Educational Technology International
2019, Vol. 20, No. 1, 83-107

Applying design thinking to the educational problems: A student-centered instructional approach and practice in an undergraduate course

Hyunjin CHA*
Dankook University
Korea

The aim of this study is to provide the values and descriptive implications of the Design Thinking (DT) method into the context of educational problems of practice in an undergraduate course. To achieve the research objective, both quantitative and qualitative studies were conducted. For the qualitative study, the student's productions and reflections on the experience of the application of the DT into educational problems were analyzed. For the quantitative research, one-group pre and post-test were designed to validate the effectiveness of the DT method into educational contexts in terms of creativity level to measure the student's Creativity Potential and Practiced Creativity, Academic Self-Efficacy Scale, and Problem-Solving Inventory. This study validated that the DT method had a statistically significant influence on those three competencies and also illustrated the detailed process from a qualitative viewpoint. The results and implications reflect the potential of the DT approach with the educational problem of practice, especially, in the ill-structured problem-solving contexts for student-centered instructional setting.

Keywords : Design Thinking; educational problems; student-centered instruction; Creativity; problem-solving

* lois6934@hanmail.net

Introduction

In recent days, interest in Design Thinking (hereafter DT) is progressively and broadly increasing in diverse disciplines including education as well as business and design contexts for both academics and practitioners (Engberts & Borgman, 2018; Wrigley & Straker, 2017). However, it is not a new approach, but a more integrative method from multi-disciplinary knowledge that combine divergent and convergent thinking into an iterative process (Henriksen, Richardson, Mehta, 2017).

The DT approach can be defined as a process to foster active engagement on creative thinking and problem-solving, and to conduct a full spectrum of innovative activities with a human-centered design mind-set (Carroll, Goldman, Britos, Koh, Royalty & Hornstein, 2010; Sweat, Blythe, Carpenter, 2017). The DT approach suggests a well-defined process and framework for creating innovative ideas and solving human problems by finding their needs. Simon (1969)'s DT model which influenced forming current design thinking approaches contains seven major phases. The d.school's model at the Hasso-Plattner Institute of Design at Stanford University (https://dschool.stanford.edu/) consisted of five stages. Even if the phases are slightly varied in use with different numbers ranging from three to seven depending on contexts, they have similar conceptual foundations on the same principles featured in Simon's first model (Dam & Siang, 2018; Sweat et al., 2017). The key components of DT consisted of three aspects: human-centered, action-oriented, and mindful process. The DT approach emphasizes hands-on projects by exploring authentic problems through empathy and making feasible prototypes through creative ideation. The activities, learning by doing, coincides with the theoretical foundations from the socio-cognitive viewpoint of learning which claims that cognitive development can be achieved by interacting with peers and constructing their own learning experience in social environments (Carroll et al., 2010).

In fact, educational problems are getting more complicated, diverse,

contextualized into multidisciplinary situations. Henriksen et al. (2017) defined such educational problems as a "problem of practice (p. 142)" in education. From this context, designing creative solutions around educational problems of practice is one of the critical competencies that are required in a current 21st century learning context. The educational paradigm has changed from producing experts who can find correct answers to the structured formula to developing human resources who can solve complicated problems with creative ideas (Carroll et al., 2010). The DT is one of the instructional approaches to strengthen such competences as creativity, divergent and convergent thinking skills, and problem-solving skills. The DT approach can provide learners with a concrete framework that can be applied to promote key competencies for 21st century (Noel & Liub, 2016). In this respect, this paper begins with a discussion of DT in relation to a new competency for learners to prepare as a future human resource.

Even if the necessity of the DT approach into educational curriculum has increased, there are few references and best practices related to its applications and experiences in higher education (Sweat et al., 2017). The context of this paper focuses on an undergraduate course, whose learning objective is to solve 'wicked' problems for diverse learners in learning environments. The aim of this study is to provide the values and descriptive implications of the DT method into the context of the educational problems of practice in an undergraduate course.

Design thinking and a new way of learning method

DT can be defined as a method of how designers apply cognitive process into so-called 'wicked' problems (Brown, 2008; Buchanan, 1992; Cross, 2011). 'Wicked' characterizes ill-structured problems with no definite formulation (Buchanan, 1992). In this context, design has a broader meaning utilized in diverse disciplines, including art, science, and business (Pendleton-Jullian, & Brown, 2015). One of the

reasons why DT has manifested in different disciplines is that it is known as an approach to lead innovative ideas and solve problems in a more creative way. The evidence from previous research and practices demonstrate the effectiveness of new ways of thinking and value creation with innovation (Calonge & Safiullin, 2015; Noel & Liub, 2016; Henriksen et al., 2017). Most evidence on the best practices of DT comes from design and business sectors. However, recently, it has been applied into multi-faceted and cross-disciplinary problems as the popularity and significance of DT has spread widely (Oh & Nah, 2014).

