International Journal on Advanced Science Engineering Information Technology

Vol.12 (2022) No. 4
ISSN: 2088-5334

Effects of Science, Mathematics, and Informatics Convergence Education on Creative Problem-solving

Seong-Won Kim [a], Youngjun Lee [b,*]

[a] *Dept. of computer education, Silla University, 140, Baegyang-daero, Sasang-gu, Busan, 46958, Republic of Korea*
[b] *Dept. of computer education, Korea National University of Education, 250 Taeseongtabyeon-ro, Cheongju, 28173, Republic of Korea*
*Corresponding author: *yjlee@knue.ac.kr*

Abstract*— The Fourth Industrial Revolution led to accelerated development and promotion of software (SW) usage in various fields. SW has been integrated into various areas to address multiple problems. As the importance of SW convergence increased, the need for SW convergence talent concomitantly increased. Korea implemented the "Science, Mathematics and Information Education Promotion Act" in 2018 to cultivate SW convergence talents. The Act includes not only the promotion of individual subjects but also science, mathematics, and information convergence education (SMICE). With the Act's enforcement, education programs for SMICE have been formulated. A study analyzed student satisfaction and perception regarding SMICE, but its effect on student education was not analyzed. Therefore, the present study analyzed the effects of SMICE on middle school students. The subjects comprised 163 middle school students who were divided into experimental and control groups. The control (n=83) received general informatics education. The experimental group (n=80) received both informatics education and SMICE. Creative problem-solving (CPS), a common competency of the three subjects, was selected as the test factor to analyze the educational effect. Changes in student CPS were examined using pre-and post-tests. The results showed no difference in the pre-test CPS between the experimental and control groups. The post-test results showed that the experimental group had higher CPS than the control. Notably, there was a significant increase in problem discovery and analysis, idea generation, persuasion, and communication metrics. These findings demonstrated that SMICE is effective in the CPS development of middle school students.

***Keywords*— Science, mathematics, informatics convergence education; creative problem-solving ability; convergence education; middle school students; software education; multi-disciplinary.**

Manuscript received 5 Feb. 2021; revised 15 Aug. 2021; accepted 10 Mar. 2022. Date of publication 31 Aug. 2022.

I. INTRODUCTION

New changes have emerged as computing has improved and merged with the existing domain. These changes are seen not only in industry, but also in society, economy, culture, and in the shape of life. Computing technologies, such as artificial intelligence and IoT, have led the fourth industrial revolution. Unlike the previous industrial revolution, the fourth industrial revolution had a fast pace of change and a wide range [1]. This is because SoftWare(SW) has been integrated into the existing domain (such as a SW+X), innovatively solving problems that have remained unsolved. This promoted the emergence of new industries and broader and more complex problems to solve than the existing ones [2]. To solve these new problems, there is a need for creative convergence talents who can solve problems by the convergence of knowledge from various fields [3], [4].

The need for convergence education has emerged to cultivate creative and convergent talents. In Korea, Science, Technology, Engineering, Arts, and Mathematics (STEAM), which added arts to Science, Technology, Engineering, and Mathematics (STEM), was introduced to the schools to cultivate convergence talents [5]. STEAM education aims to increase students' interest and understanding of science and technology by the convergence of subjects, and to cultivate convergence thinking skills based on science and technology and problem-solving skills [5], [6].

However, STEAM education has been difficult to activate due to certain limitations in schools. Lim [7] noted that STEAM education convergence was focused only on the knowledge of several subjects, and this limited STEAM to the situation where much subject knowledge was convergent. Therefore, there was no linkage or consistency between subjects or grades in STEAM convergence education [7], [8]. The observed convergence education could not develop competencies, such as science inquiry ability, STEAM literacy, engineering problem solving, and convergence attitude.

Further, convergence education combines knowledge of several subjects, and more content is learned than possible in a single subject. Therefore, convergence education seems to increase the cognitive burden on learners [7], [8]. Kim and Lee [9] analyzed the research trends of STEAM education and indicated that only 5% of STEAM studies used programming

The development of computing has promoted its convergence with other domains. As new domains and industries emerge through convergence, the demand for education to cultivate SW convergence talents has increased [10]. However, the problems of convergence education hinder fostering creative and convergent talents [9], [11]. Some studies have started addressing the limitations of convergence education by cultivating SW convergence talents in integrated science, mathematics, and informatics subjects [9], [12–[14]. The reason is that mathematics and science subjects are similar to informatics subjects and problem-solving processes. Thus, Korea has been implementing the 'Science, Mathematics, and Informatics Education Promotion Law' since 2018 to promote convergence between science, mathematics, and informatics subjects and to promote convergence education in schools. This law was previously enacted to promote science education, but as the importance of informatics education increased with changes such as the fourth industrial revolution, the law was revised to support convergence education in science, mathematics, and informatics subjects [15], [16].

