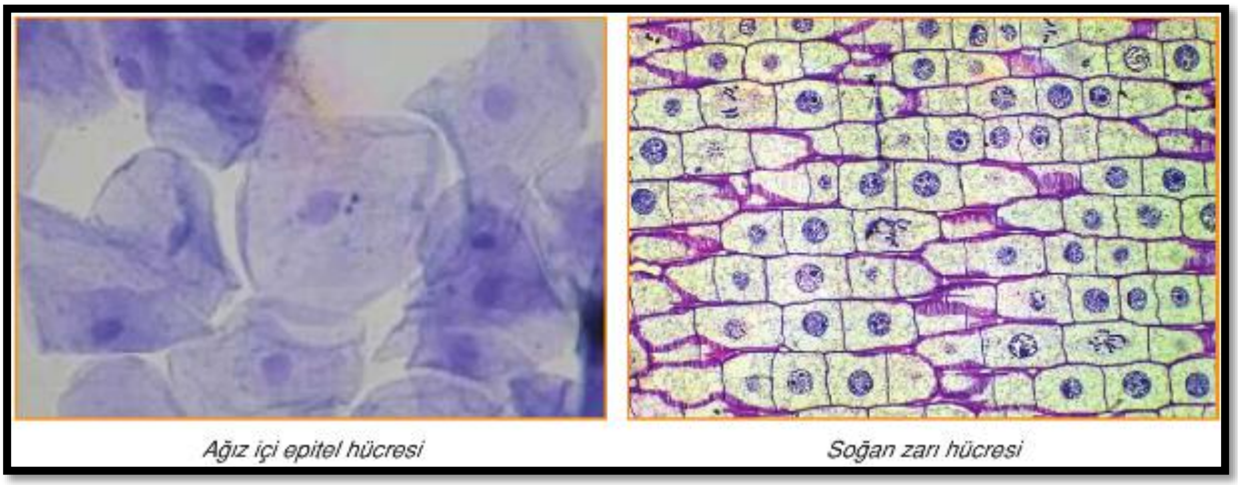
1. Arka plan: Kalabalık bir orman görüntüsü. 2. Ağaç: Ormana yakınlaşınca görülecek olan ağaç 3. Yaprak: Ağaca yaklaşılınca görünecek yaprak 4. Yaprak Kesiti: Öğrenci elindeki mikroskobu yaprağın üzerine koyunca görünecek olan yaprak kesiti

3. Ekrana, Ekran 2'deki gibi bir orman görüntüsü gelir. **Sesli yönerge:** "Bir ormana uzaktan bakıldığında yeşil bir topluluk görünür. Ormana yaklaştıkça, ormanda pek çok ağacın olduğunu fark ederiz. Ağaçlara yaklaştığımızda yapraklarını görmeye başlarız. İyice yaklaştığımızda yaprakların ayrıntılarını rahatlıkla görebiliriz. Uzaktan fark edemediğimiz ayrıntıları görebilmemiz için onları daha yakından incelememiz gerekir. Sence yaprağa, daha fazla ne kadar yaklaşılabilir? Sence yaprakları oluşturan daha küçük yapılar var mıdır? Bu yapıları, çıplak gözle görebilmemiz mümkün müdür? Büyüteçle bakmaya çalıştığımızda tüm yapıları görebilir miyiz? Sesli ve yazı yönerge: "Haydi büyüteç ile biraz daha yakından bakalım! Ekrana yaprak geldiğinde sana verilen büyüteci yaprağın üzerine bir kez dokundurman yeterli." Büyüteçle bakmaya çalıştığında tüm yapıları görebildin mi? Hayır! Çünkü tüm ayrıntıları gösteren başka bir araca ihtiyacın var. "
4. Robot yeniden ekrana gelir. Mikroskop görünsün ve sesli yönerge' Bu bir mikroskop. Hücre gibi çok küçük yapıları, ancak mikroskop ile görebiliriz. **Sesli yönerge:** "Haydi mikroskop ile yaprağa daha çok yaklaşalım! Ekrana yaprak geldiğinde sana verilen mikroskobu yaprağın üzerine bir kez dokundurman yeterli."
5. **Sesli ve Yazılı Yönerge:** "Bu gördüğün bir hücre**. Hücre,** canlıların yaşam özelliklerinin gerçekleştiği en küçük yapı birimidir." **Sesli Yönerge**: "Çevremizde gördüğümüz tüm canlılar hücrelerden meydana gelir. Doğada, yaşamlarını tek bir hücre olarak sürdüren *bir hücreli* canlılar ve çok sayıda hücreden meydana gelmiş *çok hücreli* canlılar vardır. Gözle görebildiğimiz tüm canlılar çok hücreli canlılara örnektir. *İnsan, kedi, kurbağa, ağaç, elma, inek, muz, havuç* [ekrana bu canlılar gelecektir] gibi canlılar çok hücrelidir. Çok hücreli canlıları oluşturan hücreleri görebiliyor musun? Biraz önceki ağaç örneğinde olduğu gibi çok hücreli canlıların hücrelerini ancak mikroskopla görebilirsin. Şimdi birlikte hayvan ve bitki hücrelerini incelemek için deney yapalım. 5. sınıf Fen Bilimleri dersinde canlıları; hayvanlar, bitkiler, mantarlar ve mikroskobik canlılar olarak sınıflandırdığımızı [Ekrana kavram haritası gelecektir] hatırla. Bu sınıflandırmaya göre "insan", hayvan sınıfında yer

