Development of instructional design strategies for integrating an online support system for creative problem solving into a University course

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Received: 29 May 2020 / Revised: 13 July 2020 / Accepted: 24 July 2020 / Published online: 3 August 2020
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Abstract

This study examined three cases in which an online support system was utilized to enhance creative problem solving (CPS) in a higher education setting. This study aimed to review instructional design strategies that allow the integration of an online support system into a university course. Creativity, which is defined as the ability to generate a new and useful idea, is a key competency for students to possess as it can assist them in taking effective actions in the future society. Considered to be a representative model for developing creative thinking abilities, the CPS model is known to effectively stimulate learners' divergent and convergent thinking while supporting a systematic approach to find creative solutions and enabling meaningful learning by utilizing its supporting tools. Considering the advantages derived from using the Online Support System for CPS, three cases across diverse colleges were reviewed: the College of Education, Fine Arts, and Engineering. Through comprehensive analysis, this study proposes major design strategies to achieve the integrated application of the Online Support System to university courses that encourage problem solving abilities. The study also suggests future research directions for CPS using the Online Support System.

Keywords Creativity · Creative problem solving · Online support system · Instructional design strategy

Introduction

Creativity is a key competency required of individuals in future society (Brewer and Hogarth 2018; Lim et al. 2014b). Due to the importance of cultivating creativity, many efforts have been made to enhance one's creative thinking competency in educational contexts. For instance, teaching and learning methods using technology in a class or through collaborative learning have been implemented in elementary and middle schools to cultivate creative thinkers (Schleicher 2012). Colleges are undergoing curriculum reformation or course development to further foster creativity. In engineering schools, a course of *Creative Engineering Design* was developed for freshmen, with its effectiveness being

investigated (Charyton and Merrill 2009). Such an approach emphasizes that rather than being solid and innate, the nature of creativity is fluid and that it can be developed through education and training. Creativity is used for making a new and useful product by an individual or a group (Hennessey and Amabile 1988), and can be improved through mutual interaction between its process and environment (Plucker et al. 2004).

In particular, there is an emphasis on the creative problem solving (CPS) model as it can be educationally used to enhance creativity (Runco 1994; Torrence 1979; Weisberg 2006). It is one of the representative models for boosting creativity through the comprehensive application of divergent and convergent thinking. CPS stresses the processes of identifying the problem, exploring relevant data, framing problems, and generating ideas (Treffinger et al. 2006). Such a model makes it possible to develop a variety of original ideas and reach a conclusion. CPS assists learners in augmenting their creativity by guiding them through processes that need to be considered when trying to solve a problem creatively.

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In order to provide an effective tool for learners during the process of solving a problem more creatively, it is necessary to consider using online systems or digital tools that support CPS. Activities based on online support tools can facilitate the distribution and sharing of diverse ideas. Moreover, online support systems can stimulate cooperation among learners by managing information needed for CPS (Grabe and Grabe 2000; Shneiderman 2002; Wu and Hsiao 2004). It has been proven that college courses that apply tools, like TRIZ, are more effective than prior discipline-based courses as those courses help the learners develop open-ended problem solving skills which the learners use in real life, provide a systematic approach when solving a problem, and assist in forming new perspectives to problems and solutions by widening their search beyond existing knowledge (Belski 2009). The integrative application of digital tools or online support systems for CPS could incorporate existing offline creative activities, thus allowing the effective carrying out of team projects (Lim et al. 2010).

Despite the importance of support systems and their roles in stimulating CPS, there is still a lack of approaches in enhancing creative problem-solving skills in the higher education context. Learners perceive that appropriate efforts to heighten their creativity are not being made in their college courses (Belski 2009). To achieve the aim of enhancing the creativity of learners participating in such courses, it is necessary to consider methods of integration and utilization of online supporting systems within existing courses (Lim et al. 2010; Schleicher 2012). This manifests the need for instructional design strategies to effectively combine the online support system for CPS with university courses.

Therefore, this study tried to examine how *Smart Support System for Creative Problem Solving (S³CPS)*, an online supporting system developed to enhance creative problem solving was applied by instructional design strategies in different contexts in the College of Education, the College of Fine Arts, and the College of Engineering. It intended to study the applicability and effectiveness of the instructional design strategies by analyzing the learner responses. Furthermore, the study sought to present instructional design strategies that should be emphasized in an optimal instructional approach when implementing the online support system to boost learners' creative problem-solving ability in university. The research questions are as follows.

- What are design strategies for integrating creative problem solving system into college courses?
- (1) What are the design strategies developed for integrating the online system with each course?
- (2) What are the learners' responses about the design strategies?

Theoretical background

Characteristics of creative problem solving

While it is rather difficult to find conceptual consistency when defining creativity, it has been viewed in psychological studies as either a characteristic of an individual or an attribute of a creative person (Runco 2007). Flexibility, originality, and fluency in one's thinking and expression are the main characteristics of a creative person (Guilford 1986). From a sociocultural aspect, the focus of creativity is on the culture or environment that can produce new ideas (Amabile 1996; Zhou and Shalley 2003). Integrating both views, creativity can be defined as the interaction between an individual's competency and the social process in developing a new and useful product within a particular social context (Kaufman and Plucker 2011).