DT is a user-oriented approach and research (Kim & Ryu, 2014; SAP, 2012). The origin of DT can be found from IDEO, a global design business company and d.School at Stanford University. In other words, it can be argued that the root of DT lies in both practical and academic perspectives. It also has been flexibly and dynamically evolving through different practical and academic applications. Therefore, different DT models and processes have been proposed depending on the context and application since the design steps and stages are not static and linear, but circular and iterative (Oh & Nah, 2014). For example, the process from the d.School, at Stanford University, is a more elaborative version, consisting of six steps. Brown (2008), the CEO of IDEO, suggested more simplistic three steps of DT version. However, these different DT models have common attributes: Start with problems, Ideate through both divergent and convergent thinking, Test with prototypes, and Iterative evaluations (Oh & Nah, 2014; SAP, 2012; Henriksena et al., 2017). One of the main advantages of DT compared with the traditional design process is the iteration among analytical thinking, divergent thinking, and convergent thinking with intuitive insight (Martin, 2009; Oh & Nah, 2014). In addition, it makes more possible integration from diverse points of view through iterative processes.

The coordination for integrative disciplines to complement the arts and sciences has become one of the crucial themes of effective and efficient life, as the development of information communication and technology (ICT) influences all

facets of human life (Buchanan, 1992). In fact, the human resources required in a current society are people who develop key competencies which lead to succeed in life and work for the 21st century (Trilling & Fadel, 2009). The key competencies include problem-solving skills and creativity with collaboration. Brown (2008) also emphasized that companies and stakeholders would require their employees to create and innovate ideas in order to make new forms of value by fulfilling user's needs and desires. It means that society needs human resources to develop significant innovations by solving user's 'wicked' problems. Therefore, the education sector should also follow such a new paradigm shift by finding a new way of learning processes and instructional strategies (Gulbahar & Tinmaz, 2006; Sweat et al., 2017).

In fact, in a recent year, to develop human resources with such crucial competencies for 21st century, student-centeredness such as problem-based learning, project-based learning, flipped classrooms, etc. have been gradually emphasized. Among such student-centered approaches, the problem-based learning have very similar strategies to the DT in terms of providing students with opportunities to solve authentic problems in a complicated context (Hmelo-Silver, 2004; Bell, 2010). However, in the problem-based learning, the ill-structured problem and contexts should be earlier defined by the instructor. Furthermore, the problem-based approach more focused on learning information and reasoning strategies within the prescribed steps of identifying facts, generating ideas and learning issues with reflections (Hmelo-Silver, 2004). Project-based learning also have common concepts with DT, for instance, approaching from multi-disciplinary viewpoints, producing products, solving real-world problems on the authentic settings (Larmer, 2014). However, project-based learning follows quite various steps and processes depending on the project context.

Compared with PBLs, the DT approach emphasizes the empathy and iteration of evaluation from the human-centered perspective through the coordination of divergent and convergent thinking. Such strategies can lead to dealing with the

problem in a more innovative way (Carroll et al., 2010; Stokholm, 2014). As educational problems of practice become more complicated, DT skills also become one of the crucial competencies in teaching and learning as Pendleton-Jullian and Brown (2015) asserted. In the previous research relate to DT, Henriksen et al. (2017) described how teachers creatively dealt with problems in educational practice and provided implications on adopting DT into teacher's education programs by conducting in-depth qualitative analysis of an illustrative example. Noel and Liub (2016) also applied DT into elementary level children to improve engagement and successful learning experiences. They validated the use of DT in the elementary context and illustrated the new education paradigm and methods for elementary levels, especially, in terms of the key competencies for 21st century. Through literature review, they emphasized positive impacts of the design thinking on the primary student's education such as empathizing, collaborating, improving human-centeredness and creativity through iterative prototyping and testing. At the middle-school level, Carroll et al. (2010) conducted the 'Taking Design Thinking to Schools Research Project' to extend the knowledge and skills about the role of design thinking into 7th grade class of 24 students in a semi-urban setting and proved the effects of connection between academic standards (contents) and DT. They described a rich case of how the DT became empowered agents in secondary student's learning by offering tools and the confidence to innovate the world from three major themes: design as exploring, connecting, and intersecting. They demonstrated that DT made students' learning in situated and impactful by exploring the design, promoted creative affect and confidence by connecting in collaborative teams, and integrated the contents into a challenging process by intersecting between DT tools and subject contents. Calonge and Safiullin (2015) demonstrated how the disciplinary and educationally diverse team using a DT approach conducted a project for the purpose of productivity and creativity enhancement. They proved that various dimensions of diversity such as multi-cultural, multi-disciplinary, and multi-leveled diversity have slightly more

influence on team productivity and creativity.