alıyordu. Bu nedenle, deneyimizde ağız içinden alınan epitel hücreyi hayvan hücresi olarak ve soğan hücresini ise bitki hücresi olarak inceleyeceğiz [ekrana insan ve soğan görselleri gelecektir] “

6. Robot yeniden ekrana gelir. **Sesli yönerge:** “Haydi, mikroskobunla önce bitki sonra hayvan hücrelerini incele!” Önce bitki hücresi lamelin içinde gelir. Öğrenciden, mikroskobu bitki hücresine dokundurması istenir. **Sesli ve yazılı yönerge:** “Mikroskobunu bitki hücresine dokundur!”. Daha sonra hayvan hücresi gelir. Öğrenciden, mikroskobu hayvan hücresine dokundurması istenir. **Sesli ve yazılı yönerge:** “Mikroskobunu hayvan hücresine dokundur!”.

Mikroskobunu dokundurduğunda aşağıdaki hücreleri görecektir:



7. **Sesli ve yazılı yönerge:** “Bitki ve hayvan hücrelerini gördün. Bitki ve hayvan hücrelerinin, ilk gözlemlenen farkı şekilleridir. Bitki hücreleri, köşeli yapıya sahiptir [Ekranda bulunan soğan hücresinin köşeli yapısı vurgulanır]. Hayvan hücreleri ise yuvarlak ve oval yapıdadır [Ekranda bulunan ağız içi epitel hücresinin yuvarlak ve oval yapısı vurgulanır]. “

    Alıştırma 1: Sesli ve yazılı yönerge:” Haydi alıştırma yapalım! Bitki hücresini ekrana dokundurur musun? (şekline dikkat ederek). Hayvan hücresini ekrana dokundur!”

    Robot ekrana gelir. Doğru yaparsa olumlu seslerden biri, yanlış yaparsa olumsuz ses gelecek.

8. **Robot ekrana gelir. Sesli ve yazılı yönerge:** “Biçim ve görev farklılıklarına rağmen tüm hücrelerde üç temel yapı vardır. Bu yapılar dıştan içe doğru *hücre zarı, sitoplazma* ve *çekirdek*tir. Bu temel yapıları görmek için yapman gereken sana verilen hücre zarı, çekirdek ve sitoplazma modellerini söylenen sırayla ekrana dokundurmak!”
9. **Robot ekrana gelir. Sesli ve yazılı yönerge:** “Hücre zarını ekrana dokundur!” Ekrana hücre zarının görseli gelir. **Sesli ve Yazılı Yönerge:**” **Hücre zarı:** Hücreyi dış ortamdan ayırarak ona şekil ve dayanıklılık verir. Hücre zarı canlı, esnek, seçici geçirgendir. Yani gerekli olan maddelerin hücre içine girmesine, zararlı olan maddelerin hücreden uzaklaştırılmasını sağlar.”

Alıştırma 2: Robot ekrana gelir. **Sesli ve yazılı yönerge:**” Elindeki modellerden “Hücreyi dış ortamdan ayırarak ona şekil ve dayanıklılık veren modeli ekrana dokundurur musun? ” “

Doğru yaparsa olumlu seslerden biri, yanlış yaparsa olumsuz ses gelecek.