With regard to the comprehensive approach to creativity, Rhodes (1961) proposed the "4Ps Approach," which constitutes of the following four factors: person (personality, traits, attitudes, etc.), process (thinking stages or problem solving steps for creative products), product (outcomes or results from a developed), and press (relationship between humans and their environment). Urban (1995) built on this concept and suggested an interactive structure of "4PE" (Problem, Process, Products, Personality, and Environment) centering on a "Problem," which needs to be creatively solved through the interdependency of factors like an individual and his/her environment.

The creative problem solving (CPS) model, which stresses on the creativity in a process, focuses on the possibility to enhance a learner's creative thinking ability through education and training in various contexts, including universities (Guilford 1967; Torrance 1979; Treffinger et al. 2000). The CPS model was developed as a guide to the thinking process when identifying the problem in a given situation, stating the problem in detail by referring to the relevant data, and then reaching a creative solution by considering various ideas. This model underwent numerous modifications and supplementations (Osborn 1963; Parens 1967; Isaksen and Treffinger 1985) after it was first proposed by Osborn in 1963. The model that is widely used currently is CPS Version 6.1™ (developed by Treffinger and his colleagues in 2000). It is a flexible problem-solving model that utilizes various interrelated components of ill-structured and complex problems. Creative problem solving is effectively achieved through balancing divergent and convergent thinking at each stage. Also, necessary components or processes can be selected depending on the types of problems.

The CPS Version 6.1™ (see Fig. 1) is a descriptive and flexible process, consisting of eight stages and is

Fig. 1 The CPS Version 6.1™ framework (Treffinger et al. 2000)

composed of a management component (planning your approach) and three process components (understanding the challenge, generating ideas, and preparing for action). The three process components include six specific stages (constructing opportunities, exploring data, framing problems, generating ideas, developing solutions, and building acceptance). Table 1 summarizes the component and stages of the CPS model.

In short, the main characteristic of creative problem solving with the perspective of creativity as a process, emphasizes that creative thinking can be improved through education and training. Also, it means to define what problems can actually be faced in complex and unstructured situations, to

generate various creative ideas and to derive optimal solutions to problems through repetition of divergent and convergent thinking. Design thinking, which is one of the creative approaches that have received much attention recently, has similar characteristics to CPS. Design thinking includes five phases consisting of (1) Empathy, (2) Define, (3) Ideate, (4) Prototype, (5) Test. It was developed to help overcome worries about creative activities, such as fear of failure, and to have creative confidence through the creative problem solving process (Kelly and Kelly 2013). Design thinking is similar to CPS in that it emphasizes the process of systematically approaching a problem with a very complex challenges and ultimately has the value of deriving the optimal creative

Table 1 The CPS process components and stages

Components		Stages	Description
Management Component	Planning your approach	Appraising tasks	Understanding a particular task from various angles and determining whether to apply CPS to the task
		Designing process	Deciding on the application of CPS. Designing and preparing a plan for its application
Process Component	Understanding the challenge	Constructing opportunities	Identifying broad goals, challenges, and opportunities. Setting direction for problem solving and focusing on possible opportunities and challenges
		Exploring data	Examining the task closely and deciding on the main focus of CPS
		Framing problems	Drafting numerous statements for the problem and selecting a specific statement
	Generating ideas	Generating ideas	Generating novel and diverse ideas that are pertinent to the problem statement
	Preparing for action	Developing solutions	Forming potential solutions by improving and enhancing promising possibilities
		Building acceptance	Exploring potential solutions and identifying their supports and resistances in order to find solutions that can be implemented Specifying, developing and modifying the final action plan

solution (Brown 2009; Koh et al. 2015). However, design thinking differs from CPS in that it focuses on developing and visualizing ideas by iterative improvement work of prototyping, testing rather than discussing the ideas or results. It emphasizes forming empathy at the heart so that the users often use observations and interviews to identify what the problem is in context of real lives.

Importance and the efforts of creative problem solving in college

Universities are required to take efforts to educate talented individuals who will be fit for the future society and be able to achieve qualitative developments in industries and society as a whole. Creativity, collaboration, critical thinking, and communication, which are suggested as the necessary 4Cs for the future society, have been regarded as essential abilities that college learners should possess. Talented individuals who will lead the future society should have creative problem-solving skills. As problems that arise in the real world are ill-structured and complex, a new method of solving problems must be obtained: where one can define the problem in a new way and synthesize knowledge into an innovative idea, instead of simply understanding and memorizing the knowledge or theories provided. Appropriate educational efforts should be taken to facilitate learners to generate creative approaches to solve the problem more effectively (Livingston 2010).

