Effects of Design-Based Learning on Educational Outcomes

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Abstract

The purpose of this study was to determine the effects of technology-supported tools used in educational environments to support cognitive learning processes on educational outcomes in design-based learning environments. In this context, Academic Search Complete, Eric, Ulakbim, Google Scholar and CoHE search engines were scanned. Scans performed; Digital story, Game design (Kodu), Algorithm and programming (Scratch), 3D design (Tinkercad, 3D print), Mobile programming (AppInventor) and Embedded programming (microcontroller) arguments. As a result of the scanning, 164 studies were obtained. The papers accessed by researchers were examined by taking into consideration the inclusion and exclusion criteria. In this paper, motivation, attitude, achievement, class participation, metacognition and 21st century learning of design-based learning environments were examined in terms of dependent variables in studies used design based learning environments as a primary implementation context.

1. Introduction

Design-based learning (DBL) environments are environments that allow the individual to create their own cognitive processes according to their learning preferences, styles and skills (Doppelt, Mehalik, Schunn, Silk, & Krysinski, 2008). The most important feature of these environments is that the individual creates his / her own experiences with the active participation of the process. These environments are based on constructivist learning theory as it is based on the active participation of the individual. In the design of these environments, the constructivist learning theory offered; problem/project, related cases, information resources, cognitive tools, conversation/collaboration tools and social/contextual support steps to be implemented.

DBL also supports the transfer of cognitive information since it is based on learning through experience and a product is created at the end of the process. In order to ensure the transfer of cognitive knowledge to complex, new and real situations, students should be supported with cognitive tools (Jonassen, 1999). Cognitive tools can be in the form of hands-on activities or technology-supported. Use of technology-supported cognitive tools in learning environments are effective for development of academic achievement, critical thinking, problem solving, information literacy and collaboration skills (Jonassen & Reeves, 1996; Kim & Reeves, 2007). DBL environments have a positive effect on many learning outcomes due to active participation of learners in the design and development process, the development of a product, and the support of technology-supported cognitive tools. In this context, it is aimed to determine the effect of DBL environments by using different technology supported cognitive tools on educational outcomes.

1.1. The Importance of Usage Design-Based Learning in Education

Design-based learning (DBL) provides many different advantages in learning environments. Since DBL provides a relationship with the real life of the learners in structuring their knowledge, it enables the learners to be motivated against learning (Doppelt, 2003). The learners actively participates in these environments. When the learner actively participates in the learning process, the student makes sense of the new information by matching his / her knowledge with his / her existing experiences (Driscoll, 2005b). The DBL environments aim to learn with the experience advocated by constructivist learning theory. These experiences give students not only cognitive skills but also metacognitive skills such as self-esteem and personal responsibility (Waks, 1995).

DBL environments provide a learning environment in which instructor and learners have different roles traditional lecture based teaching. In lecture based teaching environments, the instructor has the role of actively giving information, and the learner has the role of passively receiving information. On the other hand, the DBL environments support a student's active participation in the learning process by providing opportunities to create products that ensure the development of cognitive strategies and processes. The design process of constructivist learning environments proposed by Jonassen (1999), as in constructivist learning theory, should be taken into consideration in DBL environments. This design process includes problem /project, related cases, information resources, cognitive tools, conversation/collaboration tools, social/contextual support.

In DBLs, learning process is supported by real life problems or project-based activities that provide experiences with the active participation of learners, facilitating and supervising the process of the teacher (Gómez Puente, van Eijck, &Jochems, 2013). In order to provide learning with experience in these environments, it is also necessary to transfer cognitive knowledge. In order to ensure the transfer of cognitive knowledge to complex, new and real situations, it is necessary to provide students with cognitive tools (Jonassen, 1999). Cognitive tools can be in the form of hands-on activities in these environments as well as technology-supported. Technology-supported learning environments have many contributions to the learning process.

The use of technology in teaching facilitates learning because it supports different types of learning in storing and remembering information in cognitive processes (Mayer & Moreno, 1998; Paivio, 1991). In addition, the presentation of technology-supported cognitive tools provides support for learning complex information and reduces cognitive load (Driscoll, 2005a). Use of technology-supported cognitive tools in educational settings; academic achievement is effective in the development of mental skills such as critical thinking, problem solving, information literacy and collaboration (Jonassen & Reeves, 1996; Kim & Reeves, 2007).