10. **Robot ekrana gelir. Sesli ve yazılı yönerge:** “Sitoplazmayı ekrana dokundur!” Ekrana sitoplazmanın görseli gelir. **Sesli ve Yazılı Yönerge:**” **Sitoplazma:** Çekirdek ile hücre zarı arasını dolduran, yumurta akı kıvamında, yarı akışkan, içinde hücrede görev alan çeşitli organellerin bulunduğu yapıdır. Sitoplazmanın büyük bir kısmı sudan oluşur. Sitoplazmada solunum, boşaltım, sindirim gibi yaşamsal olaylar gerçekleşir. “

    Alıştırma 3: Robot ekrana gelir. Sesli ve yazılı yönerge:” Elindeki modellerden “Çekirdek ile hücre zarı arasını dolduran, yumurta akı kıvamında, yarı akışkan, içinde hücrede görev alan çeşitli organellerin bulunduğu yapının modelini ekrana dokundurur musun? ”

    Doğru yaparsa olumlu seslerden biri, yanlış yaparsa olumsuz ses gelecek.
11. **Robot ekrana gelir. Sesli ve yazılı yönerge:** “Çekirdeği ekrana dokundur!” Ekrana çekirdek görseli gelir. **Sesli ve Yazılı Yönerge:**” **Çekirdek:** Hücrenin yönetim merkezidir. Hücrede gerçekleşen tüm yaşamsal olayları düzenler ve yönetir. Çekirdek üzerinde çekirdek zarı ve çekirdek gözenekleri (por) bulunur.”

Alıştırma 4: Robot ekrana gelir. **Sesli ve yazılı yönerge:**” Elindeki modellerden “Hücrede gerçekleşen tüm yaşamsal olayları düzenleyen ve hücreyi yöneten modeli ekrana dokundurur musun? ”

Doğru yaparsa olumlu seslerden biri, yanlış yaparsa olumsuz ses gelecek.

12. **Robot ekrana gelir. Sesli ve yazılı yönerge:** “Şimdi, bitki ve hayvan hücrelerinin nasıl çalıştığını görmek ister misin? Tüm hücrelerin sitoplazmasında hücrenin solunumu, beslenmesi ve boşaltımı gibi yaşamsal olayların gerçekleştiği organel adı verilen yapılar vardır. Bu organellerden bazıları hem hayvan hem de bitki hücresinde bulunur. Önce, bu organelleri tanımaya ne dersin? Yapman gereken sana verilen modelleri ekrana dokundurmak!“

13. Ekranın üst kısmında organellerin küçük resimleri sıralanmıştır. Öğrenci hangi organeli ekranda belirtilen yere dokundur bilgi alırsa o organel görseli üzerine yeşil onay işareti gelir.
    - **Sesli ve Yazılı Yönerge: GOLGİ CİSİMCİĞİ:** Salgı maddeleri üretir. Ayrıca salgıları, kesecikler şeklinde paketleyerek depolar.

    Alıştırma 5: Robot ekrana gelir. Sesli ve yazılı yönerge: “Salgı maddeleri üreten ve salgıları, kesecikler şeklinde paketleyen modeli ekrana dokundurur musun? ”

    Doğru yaparsa olumlu seslerden biri, yanlış yaparsa olumsuz ses gelecek.
    - **Sesli ve Yazılı Yönerge: RİBOZOM:** Protein sentezleme ile görevlidir. Endoplazmik retikulumların üzerinde, çekirdek zarında veya sitoplazmada serbest olarak bulunur.

Alıştırma 6: Robot ekrana gelir. Sesli ve yazılı yönerge: “Protein sentezleme ile görevli olan modeli ekrana dokundurur musun? ”

Doğru yaparsa olumlu seslerden biri, yanlış yaparsa olumsuz ses gelecek.

- **Sesli ve Yazılı Yönerge: LİZOZOM:** Hücredeki sindirimde görevlidir. Aynı zamanda yaşlanmış ve yıpranmış hücrelerin kendi kendisini sindirerek yok etmesini sağlar.

Alıştırma 7: Robot ekrana gelir. Sesli ve yazılı yönerge: "sindirimde görevli olan modeli ekrana dokundurur musun? "

Doğru yaparsa olumlu seslerden biri, yanlış yaparsa olumsuz ses gelecek.