In this paper, one complex and ill-structured educational problem as a wicked problem (Buchanan, 1992) will be contextualized in an educational context as a case study to demonstrate how DT might be effective in solving such a wicked problem. Exemplified in an undergraduate course for an educational technology department, this paper conducted both quantitative and qualitative research to prove the effectiveness on the case study.

Methodologies

This study aims to provide the values and descriptive implications of the DT method into the context of educational problems of practice from both quantitative and qualitative research approaches. The research questions are as follows:

1. How can the DT method be applied to the educational problems of practice?
2. How effective is the DT method for improving key competencies for 21st century such as creativity, self-efficacy and problem-solving competency?

Research Design and Data Collection

This paper conducted both quantitative and qualitative studies to explore the research questions mentioned above. First of all, the student's productions and reflections on the experience of learning about and using DT as part of their team projects were analyzed during the class. All the products from each step of the DT project were captured and recorded on a Korean commercial social network service website. At the end of every class over 5 weeks, group works were uploaded to the site that shared what each group completed during class. Then, the final presentation was conducted to explain their experiences and products from each step with reflection. Then, the individual reflection paper was gathered to write on

three main questions: ① Reflection on individual roles and effort ② Your opinion about how DT played a role in facilitating projects (effects of DT) ③ Difficulties you faced during the project.

Table 1. Instrument in a quantitative study

Instrument	Definition	Reference
Creativity potential and practiced creativity (CPPC)	Creative potential: creative capacity, skills and abilities that individual processes (p. 40) *- (sample) I feel that I am good at generating novel ideas.* Practiced creativity: perceived opportunity to utilize creativity skills and abilities (p. 40) *- (sample) My creative abilities are used to my full potential at study.*	Diliello & Houghton (2008)
Academic Self-Efficacy Scale (ASES)	Assessing individual beliefs of achievement in educational duties - Confidence *(sample) I could not speak the answer even if I knew the answer when a teacher asked a question.* - Self-regulatory efficacy (*sample) I study according to the plans I made in advance* - Task difficulty preference *(sample) I enjoy challenging and solving difficult and complicated problems.*	Kim & Park(2001)
Problem-Solving Inventory (PSI)	Assessing personal perceptions of the problem-solving process - Problem-solving confidence *(sample) I trust my ability to solve new and difficult problems* - Approach avoidance style *(sample) Even if I work on a problem, sometimes I feel like I am groping or wandering and am not getting down to the real issue.* - Personal control *(sample) I have a systematic method for comparing alternatives and making decisions.*	Heppner & Petersen, (1982)

Then, for the quantitative research, one-group pre and post-tests were designed to validate the effectiveness of the DT method into educational problems of practice in terms of creativity level to measure the student's Creativity Potential and Practiced Creativity (CPPC, Diliello & Houghton, 2008), Academic Self-Efficacy Scale (ASES, Kim & Park, 2001), and Problem-Solving Inventory (PSI, Heppner & Petersen, 1982).

Creativity potential and practiced creativity (CPPC) were composed of 11-items on a 5-point Likert scale and academic self-efficacy scale (ASES) consisting of 28-items on the 5-point Likert scale, and problem-solving inventory (PSI) contained 32-items on a 6-point Likert scale, as the instruments were originally designed. The questionnaire including CPPC, ASES, and PSI with the summary on the purpose of the study and the consent form was distributed. The pre-test was conducted before the DT method was applied and the post-test was distributed after the final presentation session.

Participation Selection and educational settings

The participants in this study were students from an undergraduate course titled "Applying Universal Design for Learning (after here, UDL) in the inclusive class", which is an elective course for the Department of Educational Technology at H-university in Korea. The H-university is located in the capital city of Korea and students in the Department of Educational Technology are top-ranked nationally. The student-centered teaching methods applied in this department are emphasized through most of the curriculum in the major. Therefore, students from this major are quite accustomed to student-centered learning.

The main goal of the course is to solve problems related to the inclusive education for diverse students. UDL is one of the practical theories addressing teaching and learning difficulties for diverse students by integrating technology into a classroom context (Rose & Meyer, 2002). The approaches of UDL help to plan

curricula to alleviate learner's learning barriers and to support diverse learners. The UDL framework allows for a variety of tools and media flexibility and provides a powerful opportunity to individualize the manner in which students work toward goals. After the students learned about the basic concepts and practical cases of UDL during the second half of a 16-week semester, the DT method was integrated to conduct a group project by applying UDL guidelines and strategies into problems with diverse students. Twenty-one students in this course divided into five groups according to their interests about the purpose and user difficulty issues as shown in Table 2.