In particular, creative problem solving is important in university education because college students would have to effectively deal with practical problems linked to the real world, and promote higher-order thinking skills. General problem solving is relatively simple and has the character of a well-defined, structured task with already determined solutions. On the other hand, creative problem solving is for a very complex or ill-structured matter so that it does not easily reach the expected result (Isaksen 1985). In colleges, advanced thinking skills should be improved by considering how to approach authentic problems that can occur in reality more effectively using approaches such as creative problem solving (Al-Khatib 2012; Spector et al. 2016).

Considering the importance of creative solving mentioned above, the suggested approaches to creative problem solving are as follows. First, there should be a plan to enhance one's creative thinking ability by redesigning existing curriculums or developing courses. Lim et al. (2014b) developed a theoretical framework of redesigning curriculum to increase creativity in the context of engineering education. The framework proposed that learners should handle real-world problems as they advance with coursework. It also emphasized that freshmen should acquire fundamental concepts and principles through knowledge-based courses that teach basic theories, while ensuring that they take interdisciplinary courses on management, economics, fine arts,

and leadership courses on teamwork or communication throughout the 4 years in college. Ultimately, to help learners acquire the creative problem-solving ability, a design course or curriculum is necessary, where planning and actual implementation of problem-solving take place. For example, the development of the 'Creative Engineering Design' course considers capstone design among its contents, and it emphasizes both defining the engineering problems and improving one's ability to solve them (Lee et al. 2009). In the field of liberal arts, creative writing courses or educational programs are being used to boost creative thinking (Mayers 2009). Creative writing courses can help medical students predict problems they as medical doctors may face in the future. It helps them to contemplate the problems and how to respond to them effectively (Hatem and Ferrara 2001). Writing activities serve as a means to express their thoughts into writing and thus reflect on their actions.

Second, bearing in mind the impact of the surrounding environment on an individual's creativity, physical spaces that stimulate learners' creativity are being built. For example, Hasso Plattner Institute of Design (commonly known as the d.school), based at Stanford University, built a maker space to achieve effectiveness in learning and developing design and production skills. Learners participated in team-based creative problem-solving activities to develop prototypes using software processing tools and hardware tools like laser cutting machines and welding tools. The maker space helps enhance creative thinking ability by stimulating the learners' process of generating new ideas and assisting them in materializing the ideas into reality (Saorín et al. 2017). Considering the limitations of the existing college environment where learning is limited to knowledge-delivery-oriented approaches, Park and Choi (2014) highlighted the importance of an Active Learning Classroom (ALC) as a learning space where active participation and various activities like creative problem solving, can take place. An ALC is equipped with desks, chairs, and projectors with mobility so that team projects or creative activities can take place more easily and effectively. In the ALC environment, dynamic activities for learners including divergence and convergence of ideas may take place with heightened effectiveness.

Third, thinking techniques are being applied to enhance learners' creative problem-solving skills. For example, when students use TRIZ as a strategy to derive new solutions to the problems, they are motivated to solve problems creatively and even the ones with limited background knowledge can understand the topic in a better way (Nakagawa 2011). Design thinking, (i.e., an approach where prototypes are developed and verified based on a clear understanding of the problem), facilitates collaboration through empathy (Brown 2009) and leads to sharing and exchanging knowledge and improving collaborative thinking through the development of prototypes (Dunne and Martin 2006).

Development and application of an online support system for creative problem solving in colleges

After Osborn presented several guidelines for creative problem-solving in the 1960s, the development of information and communications technology has enabled studies to explore the possibilities of computer-supported systems or tools as effective methods for guiding the process of creative problem-solving. Web or computer-based systems can support learners' cognitive activities more effectively (Jonassen 2000). For instance, a particular system which provides the visualization of big data drawn from learners' online activities, can analyze the nature of a learner's problem-solving approach by identifying data patterns and relations from the aspects of reporting, narrative, representation, and interaction (Cybulski et al. 2015). This analysis helps develop new insights into a problem. Lim et al. (2013), who developed the principles of designing an online support system to strengthen creativity in college education, emphasized the advantages of the online supporting system that can produce and share creative ideas without time or location constraints for the effective storing and management of those ideas.

Although computer-based systems can support creative problem solving activities more effectively, major studies so far focus on what these systems can do to help creative problem-solving. It is, without a doubt, important to conduct studies on the conceptual aspects of the support systems or carry out developmental research on building the systems. However, it is just as important to examine how online systems or digital tools can be integrated and applied effectively in existing courses. In particular, to achieve a more optimized approach, the online system should be flexibly incorporated into existing course contents (Lim et al. 2010). Therefore, this study reviewed three cases that combined the online support system for CPS with existing college courses. It discusses the design strategies to be undertaken in the future to develop a more effective online support system integrated course for creative problem solving.

Methodology

Research context

This study aims to investigate the design strategies that integrate the online support system and college courses. It aims to utilize such integrated college courses to make way for creative problem solving and provide necessary measures or efforts in the future from major findings. To do so, this study took a comprehensive approach to three cases that used online support systems, and analyzed the applicability of design strategies. The three cases are from the following colleges: college of education, fine arts, and engineering (all affiliated with the "S" University in Korea) (Table 2).