2.Research questions

The aim of this study is to determine the effect of DBL environments by using different technology supported cognitive tools on educational outcomes. Within the scope of this study, the research questions are as follows:

1. What are the effects of design-based learning environments on students';

a. motivation in different learning topics?
b. students' attitude in different learning topics?
c. achievement in different learning topics?
d. engagement in different learning topics?
e. metacognition in different learning topics?
f. 21st century skills in different learning topics?

3. Research method

This study was conducted as a literature review. For the review, Academic Search Complete, ERIC, Ulakbim, CoHE (Council of Higher Education) Thesis Center and Google scholar was used for searching articles.

3.1. Search terms and domains

In order to determine the effect of design-based learning on educational outcomes, searches were made in the databases using the topics and keywords in Table 1.

Table 1. Databases, research topics and keywords searched in literature.

Databases	Topics	Keywords used
Academic Search Complete ERIC Ulakbim CoHE(Council of higher education) Thesis Center Google scholar	Digital story	Digital storytelling Digital storytelling in education
	Game design (Kodu)	Game design with kodu Kodu in education
	Algorithm and programming (Scratch)	Programming with Scratch in education Scratch use in education Algorithm training with scratch
	3D design (tinkercad, 3D print)	Tinkercad use in education 3D print in education Sketchup use in education
	Mobile programming (AppInventor)	Mobile programming with AppInventor Mobile programming with AppInventor in education

	Embedded programming (micro controller)	Microcontroller in education Embedded programming with micro controller

3.2. Research selection criteria

As a result of the literature review, 164 studies have been reached in total in experimental and quasi-experimental studies written in Turkish and English languages, except for articles that are not allowed by the author and paid in other databases. If there are published articles of the studies carried out as master's or doctoral dissertations, this study has also been reviewed. These studies were examined by considering the inclusion and exclusion criterias in Table 2. Inclusion and exclusion criterias were determined by the researchers considering the characteristics of the DBL environments.

Table 2. Inclusion and exclusion criterias

Inclusion criterias	Exclusion criterias
Real world problem-based studies	Qualitative studies.
Project based studies	Opinion studies.
Active participation of students	Instructional studies with media developed by the instructor.
Experimental and quasi-experimental studies	Educational estimates of the applications prepared with tools.
Applications for all age groups	Instructional design studies.
At the end of the teaching, the student put forward a product	Literature reviews.
Quantitative dimension of mixed research	Development studies.
Formative research.	
Experience studies.	
Presentation studies.	
Study recommendations.	

As a result of the investigations, it was seen that 39 out of 164 studies examined the effects on educational outcomes in DBL environments. The design-based researches examined in detail; 12 of them are in digital story, 2 of them are in game design with code, 13 of them are in algorithm and programming with Scratch, 3 of them are in 3D design with tinkercad or 3D print, 5 of them are in mobile programming with AppInventor, 4 of them are in embedded programming with micro controllers.

3.3. Design based learning researches examined as a result of selection criteria

The studies on the effect of DBL environments on educational outcomes were examined under the headings of research type, research aim, research method, independent variable, dependent variable, data collection tools, participants and results. The design-based research studies in the literature were further investigated based on their results to answer current study's research questions.

4. Results and Discussion

The use of DBL environments in education has an impact on many educational outcomes. Design-based learning enables learners' motivation, attitudes towards the course / material, academic achievement, active participation, metacognitive skills and 21st century skills.

4.1. Research question 1: What is the effect of design-based learning environments on students' motivation in different learning topics?

Motivation is one of the factors that should be considered in the design of instruction. In other words, the designer should design the instruction by taking the necessary measures to increase the motivation of the learners. Keeping the motivation of learners high is critical for a good instructional design (Martin, 1999). Different models are used in the design of instruction to take into account motivation. One of the most well-known models is the ARCS model. This model was proposed by Keller (1979). The model consists of four steps that should be considered in instructional design to ensure motivation (Keller, 1983, 1987). These steps; attention, relevance, confidence and satisfaction. The problem-based trainings, which are designed with ARCS model in DBL environments, contribute positively to students' motivation (Koshino et al., 2013).