Table 2. Project groups for design thinking

Group Name	Purpose	The focused user	No. of students
DOUPLE	To support students with multi-cultural backgrounds	Teachers for students with multi-cultural backgrounds	5
DAKYUNGDASE	To address mathematics learning difficulties for students with borderline-level intelligence	K-12 students (Around 4th grade)	3
DMV	To address visual challenges with a map in social studies for students with visual impairments	K-12 students (Around 6th grade)	5
TRAVEL	To design a new solution for foreigners to easily utilize subways during a trip	Foreigners	5
CONCENT	To help and support students with ADHD	Teachers to deal with students with ADHD	3

The course for applying DT during 7 weeks consisted of a 6-six-step module based on the combined version of the Stanford d.School toolkit and SAP professional development model of DT and a concluding module as follows:

- (2 weeks) Empathy and User Research: This step involves sharing a group member's individual experiences related to the user and understanding their user's problems by empathizing with users. Divergent thinking was promoted to find the problems and establish a deeper insight into their targeted users. Then, students were asked to summarize user's characteristics on learning profiles from the UDL framework. In this step, the students also found more information about their targeted users by observing and interviewing users, and researching previous literature based on the questions. Convergent thinking was promoted to summarize their observation, interview, and previous research.
- (1 week) Interpret the Results and Define a Project from a Point of View: Each group asked to interpret the user research results by sharing what they found. Then, after the logical thinking was demanded with categorizing user research data, the coordination between the divergent thinking and convergent thinking was facilitated to define their own problem for the targeted users.
- (1 week) Ideate and Generate Ideas: This is the most creative step towards ideating an innovative solution and new opportunity with their problems. The interplay between the divergent thinking with brainstorming and convergent thinking session with refining ideas from feedback were encouraged.
- (1 week) Prototype and Experiment: In this step, first of all, the sketch as a low-fidelity prototype was drawn to make the ideas tangible and visible. While the prototype was being built, ideas were shared and more detailed solutions were refined with the feedback from other peers.
- (1 week) Test and Implement: In this step, the actionable and physical prototype in high-fidelity was implemented in order to conduct an evaluation to find usability and feasibility problems or weaknesses in the prototype. Then,

the ideas were evolved through the test and implementation.

- (1 week) Final Presentation and Reflections: Finally, students conducted a presentation with their design journey, experiences, and the final products. Then, individual reflection was submitted through the DT project.

The participants consisted of nine female and twelve male, and the grade varied from year two (sophomore) to year four. Two graduate students also participated in this course and three students were enrolled in two different majors. For the quantitative study, 21 students were invited to the pre-test in a voluntary manner and informed consent was obtained. However, one student could not participate in the post-test. Therefore, data from 20 students who conducted both pre and post-test with the consent were analyzed.

Data analysis and reliability of the study

In terms of the quantitative study, the paired samples t-test was employed to measure the difference on student's CPPC, ASES, and PSI scores after conducting the group projects using the DT method during 7 weeks by gathering the data from the pre and post-tests with SPSS, Version 22. The negatively worded questions were reverse coded. Reverse scoring was done through coding the numeral scoring scale into the opposite direction. The Cronbach's alpha values for those three instruments were 0.95 for CPPC, 0.88 for ASES, and 0.90 for PSI, implying that they are reliable.

For the qualitative study, content analysis was adopted to analyze student's reflections on the group projects with the DT method. The analyzed framework for the qualitative data from productions and reflections were based on the DT phases since portfolios and products were made at the end of each phase. The final reflection papers from participants were collected and analyzed in terms of effectiveness and difficulties in utilizing DT method in their projects.

Findings

Findings from the quantitative research

Data from CPPC, ASES, PSI questionnaires were analyzed with a non-parametric method, the Wilcoxon signed ranks test. This non-parametric method was utilized to investigate differences in before and after the DT approach. The Wilcoxon signed ranks test as non-parametric test revealed that the pre-scores and the post-scores in terms of CPPC, ASES, PSI are significantly different. It means that participants had statistically significant improvements in the creativity potential ($z= -2.983$, $p < .001$), academic self-efficacy ($z= -3.261$, $p < .001$), and problem-solving competencies ($z= -2.506$, $p < .01$) shown in Table 3. That is, team projects with the use of DT methods might have a positive impact on student's creativity, self-efficacy, and problem-solving skills.