Although the Science, Mathematics, and Informatics Education Promotion Law was implemented, the application of Science, Mathematics, and Informatics Convergence Education (SMICE) at school sites is insufficient, and research on SMICE is not actively conducted. Therefore, this study aimed to apply SMICE in middle school and conducted a study to analyze the effects of SMICE on middle school students.

II. Material and Method

A. Research Overview

This study analyzed the effects of SMICE on the CPS of middle school students. The study's middle school students were divided into experimental and control groups. Both groups received informatics education, whereas the experimental group also received SMICE. The effect of SMICE on the CPS of middle school students was analyzed using pre- and post-results.

B. Participants

The research subjects were 163 middle school students, 80 students in the experimental group and 83 in the control group. The research subjects were students who agreed to participate in this study and faithfully participated in the treatment and pre-test and post-test assessments.

The characteristics of the research subjects showed more females (53.37%) than males (46.63%), although there was no significant difference between males and females. The gender ratio was similar in the experimental group and the control group. There were no sophomores or juniors, and all the subjects were freshman.

More than 80% of both groups answered 'yes' to having experienced SW education. The most experienced programming languages were blocks, followed by experience with both block and text-based programming languages, only text experience, and no programming language experience. More than 75% of the students had experienced physical computing. The average value of the interest in software education was 3.42 in the control group and 3.39 in the experimental group.

C. Measurement

The Creative Problem Solving Profile Inventory (CPSPI) developed by Lee, Pyo, and Choe [18] was used to measure the creative problem-solving ability (CPS) of middle school students. CPSPI is a test tool developed to complement the limitations of the existing CPS test tools. To proceed with the analysis of the literature review on creative problem solving for the development of CPSPI, sub-factors were derived CPSPI: Problem Finding and Analysis (PFA), Idea Generation (IG), Execution Plan (EP), Execution (EX), and Persuasion and Communication (PC). Sub-items were developed for each derived factor, and reliability and validity were verified through item and exploratory factor analysis. There are 39 questions in the test tool, with responses based on a 5-point Likert scale. The Cronbach's value of the test tool ranged from .73 to .83. The characteristics of the test tool used in this study are shown in Table 1.

TABLE I
TEST TOOL

Factor	Definition	N	Cronbach's α
PFA	Which a new question or problem is found in an unstructured problem situation	9	.80
IG	The process of creating as diverse and original ideas as possible for problem-solving.	8	.83
EP	The factor of carefully evaluating the ideas obtained from the idea, selecting the optimal alternative, constantly improving the idea to make it real, and devising a concrete action plan	10	.76
EX	The process of implementing a planned idea with confidence and making it a reality	5	.73
PC	The process of persuading others about the merits of the outcome of their own execution and drawing empathy	7	.81

D. Materials

As the Science and Mathematics Informatics Education Promotion Law was revised, Lee et al. [17] developed an educational program to activate SMICE. To develop a SMICE program, professors and teachers in science, mathematics, and informatics education collaborated to develop convergence types, themes, learning goals, teaching-learning, and educational content. The developed SMICE program was administered to students to investigate site suitability and satisfaction in the field, and teachers verified the validity of the SMICE program.

The existing convergence education was conducted with a focus on 'convergence'. Therefore, although a lot of knowledge of various subjects was presented, there was no actual convergence but rather an increase in students' cognitive burden. This caused difficulties in achieving academic achievement for students [7], [8]. In the SMICE program, three types of convergence were defined to promote meaningful convergence between science, mathematics, and informatics subjects and to develop competency emphasized in the 2015 revised curriculum. The types of convergence are 'Convergence of Subject Knowledge (CSK)', 'Real Life Problem-Solving (RLPS)', and 'Creative-Activities Curriculum and Free Semester (CACFS)'.

CSK indicates that the Core Subject (CS) exists, and the knowledge of Supplement Subjects (SS) is converged to achieve the learning goal of the core subject. For example, if science is the CS, then the mathematics or informatics subject is SS. Therefore, to achieve the learning goal of a science subject, the knowledge previously learned in mathematics and informatics subjects (knowledge learned in elementary school) is converged. RLPS is designed so that self-directed learning can be achieved by utilizing knowledge of SS for enrichment learning of CS. Lastly, CACFS is developed to solve problems in cooperation with teachers or colleagues to achieve the learning goals of the CS.

CSK was developed to be used in a regular class, whereas RLPS was developed to be used in after-school classes, and CACFS was developed to be used in creative-experience activities or free semester classes [12], [17]. The SMICE program was developed for middle and high school students. The block-based programming language (e.g., Scratch and Entry) for middle school students and the text-based programming language (e.g., Python) for high school textbooks were used in the informatics subject.