Active participation of an individual in the process is highly effective in increasing an individual's motivation against the learning environment (McCombs & Whisler, 1997). As DBL environments are the environments where the learner actively participates, the learner motivation increases. The increase in motivation results in the researches is due to the active participation of the students by the researchers (Topalli & Cagiltay, 2018). The effect of motivation, which is one of the learning outcomes, on different media in the DBL environments was examined. It is seen that these tools increase motivation and increase success in DBL environments (Chun-Ming et al., 2012; Demirer, 2013; Erol & Kurt, 2017; Topalli & Cagiltay, 2018). There are also studies showing the opposite of this situation. Göçen (2014) concluded in her study that the achievement of the students increased but there was no change in their motivation. In this study, where students' achievements increased and they developed positive attitudes, it was thought that students did not give sincere answers to motivation data collection tools. Increasing motivation positively develops positive attitudes in DBL environments (Demirer, 2013; Göçen, 2014), metacognition skills such as time management, self-test (Göçen, 2014) and also contributes to the development problem-solving skills from 21st century skills (Chun-Ming et al., 2012).

4.2. Research question 2: What is the effect of design-based learning environments on students' attitude in different learning topics?

Attitude is the cognitive and emotional preparation that has the power of influencing and directing the behaviors towards all objects, events and situations of interest that are formed as a result of an individual's life and experiences (Alport, 1935). Attitudes in learning environments are influenced by individual's life, knowledge level, interests, reinforcers, imitations and social learning. The presence of attitude can be explained as a result of the measurement and observation of cognitive thinking process, emotions and behaviors (Inceoglu, 1993). An individual's positive attitude towards the learning environment will facilitate learning, motivation, and acquiring metacognitive or 21st century skills in order to increase student success.

DBL environments enable students to develop positive attitudes towards technology-based cognitive tools, learning topics, and product discovery processes. When the researches were examined, it was seen that students developed positive attitudes towards the cognitive tools of AppInventor (Dabney et al., 2013), digital story (photo story 3) (Heo, 2009) and Scratch (Chiang & Qin, 2018). In addition to cognitive tools, students show positive attitudes towards the subjects they want to learn by actively participating in the learning process (Ke, 2014; Wang et al., 2017). DBL environments also enable students to demonstrate positive attitudes towards writing skills by creating scenarios as a result of the use of digital storytelling tools (Baki, 2015). It is seen that the studies on the attitude of DBL environments on attitude are incomplete in terms of Kodu game design, 3D design and microcontrollers and embedded programming. Experimental researches that will examine the effect of these areas on attitudes in DBL environments will guide educators for future uses.

4.3. Research question 3: What is the effect of design-based learning environments on students' achievement in different learning topics?

Success is one of the most frequently used dependent variables, which are used in most scientific researches and the effects of different teaching methods are examined. Success refers to the degree of ownership of the knowledge, skills and abilities that are desired to be acquired. Achievement results are one of the main variables that indicate whether a designed instruction is effective or not. The effectiveness of a teaching results from the level of achievement of the desired learning objectives. While preparing learning objectives, it is considered which theory will be developed based on which theory. These theories argue that success is affected by many different factors in learning environments. In learning environments; behavioral learning theory argues that success is influenced by environmental factors (Driscoll, 2005c), cognitive learning theory is influenced by factors in the process of information processing (Driscoll, 2005a), and constructivist learning theory is influenced by the individual's development, experiences and sociocultural structure (Jonassen, 1999).

Success depends on the performance of the learner. The lower the difference between the existing situation and the desired situation in human performances, the higher the success (Van Tiem, Moseley, & Dessing's, 2000). Human performance; organization system (instructional design), incentives (reward, reinforcement etc.), cognitive support (modeling, coaching, building scaffolding), tools (cognitive tools, technology supported tools), physical environment (classroom environment), lack of knowledge / skills, natural / hereditary (intelligence, physical features) capabilities are affected by internal and external factors (Wile, 1996).