Table 3. Results from Wilcoxon signed ranked test

	Pre test (N=20)		Post test (N=20)		Difference	Z	Cohen's D (*d*)
	M	SD	M	SD			
CPPC	3.74	.720	+.33	.556	.517	-2.983***	.517
ASES	3.40	.465	+.29	.522	.573	-3.261***	.573
PSI	4.15	.587	+.19	.497	.353	-2.606**	.353

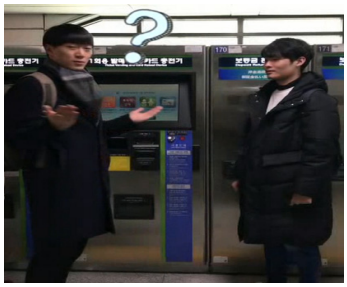
*$p<.05$, **$p<.01$, ***$p<.001$

Findings from the analysis of the student portfolios and reflections

As described in the method section, the objective of this study is to provide deeper insight into how the DT method might be applied into the context of the educational problems of practice and to explore and exemplify the experience of

DT cases in the higher education setting. In particular, since the educational practice related to solving problems for diverse learners is one of the wicked and ill-structured tasks (Buchanan, 1992), participants required structured guides to reach creative solutions. In this section, the student works and reflections through the process of the DT projects were analyzed. The followings are the findings from the analysis of the student portfolios and reflections.

Table 4. Examples of products at each phase of the DT process

Step	Sample1	Sample 2
Empathy	Empathy Map by DOUPLE	*d* UDL profile analysis by DMV
Define	*x*	By DMV (Their problem statement) 'There should be addressed visual challenges with a map in social studies for students with visual impairments in high schools, especially with the use of the digital textbooks'
Ideation	Brainstorming by DMV	*t* Categorizing by DAKYUNGDASE
Prototype	*l*Low-fidelity prototype (Instructional activity tips to promote a relationship with friends for students with ADHD) By CONCERT	 High-fidelity prototype (video-clip) by TRAVEL
● e s t	By TRAVEL	

First of all, in the empathy stage, students said that they could have an opportunity to establish a deeper understanding on targeted students. In fact, it was not an easy task to define diverse students including students with special needs, and analyze their individual characteristics in details. Therefore, the empathy stage provided students with tangible methodologies and guides such as an empathy map to analyze their targeted users. A participant reflected that to empathize the targeted learners through DT transformed our viewpoints from vain discussion to authentic and actionable plans. Each group generated UDL profiles of the targeted users and empathy maps in this phase as shown an example in Table 4. In fact, there have been many education policies and programs to help diverse students around the globe, but participants analyzed that they are too formal, but not effective. Participants acknowledged that the DT approach lets them think about the solution from a more authentic and practical perspective.

However, at the end of the project, participants reflected that the empathy stage would be the most challenging and important stage due to limited time and resources. In addition, they admitted that the empathy phase might help to immerse them into a given context and to seek inspiration for their solutions (Kelley & Kelley, 2013).

Secondly, in Define stage, students can approach problems with diverse learners by framing and reframing a UDL practical framework from three different brain network perspectives (Rose & Meyer, 2002). The UDL framework provides three templates: class learning profile, curriculum barriers and UDL solutions. These forms speak to foundational ideas in understanding educational contexts with diverse learners and connecting with the 2nd step, defining a problem. As Henriksen et al. (2017) also suggested, framing and reframing the problem from different viewpoints might help examine its complexities and lead to deeper exploration of their problems. Indeed, students iteratively tried to frame and reframe the problem and the UDL framework plays a scaffolding role about how to approach defining problems with their targeted students. Such an opportunity to frame and reframe

the problem let the students not simply approach diverse learners from an old-fashioned categorized person with special needs. Rather, they tried to reframe and articulate the problems with the empathy of their real needs by combining the UDL framework with insights. For instance, the DMV group could establish an insight on the map representation of the digital textbooks in social studies by reframing the contexts and focused on a problem for the visually impaired students.

Thirdly, in ideate stage, divergent and convergent thinking was required in an iterative manner (Runco, 1993). Brainstorming was utilized to encourage divergent thinking and then, sorting, categorizing, and synthesizing ideas promote convergent thinking. In this phase, students realized the power of iteration between divergent and convergent thinking. A participant reflected that divergent and convergent thinking made us develop a wider viewpoint and focus on ideas with attention. This process is not very familiar, but interesting and beautiful. However, some participants expressed difficulties in divergent thinking aspects and collaborations with peers through this process. They said that they were more familiar with focusing on a solution before immersing into divergent thinking and sparking wild ideas. Some students said that at the moment of the divergent thinking aspect, they had difficulties facing thinking unconsciously convergent solutions before divergent thinking themselves as well as thinking logically without enough inspiration. This could be one of the differences between DT and PBLs approaches. Usually, PBLs require students with the steps where students think logically and systemically to find solutions. Furthermore, even if rules and guidance were given not to criticize other peer's opinions during brainstorming, some of participants tended to criticize others, stopping them from generating ideas. One of the groups redefined a targeted user group and problem by cycling back to the first stage since they realized that they did not empathize users enough while they were generating ideas. From the ideate stage, each group chose different products for their solution, such as a multimedia game, a video clip, professional development program, etc. The DT approach let students create diverse types of product depending on their findings

from previous stage.