- **Sesli ve Yazılı Yönerge: Ribozom:** Protein sentezleme ile görevlidir.

Alıştırma 8: Robot ekrana gelir. Sesli ve yazılı yönerge: "Protein sentezleme ile görevli olan modeli ekrana dokundurur musun? "

Doğru yaparsa olumlu seslerden biri, yanlış yaparsa olumsuz ses gelecek.

- **Sesli ve Yazılı Yönerge: MİTOKONDRİ:** Hücrelerin ihtiyacı olan enerjiyi üretir.

Alıştırma 9: Robot ekrana gelir. Sesli ve yazılı yönerge: "Enerji üreten modeli ekrana dokundurur musun? "

Doğru yaparsa olumlu seslerden biri, yanlış yaparsa olumsuz ses gelecek.

- **Sesli ve Yazılı Yönerge: ENDOPLAZMİK RETİKULUM:** Hücrede maddelerin taşınmasını sağlar. Hücre içini ağ gibi sararak yollar oluşturur.

Alıştırma 10: Robot ekrana gelir. Sesli ve yazılı yönerge: "Hücrede maddelerin taşınmasını sağlayan modeli ekrana dokundurur musun? "

Doğru yaparsa olumlu seslerden biri, yanlış yaparsa olumsuz ses gelecek.

- **Sesli ve Yazılı Yönerge: KOFUL:** Hücreye zarar verebilecek ya da fazla olan maddeleri depo eder. Bitki hücresinde az sayıda ve büyüktür. Hayvan hücresinde ise çok sayıda ve küçüktür.

Alıştırma 11: Robot ekrana gelir. Sesli ve yazılı yönerge: " Hücreye zarar verebilecek ya da fazla olan maddeleri depo eden, bitki hücresinde az sayıda ve büyük; hayvan hücresinde ise çok sayıda ve küçük olan modeli ekrana dokundurur musun? ”

Doğru yaparsa olumlu seslerden biri, yanlış yaparsa olumsuz ses gelecek.

14. **Robot ekrana gelir. Sesli ve yazılı yönerge:** “Bitki ve hayvan hücresinin en önemli farklarından biri bitki hücresinin şeklini veren hücre duvarına sahip olmasıdır. Şimdi sadece bitki hücresinde bulunan hücre duvarını ekrana dokundur!” Ekrana hücre duvarının görseli gelir. **Sesli ve Yazılı Yönerge:**” **Hücre duvarı:** Bitki hücrelerinde bulunur. Hücre zarını çevreleyen dayanıklı, sağlam ve cansız yapıdır. Hücreyi dış etkilere karşı korur.”

    Alıştırma 12: Robot ekrana gelir. **Sesli ve yazılı yönerge**:” Elindeki modellerden “Bitki hücrelerinde bulunan ve hücre zarını çevreleyen dayanıklı, sağlam ve cansız yapı modelini ekrana dokundurur musun? ”

    Doğru yaparsa olumlu seslerden biri, yanlış yaparsa olumsuz ses gelecek.
15. **Robot ekrana gelir. Sesli ve yazılı yönerge:** “Şimdi sadece bitki hücresinde bulunan kloroplastı tanıyalım. Kloroplastı ekrana dokundur!”

Sesli ve Yazılı Yönerge: “**Kloroplast:** Bitki hücresinde bulunan, hayvan hücresinde bulunmayan kloroplast, bitkinin besin ve oksijen üretmesini sağlar. Ayrıca yeşil renkli olduğu için bitkinin yeşil görünmesinin sağlar.”

Alıştırma 13: Robot ekrana gelir. **Sesli ve yazılı yönerge**:” “Bitki hücresinde bulunan, hayvan hücresinde bulunmayan, bitkinin besin ve oksijen üretmesini sağlayan modeli ekrana dokundur musun?” Doğru organeli dokundurur ise olumlu seslerden biri, yanlış yaparsa olumsuz ses gelecek.

16. **Robot ekrana gelir. Sesli ve yazılı yönerge:** “Şimdi sadece hayvan hücresinde bulunan sentriyolleri tanıyalım. Sentriyolleri ekrana dokundur!”

    Sesli ve Yazılı Yönerge: “**Sentriyoller:** Hayvan hücresinde çiftler hâlinde bulunurken bitki hücresinde yoktur. Hücrenin bölünmesinde görevlidir.”