It is essential for the individual to gain experience in DBL environments. Therefore, in these environments, active learning of the learner is ensured and practical learning is provided. Success levels vary depending on the learner's active participation. Students' achievement can be increased by using different technology supported cognitive tools in DBL environments. In the studies, it is seen that Scratch (Su et al., 2014) and 3D printing (Dahle & Rasel, 2016), one of the technology-supported learning tools used in DBL environments, increase student achievement compared to the environments where teaching strategy is used with traditional presentation. In addition to these studies, there are studies comparing the effect of different technology supported cognitive tools on success. Omar (2018) examined the impact of microcontrollers, Scratch tools and programming success in traditional environments. As a result of the study, it was observed that students using microcontrollers were more successful than Scratch users and the traditional learning group was the lowest. Korkmaz (2018) also compared Scratch and Lego Mindstorms Ev3 applications and concluded that Lego Mindstorms Ev3 contributes more to success. In addition, AppInventor (Papadakis et al., 2016) and digital stories (Büyükcengiz, 2017; Chun-Ming et al., 2012; Demirer, 2013; Göçen, 2014; Sancar-Tokmak & Incikabi, 2013) also has a positive effect on success. Students' positive attitude towards the course or application (Cetin, 2016; Chiang & Qin, 2018; Korkmaz, 2016; Lewis, 2011) and high levels of satisfaction (Chen et al., 2016) are among the factors affecting success. Collaboration in DBL environments also increases the success of individuals because it enables peer learning (Lewis, 2011).

4.4. Research question 4: What is the effect of design-based learning environments on students' engagement in different learning topics?

Participation is the inclusion of the student in the learning processes. In a learning environment, if the course is considered important by the student and falls within the student's interest, the student makes an effort to make more effort, ie to participate more (De Volder & Lens, 1982; Miller, Greene, Montalvo, Ravindran, & Nichols, 1996; Wigfield & Eccles, 2000). Therefore, providing motivation in learning environments is an important factor for participation (Skinner & Belmont, 1993). In learning environments, many technology-supported cognitive tools can be used in order to attract students' interest and to ensure their participation. Considering the students' tendency to technology, it is possible to create the necessary interest for participation with technological tools. DBL environments provide learning environments where students' participation is actively provided. At the same time, the use of technology-supported cognitive tools in students' activities / product discovery processes is also provided by the DBL environments.

As a result of the research studies conducted on the effect of DBL environments on educational outcomes, it was concluded that active participation is seen as the main element in all researches. Providing active participation in these environments plays an active role in the development of students' achievement (Su et al., 2014; Topalli & Cagiltay, 2018), motivation (Chang et al., 2017; Chun-Ming et al., 2012), positive attitude (Dabney et al., 2013; Wang et al., 2017), and development of metacognitive skills (Dere, 2017; Saritepeci, 2017) and 21st century skills (Akcaoglu & Koehler, 2014; Pellas & Vosinakis, 2018; Roscoe et al., 2014). In the researches, the effects of active participation among the effects of DBL environments on educational outcomes were not examined. The reason for this is thought to be due to the active participation of one of the main characteristics of the DBL environments. Participation in DBL environments positively affects the achievement of students of different learning levels (primary, secondary, high school and higher education). The use of different technology supported cognitive tools in these environments also plays a major role in ensuring participation. It was concluded that digital story creation tools (storyboardthat, powtoon, photo story), Scratch, AppInventor, Kodu, Microcontrollers, 3D printing and Tinkercad tools that were examined in the scope of this study had an effect on students' active participation and different learning outcomes.

4.5. Research question 5: What is the effect of design-based learning environments on students' metacognition in different learning topics?