In the case of the College of Education, "Introduction to Education" was an undergraduate course in the department of education, which consisted of lectures by the instructor, e-learning contents on creativity, and team projects. Among those teaching methods, the e-learning contents for introducing the creativity topic to learners were delivered from the first 3 weeks of the course, and team projects were carried out from the 4th week to the end of the semester in order to develop creative solutions for the problems regarding teaching practicum. It used online classes to help the understanding of CPS, along with the online support system for CPS in a blended learning environment that integrated the online and offline learning activities. Regarding the application of the CPS, entire stages of the CPS process components were applied step by step on a weekly base. Out of the 35 learners who took the course, eight were interviewed to collect and analyze their responses (Lim et al. 2009).

The course of "Integrated development studio" at the College of Fine Arts aimed to strengthen the ability of learners to plan creative and innovative problem-solving processes and develop various business models. As it was an interdisciplinary course, students were from diverse majors such as colleges of fine arts, engineering, social sciences, and human ecology, and teams were organized to have four to

Table 2 The main characteristics of the three cases for CPS

Differences	Case		
	Case 1	Case 2	Case 3
Education context	College of Education	College of Fine arts	College of Engineering
Learning environment	Blended	Offline	Blended
Applied CPS process components	Understanding the challenge Generating ideas Preparing for action	Generating ideas	Generating ideas
Number of students (Interviewees)	35 (8)	21 (21)	112 (10)
Data collection	In-depth interview	Semi-structured survey	In-depth interview
Data analysis	Transcription → Coding → Conceptualization → Categorization		

five learners from different majors. The task for the learners in this course was to devise creative ideas and to propose the solution for developing a scenario in order to produce a promotional video that could introduce the core technology of ‘T’ company by highlighting their advantages. In this case, the system was utilized to support CPS activities in an offline class environment. In this course, 21 learners took the class. A semi-structured survey was utilized to analyze their responses (Lim et al. 2014a).

“Design, Production, and Practical Training” is a major course in the Department of Mechanical and Aerospace Engineering. Students taking the course were supposed to learn the process of developing a product through an optimal design that should consider the restrictive conditions of the clients along with fulfilling their functional needs. The task that the students in the course had to carry out was designing and building a robot. As shown in Figure 2, the robot should be able to transfer the golf balls on the racks of rail 1 to those of rail 2 while moving from area a to area b. Then, it must once again move the golf balls from the racks of rail 2 to those on rail 1 while returning from area b to area a. A total of 112 learners were divided into teams of six to eight members to participate in the team project. By creatively designing and producing robots appropriate to the given topic, the learners were able to apply their engineering knowledge and become familiar with the systematic engineering design methodology. In the case of the College of Engineering, team projects took place throughout the semester while operating in a blended learning environment.

For the application of S³CPS, discussions were held with the instructor of the course regarding creative robot designs. As a result of discussions, the use of S³CPS, a tool for supporting the process of diverging and converging ideas, was deemed effective during the conceptual design stage, a specific procedure of engineering design in this course. During the conceptual design stage, the students came up with a variety of robot design alternatives that might satisfy the requests of clients. Then, they selected the optimal design alternative by comparing and analyzing them. The CPS stage of generating ideas was implemented for 3 weeks to solve the problem of having to creatively produce an original robot. Out of the 112 learners who took the course, 10 of them were interviewed to analyze their responses (Lim et al. 2016).

The data collected in this study were analyzed through data transcription, coding, conceptualization, and categorization according to the general analysis procedure of qualitative research (Strauss and Corbin 1990). First, the data collected from learners were transferred. In the coding stage, the core concepts were derived, and in the conceptualization stage, repeated contents or meanings were synthesized and conceptualized by reviewing the contents corresponding to strengths and weaknesses several times. Next, in the

categorization step, the concepts derived through the above process were categorized into relevant areas meaningful to each other.

The smart support system for creative problem solving

The *Smart Support System* for CPS (S³CPS) used in the above cases was developed based on the CPS version 6.1 model proposed by Treffinger et al. (2000). The online support system was developed in 2009 by Lim et al. (2009). It is an online system that guides users through activities to solve problems creatively and has been revised and supplemented by previous studies so far. The characteristics of the thinking tools provided by S³CPS were largely composed of divergent thinking and converging thinking. Divergent thinking involved finding and defining problems in the creative problem-solving process, and deriving various creative solutions. Convergent thinking evaluated a variety of ideas through a logical, critical, analytical, and comprehensive view of the problem situation and devised the optimal solution to the problem. It is closely related to deriving a practical solution by selecting the most optimal solution among many ideas generated from divergent thinking. In short, it provided divergent thinking tools promoting the generation of ideas at each stage of the CPS and convergent thinking tools supporting to select the optimal ideas. It is possible to use brainstorming, HIT, PMI, evaluation matrix as tools in the system. (see. Table 3, Figs. 3, 4).