    Alıştırma 14: Robot ekrana gelir. **Sesli ve yazılı yönerge**:” “Hayvan hücresinde çiftler hâlinde bulunurken bitki hücresinde bulunmayan ve hücrenin bölünmesinde görevli olan modeli ekrana dokundur musun?” Doğru organeli dokundurur ise olumlu seslerden biri, yanlış yaparsa olumsuz ses gelecek.

17. **Sesli ve Yazılı Yönerge:** "Bitki ve hayvan hücrelerinin özelliklerini ve organellerini öğrendin. Şimdi tekrar hatırlayalım. "Aşağıdaki tablo sırasıyla ekrana gelir. İçindekilerde sesli olarak da söylenir.

Bitki Hücresi	**Hayvan Hücresi**
Köşeli bir şekle sahiptir.	Oval bir şekle sahiptir.
Kloroplast bulunur.	Kloroplast bulunmaz.
Sentriyolleri yoktur.	Sentriyolleri vardır.
Hücre duvarı vardır.	Hücre duvarı yoktur.
Kofulları büyük ve az sayıdadır.	Kofulları küçük ve çok sayıdadır.

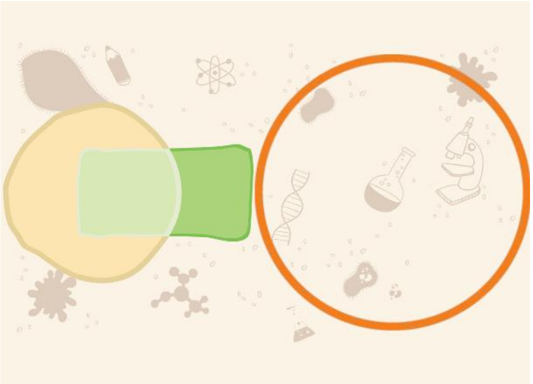
BÜTÜNCÜL ALIŞTIRMA

1. **Robot ekrana gelir. Sesli ve yazılı yönerge:** "Merhaba, ekranda hayvan ve bitki hücrelerinden oluşan venn şemasını görüyoruz [Venn şeması ekrana gelir]. Haydi, venn şemasını dolduralım. Önce ortak olan temel birimleri ve organelleri ekrana dokundur!"

Sesli ve yazılı yönerge: "Şimdi sadece hayvan hücresi bulunan organeli dokundur!"

Sesli ve yazılı yönerge: "Şimdi sadece bitki hücresi bulunan organeli ve temel birimi dokundur!"

(Aşama aşama önce ortaklar sonra hayvan sonra bitki sorulur.)



1. Hücre zarı	2. Hücre duvarı	3. Mitokondri
4. Koful	5. Endoplazmik retikulum	6. Golgi cisimciği
7. Ribozom	8. Lizozom	9. Sitoplazma
10. Çekirdek	11. Sentriyol	12. Kloroplast

ÖN TEST-SON TEST (22 Soru)

Sorular rastgele hem yazılı hem sözlü olarak ekrana gelecektir.

13. Hücreyi dış ortamdan ayırarak ona şekil ve dayanıklılık veren modeli ekrana dokundurur musun?
14. Hücrede gerçekleşen tüm yaşamsal olayları düzenleyen ve hücreyi yöneten modeli ekrana dokundurur musun?
15. Çekirdek ile hücre zarı arasını dolduran, yumurta akı kıvamında, yarı akışkan, içinde hücrede görev alan çeşitli organellerin bulunduğu yapının modelini ekrana dokundurur musun?
16. Salgı maddeleri üreten ve salgıları, kesecikler şeklinde paketleyen modeli ekrana dokundurur musun?
17. Protein sentezleme ile görevli olan modeli ekrana dokundurur musun?
18. Sindirimde görevli olan modeli ekrana dokundurur musun?
19. Enerji üreten modeli ekrana dokundurur musun?