Metacognition is defined as thinking of thinking. Metacognition in Turkish literature; executive cognition, metacognition, cognitive awareness. Metacognition is the awareness and control of an individual's own knowing processes (Huitt, 1997). Metacognition in learning environments is important in terms of contributing to the individual in terms of language development, self-control, writing, memory and problem solving skills, knowing which areas an individual is missing, and what his or her own experiences are in order to ensure permanence in learning (Flavell, 1979). In order to have metacognition, metacognitive knowledge and metacognitive skills are required. In order to have metacognition information, one has to know what he / she believes in, the state of the current knowledge and what kind of cognitive activities will be operated (Flavell, 1979). Metacognition skills are planning, observation, testing, correction, selection and evaluation of specific strategies (Brown, Armbruster, & Baker, 1986).

DBL environments enable students to operate their learning processes by being informed about their own learning with active participation. In these environments, students are able to organize their time management skills and cognitive knowledge as they seek solutions to problems in a limited time (Göçen, 2014). Furthermore, Göçen (2014) also states that in addition to time management, students contribute to metacognitive skills in terms of processing information, selecting main ideas, identifying study assistants, and self-testing and developing test strategies. Self-assessment and self-efficacy knowledge, which is one of the metacognition skills, is supported by DBL environments (Baki, 2015; Heo, 2009; Korkmaz, 2016; Liu et al., 2013). In the teaching of programming in DBL environments, the student develops his / her planning and organizing skills by providing information to the students about how they can structure information and develop information processing thinking skills. In addition, the product development process allows the individual to test, correct, select and evaluate specific strategies.

4.6. Research question 6: What is the effect of design-based learning environments on students' 21st century skills in different learning topics?

In line with the developing technology and changing learning needs, the skills required for the learners today are called 21st century skills. Individuals must have 21st century skills to become well-educated citizens (Wangenheim, Alves, Rodrigues, & Hauck, 2017). 21st century skills include the skills, education, attitudes and mental habits that today's students must have in order to find work in the future. In the study conducted by Sarıer (2010) using PISA data, it was concluded that the scores obtained from the exams conducted by OSYM in Turkey do not have any relation with academic achievement. In other words, although students are academically successful, they fail the exams. Sarıer (2010) thinks that this situation stems from the fact that the educational environments in Turkey are teacher-centered and the student is a passive listener. In line with this idea, it can be said that the students have memorized the information about their courses and forgot after some time after internalization and transfer. 21st century skills need to be developed to prevent such situations, to make students aware of their own learning, and to ensure transfer and persistence. 21st century skills are grouped under three main headings: learning and innovation skills, life and career skills, and information, media and technology skills, as shown in Figure 1 (Trilling & Fadel, 2009). The 11 skills collected under these headings are called the 21st century skills.

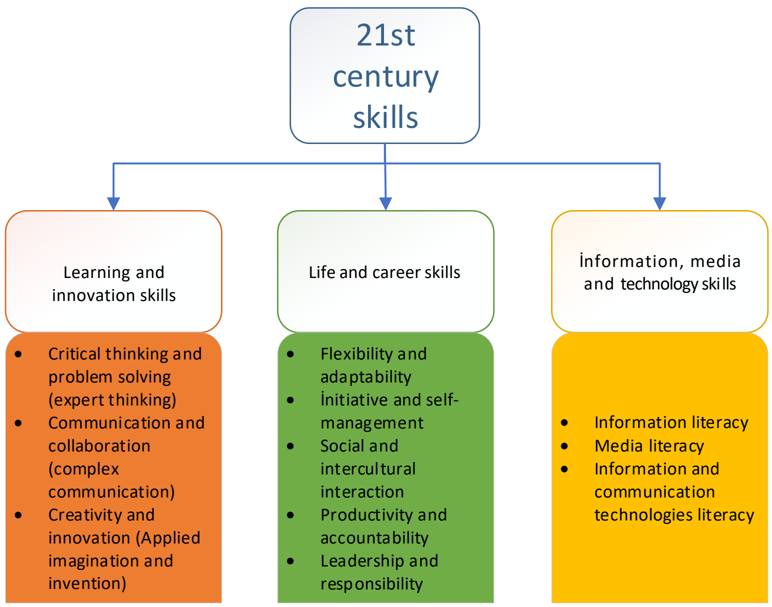

Figure 1. 21st century skills

21st century skills can be learned through problems and questions in learning environments (Trilling & Fadel, 2009). Small groups cooperative learning method, project-based learning method, problem-based learning method and DBL methods can be used in developing 21st century skills in learning environments (Bellanca, 2010; Rotherham & Willingham, 2009; Trilling & Fadel, 2009). As DBL environments provide project / problem-based learning and students are guided by the teacher during the learning process, they are one of the ideal learning environments in teaching these skills. These environments enable students to acquire learning and innovation skills, life and career skills, and information, media and technology skills.