The design principles applied for development of the system are as follows: First, team activities must promote creativity (Agrell and Gustafson 1996; Sternberg 2009). In order to develop creativity, a team must be organized, and emphasis should be placed on its activity. Setting up groups is realized in the S³CPS. It also includes functions like sharing opinions by each group, making it feasible to conduct cooperative activities within the class. Second, the flexibility of the CPS model should be reflected in the S³CPS (Puccio et al. 2004). This makes it possible to flexibly apply each stage in the CPS model according to the conditions of a course and its learners. Third, emphasis should be placed on the balance between divergent and convergent thinking (Treffinger and Isaksen 2005). The prior versions of the CPS model mostly focused on divergent thinking. However, in

Fig. 2 A problem of the engineer course

Table 3 Thinking tools of S³CPS

Types of thinking	Thinking tools	Functions
Divergent thinking	Brainstorming	Used to generate ideas from multiple perspectives
Convergent thinking	HIT	Used to narrow down a solution from among numerous solutions by marking in front of the most promising ones with a check (✓)
	PMI (Plus, Minus, and Interesting)	Used to verify solutions to a problem by analyzing a single idea or focusing on a principle. ('P' stands for Plus and marks the pros of an idea, 'M' stands for Minus and marks the cons, 'I' stands for Interesting and marks the interesting aspects)
	Evaluation Matrix	Used to identify the strengths and weaknesses of various ideas according to the evaluation criteria and to make a selection accordingly

Fig. 3 Example screen of S³CPS: *Brainstorming*

order to increase the effectiveness of CPS, there must be a balanced application of both divergent and convergent thinking. Thus, both types of activities were made feasible in the S³CPS system.

Results

“Introduction to education” course at the college of education

Design strategies

The design strategy for utilizing the supporting system of the CPS in the College of Education course is developed by reviewing the previous researches. From the analysis of

the previous researches, the following eight design strategies are ascertained: (1) providing an instruction manual to introduce the use of CPS supporting system, (2) providing guidelines on each stage of CPS during the offline class, (3) providing the blended learning environment for discussions among team members in the offline class and for divergent and convergent thinking activities in the online courses, (4) providing the feedback to the learners about the CPS activities during the offline class, (5) considering learners' academic schedules such as mid-term and final exams, (6) writing a reflective journal in order to stimulate reflective thinking on learners' CPS activities, (7) selecting appropriate tools for facilitating convergent thinking, and (8) offering tutoring services through a teaching assistant. The Table 4 below summarizes the design strategies by the contents of each stage in the course.

Fig. 4 Example screen of S³CPS: *Evaluation Matrix*

Learners' responses

From the analysis of the learners' responses regarding the course with the above mentioned design strategies, the majority of learners stated that their thoughts on creativity have changed, and they could overcome the time and spatial constraints of creative problem solving by utilizing the online support system. Furthermore, the activities in the blended learning environment with the supporting system assisted them in carrying out a smooth team project by recording and confirming the opinions by each team member.

With regard to the utilization of the system, learners were able to take diverse approaches since each team could select its own thinking tools for solving problems. They also stated that the manual of the support system for activities was helpful to understand how to use the system beforehand. Moreover, the reflective approach through writing journals on activities using the online support system and feedback from the instructor were helpful to verify whether they could carry out the activities in an appropriate manner and comprehensively integrate the contents and activities. On the other hand, technical problems were found to be a major shortcoming of the system. In particular, learners experienced inconvenience due to the technical errors caused by the instability of the system, and additional functions were suggested to integrate common ideas proposed by learners. Some learners also mentioned that sequentially following the CPS process components was perceived as a frame which rather limited the expansion of thoughts.

"Integrated development studio" course at the college of fine arts

Design strategies

Four design strategies were developed for more effective and creative problem solving by using the supporting system. First, a preliminary orientation should be offered to increase accessibility to the supporting system. Through the orientation, learners understood the role of the support system in relation to CPS activities. Second, divergent and convergent thinking should be repeatedly used through the selection of thinking tools considering the feature of the problem. The purpose of the course was to solve a certain problem by coming up with appropriate ideas and gathering promising opinions on them. Therefore, divergent and convergent thinking activities were repeated three times regarding the following dimensions; the ideas based on learners' experience on speed, sound quality, security, coverage and connection which are the core technical factors of the company, keywords that properly represent the significance and experience of the factors, and technology that can solve the problem. Third, the instructor should play a role as a facilitator, rather than a message deliverer. By acting as the facilitator of the team activities, the professor stimulated group activities and gave advice and feedback on ideas formed through divergent and convergent thinking. Fourth, considering the fact that creative ideas could be generated using diverse sources of information, learners should be permitted to

Table 4 Activities in the course of college of education

Course stage			Offline activity	Online CPS supporting system activity	Others
Preparation for the course			Implementing creative education Introducing the topic for the team project Providing problem directions for the team project	Studying with e-learning contents Writing a reflective journal	–
Preparation for CPS activity			Introducing the CPS supporting system Presenting the problems for the team project Organizing team members Selecting a team leader	Being familiar with the manual for CPS supporting system Registering on CPS supporting system	
CPS implementation	Understanding the problem (challenge)	Constructing opportunities	Introduction of each stage	Using divergent thinking tool: brainstorming	Support for the project from a teaching assistant (participating in team board, answering the inquiries, and providing feedback)
		Exploring data	Discussion among team members	Using convergent thinking tool	
		Framing problems	Providing monitoring and feedback from the professor	(optional): HIT, PMI, Evaluation Matrix	
	Generating ideas	Generating ideas		Writing reflective journal by each stage	
	Preparing for action	Developing solutions Building acceptance			
Evaluation			Presentation of the team project Mutual evaluation among team members	–	–

approach information by utilizing books and internet in the offline class environment.