Fourthly, in prototype stage, various prototyping tools were utilized depending on each team's idea. Participants started with low-fidelity prototypes such as sketch, post-it mock-up, or storytelling, and then they built the prototypes more tangibly in the form of movie clips, educational games with the use of the PPT animation, multimedia content storyboards for teacher's training courses, etc. They reflected that prototyping brought their ideas to life and more tangibly with excitement.

Finally, in the test stage, participants evaluated their prototypes by interviewing the targeted users or experts in the educational areas. During the evaluation, participants had opportunities getting feedback on detailed features of their prototypes and improving them through revision. However, instructors reflected that students were not well-prepared to get criticism on their ideas even if they agreed on the reflections that the productive feedback benefited their work. The reasons can be analyzed that they were more accustomed to get a grade from assessment (Henriksen et al., 2017) and they believed that harmony was more important than criticizing each other, a result of being of the culture in an eastern country context (Hofstede, & Hofstede, 2005). Therefore, the value of the test and feedback should be emphasized and communicated that failure is not a shame, but an essential part of learning (Dweck, 2006; Lewis 2015).

Discussions and Implications

This empirical study exemplified how students applied DT into problems with diverse learners as an educational problem. In this section, implications based on the quantitative and qualitative studies will be discussed as follows.

First of all, it was found that DT frameworks can promote student's learning in an innovative way. In this research context, the participants with an educational technology background were accustomed to project-based learning methods in

courses, but many participants discussed that DT provided a tangible framework and structured guidance for their ill-structured problems in a course, and it helped them understand how to approach creative problems systematically. Stokholm (2014) also argued that Design-based learning has a more dynamic process and influences on producing creative and innovative ideas, compared to PBLs. In this study, students also emphasized that the DT approach made them think more creatively and divergently. The design thinking tools and methods scaffold students as solid foundations for complex and challenging educational practice by facilitating a more creative approach (Seo, 2017; McLaughlan & Lodge, 2018).

Secondly, this study proved that the DT method has an impact on student's creativity, confidence and self-efficacy as well as problem-solving skills from both quantitative and qualitative study. As indicated in the results of the quantitative research, creativity potential and practiced creativity (CPPC), academic self-efficacy (ASES), and problem-solving skills (PSI) showed statistically significant improvements after DT projects, in accordance with discussion from previous literatures (Carroll et al., 2010; Henriksen et al., 2017; Nowl & Liub, 2016). In addition, at the reflection stage, most of participants reviewed that they felt like improving creative skills and mind-set so called "creative confidence" (Rauth, Köppen, Jobst, & Meinel, 2010, p.1) and expressed pride with the process as well as their final products through DT projects, which are related to constructs derived from academic self-efficacy and problem-solving (Satici & Can, 2016).

Thirdly, this case demonstrated how instructors in an undergraduate course support students in generating creative ideas and solving problems from an innovative viewpoint, especially in the student-centered instructional strategies. In the Empathy phase, students discussed that field observation and interviews with users are necessary to get insight into their problems. Inspiration on the solution in educational problems of practice depends on empathizing users, whose results might affect later phases. In the Define phase, it is crucial to view the problems from different perspectives. The iteration of framing and reframing through the

UDL framework helps to promote such varied viewpoints in this study. Therefore, instructors can facilitate multiple perspectives with solid scaffolds and templates. In the Ideation phase, iteration between divergent and convergent thinking aspects should be encouraged. Furthermore, during brain-storming, it should be emphasized that criticizing other's ideas and opinions stop peers thinking broadly and divergently. In the Prototype and Test phases, it should be facilitated that productive feedback from failure could improve their creativity and final products. Instructors should help students to realize that evolving thoughts through iteration is a virtue of the design thinking approach (Dweck, 2006; Lewis 2015). The iteration and coordination between divergent and convergent thinking are the crucial factors which should be focused in the DT approach, compared to the PBLs approach (Carroll et al., 2010; Nowl & Liub, 2016). In summary, the instructors should play an active role as a facilitator in consideration of such a special process and focus of the DT approach, whose success can be activated by the facilitator's role and functioning (Goodyear & Dudley, 2015).

Finally, participants admitted that the DT approach let them think about educational practice from an authentic perspective. While students conducted DT projects, they faced many points to prioritize ideas and make decisions on more user-centered solutions. They reflected that they tried to think about authentic solutions through DT and at the convergent thinking moment, it anchored them in authentic problems of practice (Norton & Hathaway, 2015) and they became engaged in the project from a feasible and practical perspective (Henriksen, 2017). This perspective led the participants to conclude that they conducted a worthwhile task and their products were fruitful.