Critical thinking, problem solving, communication and creativity skills of learning and innovation skills in DBL environments were discussed in the studies examined. Critical thinking is the ability to make explanatory and evaluative information judgments in order to decide how to behave, what to believe, and to express these information judgments verbally (Evancho, 2000). Students can make information judgments and express them with their practices in DBL environments. In this way, students' critical thinking skills are developed (Chung, 2007; Emert, 2013; Pellas & Vosinakis, 2018; Wang et al., 2017). Problem solving skills can be defined as the ability of the student to produce solutions to new problems encountered by using existing knowledge. Researches examining the effect of DBL environments on educational outcomes, it is seen that problem solving skills can be increased by means of cognitive technology supported tools (Akcaoglu, 2014; Akcaoglu & Koehler, 2014; Chun-Ming et al., 2012; Korkmaz, 2018; Kwon et al., 2012; Pellas & Vosinakis, 2018; Vatansever & Göktalay, 2018).Communication skill is the characteristic that an individual should have in order to express his / her thoughts clearly and to take part in group works. It is ensured that students' communication skills are improved through collaborative studies in DBL environments (Moreillon & Hall, 2014). The ability to creative thinking can be defined as the use of existing or new information to bring different perspectives, innovations and unconventional thoughts to different situations. (Bentley & Yıldırım, 2004). In DBL environments, students learn from their own experience, which is a requirement of constructivist learning theories. As each student's life will vary, their learning will also differ. In this learning, it is influenced by the creative ability of the students to propose solutions to the problems faced by individuals by using different tools, different scenarios, different products and different algorithms. In these environments, students develop creative thinking skills while developing products with problem-based technology-supported tools (Emert, 2013; Pellas & Vosinakis, 2018).

In the experimental and quasi-experimental studies on design-based learning environments, there is no direct research that measures life and career skills. However, studies also asserted that students can develop self-management and entrepreneurship skills through developing games (Kafai & Burke, 2015), and increase their social skills by interacting teachers and peers through collaboration activities. Also; Lewis (2011), in his research, argued that productivity could be higher than students' single work. In addition, students gain leadership skills in group work. In all of the researches, students have the responsibility skills since they develop a solution for a problem / have their own projects.

The DBL environments also contribute positively to the 21st century skills of information literacy, media literacy and information and communication technologies literacy skills. These environments contribute to information literacy through the development of reflective thinking and writing skills (Baki, 2015; Çıralı, 2014). Computational thinking skills can be defined as system design with the use of computer sciences, problem solving and revealing human behaviors (Wing, 2006). Students' computational thinking skills can be improved with the use of computer-aided tools in DBL environments (Büyükcengiz, 2017; Morelli et al., 2011; Roscoe et al., 2014).

5. Conclusions

As a result of the current study, it was concluded that DBL environments have a positive impact on many learning outcomes. However, it was observed that some learning outcomes were not included in the examined studies. In the literature, there is no experimental research about flexibility and adaptability, assertiveness and self-management, social and intercultural interaction, productivity and accountability, leadership and responsibility skills. Similarly, DBL environments have been interpreted as enabling metacognitive skills of practice, feedback and evaluation, but experimental studies are not included. In future studies, the effects of different technology supported cognitive tools not included in the research can be examined. In addition, the number of experimental and quasi-experimental studies in which different independent variables were examined was found to be low. In the same way, the number of samples was observed to be low. Increasing the number of studies and sample numbers will increase the effect size. In the studies, it was observed that evaluations were made frequently with questionnaires, success tests and scales. In the literature, very few findings have been encountered for the evaluation of the products developed by the students. Since these products are thought to have a major impact on learning outcomes, they should not be ignored in future studies.

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