Learners' responses

It was observed that a major strength of the support system, which was simply used as a digital tool, could actually facilitate the divergence and convergence of multiple ideas. Thinking tools applied in the online support system could be used in the offline learning environment in order to stimulate learners' thinking for problem-solving activities. Also, positive impacts were found, the first showed that the preliminary orientation was helpful for learners to properly utilize the system, and the second revealed that all team members actively participated without exclusion of certain members since every team member's thoughts were recorded on the online support system. On the other hand, the shortcomings of the supporting system were determined to be as follows: the limited number of provided thinking tools which made it difficult to carry on diverse activities, inconvenient process of setting up a tool, difficulty to observe how a learner's ideas and opinions were being submitted in real

time. Additionally, it was required that the system needed a report function to print out the activity results in a separate report file.

"Design, produce, and practical training" course at the college of engineering

Design strategies

The following are the design strategies applied to the aforementioned context of the engineering course. First, a blended learning environment that linked the traditional face-to-face environment and the online environment together should be provided. The two environments displayed different characteristics with respect to thinking modes and learning activities that could be supported. In particular, the process of solving problems that engineering students might encounter was of a complex nature. Therefore, support should be given to learners to provide both physical and virtual spaces for the CPS activities in order to encourage appropriate divergent and convergent thinking in online and offline environments. Second, team-based projects should be implemented.

Projects are widely used in engineering courses, and creativity could be more effectively manifested through complex interactions among team members rather than from an individual approach. Innovative ideas could be developed, improved, verified, selected, and executed through diverse interactions among the team members. Third, authentic tasks should be provided. For learners to experience the process of CPS, it was more effective to use complex problems in a realistic context, rather than simple and structured problems. Fourth, through the use of S³CPS, thinking tools should be employed continuously. Not only did the supporting system take on the role of a medium for diverse communication, but it also effectively supported the process of solving problems by offering thinking tools appropriate to the nature of the project. Lastly, the use of the support system and the management of course should be announced, and practice opportunities should be provided. This provision helped learners to adapt to using the system and its tools. Table 5 is a summary of activities based on the above design strategies.

Learners' responses

With regard to the design strategies used in the engineering course, the majority of learners responded that using the online support system was not only helpful in expanding

their thinking process, but also in the systematic progressing, recording, and organizing of the project. Using the online support system allowed the learners to propose diverse ideas and opinions without the constraints of time and location. The system's constant accessibility from the aspect of time and location was a major strength as it made it possible for learners to think and record ideas at any time and place. Furthermore, the learners stated that it was possible to observe how the problem solving was happening at the present, and that it was helpful in objectively evaluating various design alternatives by using the thinking tools. On the other hand, there was the opinion that the online activities were not enough. In the case of college of engineering, activities of CPS mostly took place in the offline learning environment, and the system in the online environment was mostly used for recording results or opinions. In addition, some learners responded that the activities in each stage of blended learning environment that combines the online and offline activities were time-consuming. Lastly, the learners stated that making use of the system was inconvenient as it was somewhat unfamiliar.

Table 5 Activities in the college of engineering course

Stages	Content	
	Online activities	Offline activities
I. Preparation stage	Registering on the online system	Introducing team project task Providing instruction to learners to use CPS model and system Forming teams and explaining team activities
II. Practice stage	Selecting the team leader Coming up with a team name (practice activity)	Providing an opportunity to practice (coming up with a team name) Describing the procedure for a practice activity
III. Implementation stage		
Exploring operation principle (Thinking tool: Brainstorming)	② Organizing and submitting one's ideas	① Providing ideas and feedback ③ Re-discussing ideas submitted to S ³ CPS
Coming up with the design alternatives (Thinking tool: HIT)		Integrating operation principles and coming up with six to eight design alternatives
Analyzing design alternatives (Thinking tool: Evaluation Matrix)	① Registering evaluation criteria for design alternatives (team leader) ② Evaluating each design alternative (all team members)	③ Discussing evaluation results for each design alternatives ④ Selecting three to four design alternatives
Discussing pros/cons of design alternatives (Thinking tool: PMI)	② Organizing and submitting one's own opinion	① Discussing pros/cons and improvement plans for selected design alternatives ③ Re-discussing ideas submitted to S ³ CPS
Evaluating final design alternative (Thinking tool: Evaluation Matrix)	① Evaluating the design alternative based on the list of client requests (1 to 5 points evaluation that weighs each evaluation criterion)	② Deducing or selecting optimal design alternative by discussing evaluation results
IV. Evaluation stage	Evaluating online activity (teaching assistant)	Presenting team's outcome (learners) Evaluating team presentation (professor, teaching assistant)