Conclusion

This study validated that the DT method has a statistically significant influence

on student's creativity, confidence, academic self-efficacy, and problem-solving skills from a quantitative viewpoint. It also illustrated the detailed process and implications with the DT approach in the ill-structured educational problems in an undergraduate course from a qualitative viewpoint. The implications reflect the potential of the DT approach for student-centered instructional strategies.

This study has limitations regarding the limited context and number of participants as mentioned earlier. However, the purpose of this study is not to generalize the results and implications of the quantitative figures. Therefore, the authors would like to suggest that the study extend into a wider context and range of the participants to generalize the impact of DT into educational context. Moreover, this study did not measure student's productivity on student's final achievements, compared to the traditional project-based learning method. Therefore, future studies might focus on validation of the impact of DT methods connected to academic standards (learning objectives) at the undergraduate level as Carroll, et al. (2010) demonstrated at the middle-school level.

References

Bell, S. (2010). Project-based learning for the 21st century: Skills for the future, *the Clearing House, 83*, 39-43.

Brown, T. (2008). Design Thinking, *Harvard business review, 86*(6), 84-92.

Brown, T., & Wyat, J. (2010). *Design Thinking for Social Innovation, Stanford Social Innovation Review*, Winter 2010.

Brown, T. (2011). *Why Social Innovators Need Design Thinking, Stanford Social Innovation Review Blog*, 2011. http://www.ssireview.org

Buchanan, R. (1992). Wicked Problems in Design Thinking, *Design Issues, 8*(2), 5-21.

Calonge, D. S., & Safiullin, A. F., (Lee, E.) (2015) Can culturally, disciplinarily and educationally diverse (D3) teams function and be creative? A case study in a Korean university, *Educational Studies, 41*(4), 369-392.

Carroll, M., Goldman, S., Britos, L., Koh, J., Royalty, A., & Hornstein, M. (2010). Destination, Imagination and the Fires Within: Design Thinking in a Middle School Classroom, *International Journal of Art & Design Education, 29*(1), 37-53.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences (2nd ed.)*, Hillsdale, NJ: Lawrence Earlbaum Associates.

Cross, N. (2011). Design thinking: understanding how designers think and work. In R. M. Berg. (Eds.) (2009), *The Design of Business*, Harvard Business Press.

Dam, R., & Siang, T. (2018) 5 stages in the design thinking processes, interaction design foundation, online published in https://www.interaction-design.org/literature/article/5-stages-in-the-design-thinking-process

Diliello, T. C., & Houghton, J. D. (2008). Creative potential and practised creativity: Identifying untapped creativity in organizations, *Creativity and Innovation Management, 17*(1), 37-46.

Dweck, C. S. (2006). Is math a gift? Beliefs that put females at risk, In S.J. Ceci & W. Williams (Eds.) (2006), *Why aren't more women in science? Top researchers debate the evidence*. Washington, DC: American Psychological Association.

Engberts, F., & Borgman, H. (2018). Application of Design Thinking for Service Innovation: Current Practices, Expectations and Adoption Barriers, *Conference Proceedings: Hawaii International Conference on System Sciences*, January 2018, 1611-1620, DOI10.24251/HICSS.2018.201

Gentry, E. (2000). Creating Student-centered, Problem-based Classrooms. In (Ed.), (p.). Huntsville: University of Alabama in Huntsville. Retrieved February 10, 2003, from http://aspire.cs.uah.edu/

Goodyear, V., & Dudley, D. (2015), "I'm a Facilitator of Learning!" Understanding What Teachers and Students Do Within Student-Centered Physical Education Models, *Quest, 67*(3), 274-289.

Gulbahar, Y., & Tinmaz, H. (2006). Implementing Project-Based Learning and E-Portfolio Assessment in an Undergraduate Course, *Journal of Research on Technology in Education, 38*(3), 309-327.

Hasso-Plattner Institute of Design at Stanford, (2018). d.school: Standford University, https://dschool.stanford.edu/

Henriksen, D., Richardson, C., & Mehta, R. (2017). Design thinking: A creative approach to educational problems of practice, *Thinking Skills and Creativity, 26*, 140-153. DOI: http://dx.doi.org/10.1016/j.tsc.2017.10.001

Heppner, P. P., & Petersen, C. H. (1982). The development and implications of a personal problem-solving inventory. *Journal of Counseling Psychology, 29*(1), 66-75.

Hmelo-Silver, C. E. (2004). Problem-based learning: What and how do students learn?. *Educational Technology Review, 16*(3), 235-266.

Hofstede, G., & Hofstede, G. J. (2005). *Cultures and organizations: Software of the mind* (2nd ed.). New York: McGraw-Hill.