20. Hücrede maddelerin taşınmasını sağlayan modeli ekrana dokundurur musun?
21. Hücreye zarar verebilecek ya da fazla olan maddeleri depo eden, bitki hücresinde az sayıda ve büyük; hayvan hücresinde ise çok sayıda ve küçük olan modeli ekrana dokundurur musun?
22. Bitki hücrelerinde bulunan ve hücre zarını çevreleyen dayanıklı, sağlam ve cansız yapı modelini ekrana dokundurur musun?
23. Bitki hücresinde bulunan, hayvan hücresinde bulunmayan, bitkinin besin ve oksijen üretmesini sağlayan modeli ekrana dokundur musun?
24. Hayvan hücresinde çiftler hâlinde bulunurken bitki hücresinde bulunmayan ve hücrenin bölünmesinde görevli olan modeli ekrana dokundur musun?

Şimdi eline hayvan ve bitki hücresi modellerini al, söylenen özellik hangi hücreye ait ise o hücreyi ekrana dokundur.

1. Köşeli bir şekle sahiptir.
2. Oval bir şekle sahiptir.
3. Kloroplast bulunur.
4. Kloroplast bulunmaz.
5. Sentriyolleri yoktur.
6. Sentriyolleri vardır.
7. Hücre duvarı vardır.
8. Hücre duvarı yoktur.
9. Kofulları büyük ve az sayıdadır.
10. Kofulları küçük ve çok sayıdadır.

Olumlu ses:

Harikasın!

Bravo!

Mükemmelsin!

İyi gidiyorsun devam et!

Mükemmel gidiyorsun devam et!

Doğru olanı buldun!

Bu bir hayvan hücresinin zarı

Bu bir bitki hücresinin zarı

Bu bir hücre duvarı

Bu bir mitokondri

Bu bir koful

Bu bir endoplazmik retikulum

Bu bir golgi cisimciği

Bu bir ribozom

Bu bir lizozom

Bu bir sitoplazma

Bu bir çekirdek

Bu bir sentriyol

Bu bir kloroplast

Olumsuz ses:

Daha dikkatli bakmalısın!

Bu bitki hücresinin zarı değil

Bu hücre duvarı değil

Bu mitokondri değil

Bu koful değil

Bu endoplazmik retikulum değil

Bu golgi cisimciği değil

Bu ribozom değil

Bu lizozom değil

Bu sitoplazma değil

Bu çekirdek değil

Bu sentriyol değil

Bu kloroplast değil

Bu bir kloroplast ve sadece bitki hücresinde bulunur, hayvan hücresinde bulunmaz

Bu bir sentriyol ve sadece hayvan hücresinde bulunur, bitki hücresinde bulunmaz

Bu bir hücre duvarı ve sadece bitki hücresinde bulunur, hayvan hücresinde bulunmaz

CURRICULUM VITAE

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EDUCATION

2013 - 2017 Middle East Technical University, Institute of Science, Computer Education and Instructional Technology, Ph.D.

2010 - 2013 Sakarya University, Institute of Educational Science, Computer Education and Instructional Technology

2006 - 2010 Yıldız Technical University, Faculty of Education, Department Of Computer Education and Instructional Technology, B.S. with highest honors in Computer Education and Instructional Technology Education

2002 - 2006 Atatürk Anatolian Vocational Girl's High School And Vocational High School, Kayseri, Department of Computer (with highest honors)

WORK EXPERIENCE

Year	**Place**	**Enrollment**
2012 November-present	Istanbul University Faculty of Education	Research Assistantship (RA)
2015 July-2015 September	New York University-CREATE LAB	Visiting Scholar
2010 November-2012 November	Bahçeşehir University	Research Assistantship (RA)
2010 September-2010 November	İstanbul University	Educational technologist-Instructional Designer

FOREIGN LANGUAGES

Advanced English

PROJECTS

April 2013 –April 2015	TUBITAK 1010 EVRENA Project. "The Role of Migration in School Engagement: The Effect of Social Capital, Psychological and Cultural Processes on High School Success" Position: Scholarship Student
June 2012 – June 2013	Sakarya University. BAP. "Reduction of Specific Learning Difficulties Through the Web-Based Adaptive System" Position: Researcher
May 2011- June 2012	TUBITAK 4004 Project "Changing Lives Through Technology" Position: Researcher/Specialist
September 2009- September 2010	Istanbul University. BAP. "Web 2.0 Project" Position: Assistant Researcher

PUBLICATIONS

SSCI

Polat, E., Adiguzel, T., & Akgun, O.E. (2012). Adaptive Web-assisted learning system for students with specific learning disabilities: A needs analysis study. Educational Sciences: Theory & Practice, 12(4), 3243-3258.

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