Features of design strategy and directions for improvement

Features of design strategy

The features of design strategies for a more effective integrated use of the online support system in university courses are presented in terms of pre and early stages of the course implementation by comprehensively analyzing the three aforementioned cases. Above all, two key design strategies can be identified in the pre and early stages of course implementation. First, information on the online support system and on how to use it must be understood prior to the integrated use of the online support system. As seen in all of the above three cases, it was found that prior guidance or orientation on the online support system helped the learner to use the system more effectively. No matter how effective a developed online support system or tool is, effective improvements in creative problem-solving capabilities cannot be achieved if the user is not able to use it proficiently by prior practices. Therefore, learning the features and the online support system itself prior to actual use is important for creative problem-solving because it will encourage learners to think about how to use the digital tools or the online support system, and help learners select and use the most appropriate tools.

Second, authentic tasks should be designed and utilized. The problems used in all three cases, i.e., the educational practice at the college of education, the development of a scenario for T company's promotional video at the college of fine arts, and the development of a creative robot at the college of engineering, all have an authentic problem to be solved creatively. In particular, creative solutions to authentic tasks through all stages of the creative problem solving course, such as at the college of education, require the process of defining what the problem is, setting up alternative hypotheses, generating ideas, collecting and analyzing additional data for review, and compiling, which leads to reasoning for a critical approach. This can help solve problems more effectively and find creative solutions. The authentic tasks should be approached in various ways because they are ill-structured rather than having a structured character. In order for creativity to be practiced more effectively, it is necessary to induce authentic experiences in a particular area or task and to perform a comprehensive analysis since authentic tasks include the nature of problems occurring in a specific area with various factors that have mutual effects. In short, providing authentic problems for creative problem-solving can help learners comprehensively access the knowledge needed in the area or course in order to create the optimal solution.

Next, in the actual stage of operating the courses, the key features are a team-based approach, continuous performance

of divergent and convergent thinking activities using thinking tool, and instructors' monitoring and feedback. First, in order to promote creative problem-solving activities by integrating the online support system in university courses, activities should be centered on teams rather than individuals. Like in the case of the college of engineering where team-based project is conducted, team-focused creative problem-solving activities using the online support system can further refine the opinions and thoughts of individual learners through interactions with fellow learners. In addition, team-based project activities can be performed effectively because individual learners can access and check the thoughts and opinions of team members created in the online support system anytime, anywhere. Ultimately, a team-based approach using the online support system improves the flexibility and elaboration of learners' thinking, enables continuous confirmation of opinions, and thereby creates new and challenging ideas and solutions in various ways.

Second, harmonious activities of divergent thinking and convergent thinking using appropriate tools should be conducted. Divergent thinking tools such as brainstorming and convergent thinking tools, such as HIT, PMI, and Evaluation Matrix in S3CPS, enable repetitive and continuous activities of both modes of thinking in the creative problem-solving activities of learners. Divergent thinking in creative problem-solving, which emerges in the process of finding out what the problem is and defining it and finding an original solution to a new hypothesis, creates a variety of new ideas. Convergent thinking makes it possible to select the optimal alternative through critical analysis and the evaluation of multiple ideas. The creative problem-solving process can be more effective when the two thinking activities are harmonized rather than being done separately.

Lastly, continuous monitoring and feedback from the instructor is required regarding the learner's creative problem-solving activities using the online support system. Monitoring and feedback from instructors provided during creative problem-solving activities in the case of the college of education and the evaluation stage in the case of the college of engineering promote guided participation for learners. Through this, learners can focus more on creative problem-solving activities, actively carry out activities, and perform reflective thinking on their own solutions.

Directions for improvement

It was confirmed through the case in the college of education, fine arts, and engineering that the design strategies for integrating and using the online support system, S³CPS for each course can indeed assist learners develop their creative problem-solving abilities. With this, suggestions on what improvements should be made in the future in order to

improve creative problem-solving skills, optimized through a comprehensive analysis, are as follows.

First, more emphasis should be placed on the importance of re-defining the problem and must be considered an important step in the creative problem-solving process. With the exception of the case of the college of education among the three aforementioned cases, activities focused mainly on the generation of ideas and the establishment of solutions. Many existing studies related to creative problem-solving also mainly focus on the creation and evaluation of ideas (Finke et al. 1992; Hunter et al. 2008). In addition, the exploration of predictor variables including curiosity is underway, which can have a positive impact on creative problem-solving (Hardy et al. 2017). However, the various problem situations that arise in the real world are interlocked with the rapidly changing environment, and the problem itself can change depending on the situation. It has complexity considering the characteristics of the site. Therefore, it is important to approach the problem itself because of the liquidity and complex characteristics. Since problem solving begins with the perception of what the problem is, not only can the derived creative results differ depending on how the learner defines the problem, but also a new perspective may be formed through the process of re-defining the problem. After clarifying the nature of the problem, the strategic planning activities of the learners to solve the problem can be more (Rubenstein et al. 2019).