Kelley, T., & Kelley, D. (2013). *Creative confidence: Unleashing the creative potential within us all.* Crown Business.

Kim, A.Y., & Park, I. Y. (2001). Construction and validation of academic self-efficacy scale, *The journal of Educational Research, 39*(1), 95-123.

Kim, J., & Ryu, H. (2014). A Design Thinking Rationality Framework: Framing and

Solving Design Problems in Early Concept Generation, *Human–Computer Interaction, 29*(5-6), 516-553, DOI: 10.1080/07370024.2014.89670

Lee, S. E., & Kim, Y. M. (2018). The Effects of PBL Class on University Student's s Creative Problem Solving Competence, Self-efficacy and Class Participation, Journal of Educational Innovation Research, 28(2), 73-89.

Lewis, S. (2015). *The rise: Creativity, the gift of failure, and the search for mastery*. Simon and Schuster.

McLaughlan, R., & Lodge, J. M. (2018). Facilitating epistemic fluency through design thinking: a strategy for the broader application of studio pedagogy within higher education, *Teaching in Higher Education*, DOI: 10.1080/ 13562517.2018.1461621

Na, J. Y. (2017). The effects of the PBL on teacher efficacy of pre-service early childhood teachers, *Journal of thinking development, 13*(1), 27-48.

Noel, L., & Liub, T. L. (2016). Using Design Thinking to create a new education paradigm for elementary level children for higher student engagement and success. *Proceedings of DRS 2016, Design Research Society 50th Anniversary Conference.* Brighton, UK, 27–30 June 2016.

Norton, P., & Hathaway, D. (2015). In search of a teacher education curriculum: appropriating a design lens to solve problems of practice. *Educational Technology, 55*(6), 3–14.

Oh, E. K., & Nah, K. (2014). Design Thinking Process Model and its Application to Social Innovation, *Journal of Korea Design Knowledge, 32*, 31-44.

P21(Partnership for 21st Century Learning) (2018). Framework for 21st Century Learning, http://www.p21.org/about-us/p21-framework

Heppner, P. P., & Petersen, C. H. (1982). The development and implications of a personal problem solving inventory. *Journal of Counseling Psychology, 29*, 66–75.

Pendleton-Jullian, A. M., & Brown, J. S. (2015). *Design unbound: evolving design literacy pathways of efficacy*. CreateSpace: a DBA of On-Demand Publishing, LLC.

Rauth, I., Köppen, E., Jobst, B., & Meinel, C. (2010). Design thinking: an

educational model towards creative confidence. DS 66-2: *Proceedings of the 1st international conference on design creativity* (ICDC 2010).

Rose, D. H., & Meyer, A. (2002). *Teaching every student in the digital age: Universal Design for Learning*. ASCD.

Runco, M. A. (1993). Divergent Thinking, Creativity, and Giftedness, *Gifted Child Quarterly, 37*(1), 16-22.

Satici S. A., & Can, G. (2016). Investigating Academic Self-efficacy of University Students in Terms of Socio-demographic Variable, *Universal Journal of Educational Research, 4*(8), 1874-1880.

SAP (2012). *Introduction to Design Thinking, SAP User Experience Community*, from https://experience.sap.com/skillup/introduction-to-design-thinking/

Seo, E. K. (2017). Development of creative thinking and coding course method on Design Thinking using Flipped Learning, *Journal of Learner-centered Curriculum and Instruction, 17*(16), 173-199.

Simon, H. A. (1916). *The sciences of the artificial, 3rd edition*, USA: Massachusetts Institute of Technology.

Sweat, C., Blythe, H., & Carpenter, R. (2017). Why Design Thinking should matter to higher education, Part I, *The National teaching & Learning Forum, 26*(3), 5-7.

Stokholm, M. (2014). Problem based learning versus design thinking in team based project work, *Proceeding of International conference on engineering and product design education 4-5,* September, 2014, University of Twente, the Netherlands.

Trilling, B., & Fadel, C. (2009). *21st century skills: Learning for life in our times*. San Francisco: Jossey-Bass.

Wrigley, C. & Straker, K. (2017). Design Thinking pedagogy: the Educational Design Ladder, *Innovations in Education and Teaching International, 54*(4), 374-385, DOI: 10.1080/14703297.2015.1108214

Hyunjin CHA

Invited Professor, Dankook University

Interests: Learner Experience (LX), Human-Computer Interaction (HCI), Universal Design for Learning (UDL), Design Thinking (DT), Learning Science, ICT4ED (ICT for Education Development)

E-mail: lois6934@hanmail.net

Received: April 5, 2019 / Peer review completed: April 26, 2019 / Accepted: April 27, 2019