Second, reflective activities should be strengthened in the creative problem-solving process and at the post-stage. In general, reflection means thinking deeply on one's learning experience by comprehensively looking back on what has been learned (Boud et al. 1985). A reflection journal not only organically connects existing knowledge with newly learned content but also serves a means to stimulate learners to change their behavior or to think, and to evaluate learning processes and results (Brodie 2007; Williams 2006). Reflection enables an analysis of the surrounding situation or environment. It can also help understand the nature of the problem in the process of analyzing the problem from various perspectives and creatively solving the problem. In addition, it can provide learners with opportunities for reflection, and strengthening reflection will have a positive impact on promoting thinking on how to approach and solve problems. This is because reflection serves as a catalyst for approaching a specific problem or situation from a new perspective and putting it into action through an analytical approach, and for facilitating the exploration of new approaches to solving the problems (Kolb 1984; Schön 1987). By providing learners with questions that can promote reflection, such as "What is the connection between the learning content and the creative problem-solving activities using online system at this stage?," "What strengths do an individual learner's ideas have when compared to other fellow learners' opinions

or ideas?," "What should be considered more when developing ideas as prototypes?" in the university courses that integrate the online support system, more effective problem-solving can be enabled with the continued reflective activities after the completion of creative problem-solving activity processes. Conducting reflective activities in the creative activity process will promote the creation of original ideas (Hao et al. 2016); furthermore, it will help internalize the learning content and critically check the learner's own thoughts, actions, situations, etc., to help form a mindset for new thoughts or actions. By linking them to the learners' own experiences, it will help embody the education content by encoding it into long-term memory of how to approach a situation that is similar to the content or problem learned through a university course.

Third, it is necessary to diversify plans for the use of thinking tools and the online support system. In the case of the college of education and the college of engineering, the activities were conducted in a blended learning environment, whereas in the case of the college of fine arts, the use of the online support system was achieved in an offline environment. In particular, some of the learner responses identified in the cases used in the blended learning environment utilized the online support system for simply writing comments in text form. The reason for this is that thinking tools, such as brainstorming, PMI, etc., are limited to writing ideas or opinions, and the usage plan of the support system in the online learning environment is limited to generating or reviewing ideas. Therefore, it is necessary to add thinking tools that allow various participation and activities to take place in the online environment as well. For example, Bernstein and Bernstein's (2013) thinking tools (Observing, Imaging, Abstracting, Recognizing Pattern, Pattern Forming, Analogizing, Body Thinking, Empathizing, Dimensional Thinking, Modeling, Playing, Transforming, Synthesizing), forced connection method, six thinking hats need to be supplemented and improved so that they can be used at each stage of the creative problem solving process. In addition, specific plans are needed on how to utilize the online support system. One option is to consider seamless learning using the online support system. For example, if the focus is on re-defining what the problem is in the offline environment, it should be considered that learners not only write their opinions about specific problems or tasks in everyday life in the online learning environment using S³CPS, but also find or discover the various materials needed to solve the problem in real life and accumulate them in the system, as well as perform various data collection and analysis activities necessary for problem solving. This will enable students to investigate more diverse phenomena in everyday life, beyond what they have learned, and to demonstrate principles and knowledge in other situations.

Conclusion

The purpose of this study is to present key design strategies to be considered in order to achieve the optimal operation by reviewing three cases of integrating and utilizing the online support system that can effectively support creative problem solving in university courses. In addition, the goals were to check whether the online support system S³CPS developed based on learner responses is applicable to university courses and to derive future research and directions for improvement. To this end, this study confirmed the possibility of integrated use of the support system for solving creative problems in university courses by comprehensively analyzing the cases in the college of education, fine arts, and engineering at 'S' University in Korea, which applied S³CPS based on the creative problem solving model of Treffinger et al. (2000). As a result of a comprehensive analysis of the three cases, it was determined that for the effective use of the online support system, it was essential that information on the online support system and how to use it must be learned in the pre- and early stages of operations and that the design of authentic tasks should be considered. In the operational phase, it is necessary that a team-based approach be taken in terms of activities, that a harmonious linkage exist between divergent thinking and convergent thinking activities using the tools of the online support system, and that instructor monitor and provide feedback regarding the creative problem-solving activities. It has been shown that the above strategies help learners diversify ideas and converge them in performing creative problem solving activities using the online support system and promote creative problem-solving activities regardless of time and place. Strategies such as the continuous monitoring by instructors and the provision of feedback will facilitate participation in problem solving activities. Ultimately, the integrated use of the online support system in university courses provides ease of access to creative problem-solving activities and helps promote creative thinking.

Through this study, major design strategies and directions for integrating S³CPS system with the university courses were suggested. This study confirmed the effectiveness of design strategies based on learner responses. However, it is necessary to study the overall responses by identifying how the instructors responded in addition to the learners' responses. This study is meaningful in that it provides practical guidance on how to integrate the online support system to improve creative problem solving abilities reflecting the different circumstances of each course.

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