In the SMICE program, convergence education was based on the core competencies of the subject. Therefore, the common competencies of science, mathematics, and informatics subjects were derived, and the teaching-learning process was designed based on the common competencies. The core competencies of the science, mathematics and informatics subjects were analyzed in the 2015 revised curriculum to derive common competencies. So, the problem-solving ability was derived as a common competency [15]. As a result of comparing the problem-solving process of the three subjects, the teaching-learning process was designed with understanding-design-implement-evaluation. In the 'understanding' stage, the problem is comprehended, and the relevant factors are derived to solve the problem. In the 'design' stage, a problem is structured (problem decomposition, pattern recognition, and abstraction), and an algorithm is designed and 'executed' to solve the problem. In the 'implement' stage, program screening and programming are performed. Lastly, in the 'evaluation' step, problem-solving is evaluated through the output result according to the input from the program [17].

The educational program derived three themes: the CS of science, mathematics, and informatics by convergence type (CSK, RLPS, and CACFS) [17]. Further, an educational program was developed based on the theme.

E. *Treatments*

Middle schools in Korea are taught as a compulsory state-led curriculum. Therefore, except for schools operated for special purposes, all middle schools in Korea should be taught based on the same curriculum. Although textbooks are different for each school, the same educational content is taught, as the textbooks are also certified by the country. Therefore, the informatics education treatment was the same in each school. It was difficult to conduct different treatments for each class in one school, so treatments were performed at two schools. One school recruited an experimental group, which received informatics education and SMICE, while the other school was set as a control group and received informatics education.

The treatments were conducted for two months, from December 2019 to January 2020 (9 hours). The control group received treatment based on the middle school informatics curriculum of the 2015 revised curriculum in Korea. The main contents of the treatment were algorithm design and programming for problem-solving. Teaching-learning proceeded in the order of explanation of learning content, algorithm, problem-solving by programming, and problem application.

The experimental group conducted the same informatics education as the control group and treated the SMICE program. The SMICE program was conducted based on the middle school textbook developed by Lee et al. [17]. The teaching-learning process proceeded in the following order: understanding-design-implement-evaluation.

The programming language used Entry in the control and experimental groups. In the 2015 revised curriculum, a block-based programming language is recommended for middle school informatics subjects, and all textbooks were written using block-based programming. Therefore, as indicated by Lee et al. [17], textbooks developed for middle school students were developed using a block-based programming language.

As a block-based programming language, Scratch is usually used. However, informatics education uses Entry more in Korean elementary and middle schools. Entry is a block-based programming language similar to Scratch, but it has been developed as an educational tool suitable for the educational field in Korea [20]. It is a block-based programming language that is widely used in Korea by continuously supporting new blocks or functions at the request of Korean teachers or researchers. Thus, in the treatments performed in this study, Entry was used as the programming language.

F. *Analysis*

This study assessed the effect of SMICE on the CPS of middle school students. The differences between the two groups in the pre-test - and post-test were analyzed using an independent sample t-test. To evaluate the group-specific changes according to the treatment, pre-test and post-test were analyzed by the paired sample t-test.

III. Results and Discussion

A. Results

In the pre-test results, there was no statistically significant difference in creative problem-solving abilities between the experimental group (M = 2.95, SD = .43) and the control group (M = 2.94, SD = .41), t = -.14, p = .89. Also, PFA (t = -.14, p = .89), IG (t = .62, p = .54), EP (t = -.47, p = .64), EX (t = -1.25, p = .21), and PC (t = 1.30, p = .19) did not show any significant difference. These results confirmed that the CPS of the experimental and control groups was not different before treatment was performed. Although the schools of the experimental and control groups were not the same, there was no difference in the CPS of the two groups because education was delivered using the same curriculum.

In the control group, CPS was improved in the post-test (M= 2.98, SD= .49) than in the pre-test (M= 2.94, SD= .41). However, the difference between the pre-test and post-test was not statistically significant, t = -.60, p =.55. There were no statistically significant differences in PFA (t = -.03, p = .98), IG (t = -.13, p = .90), EP (t = -.49, p = .63), EX (t = -1.67, p = .10), and PC (t =.60, p = .55). Therefore, middle school students who received informatics education did not show any significant change in their CPS. According to these results, the control group did not exhibit a significant change in CPS due to the treatment. The change in CPS of the control group is shown in Table 2.

TABLE Ⅱ
Independent Samples t-test Results in Control Group

	Test	*M*	*SD*	*t*	*p*
PFA	Pre	2.73	.78	-.03	.98
	Post	2.73	.79		
IG	Pre	2.82	.63	-.13	.90
	Post	2.83	.62		
EP	Pre	3.24	.71	-.49	.63
	Post	3.30	.70		
EX	Pre	2.57	.79	-1.67	.10
	Post	2.77	.72		
PC	Pre	3.58	.95	.60	.55
	Post	3.50	.85		
Total	Pre	2.94	.41	-.60	.55
	Post	2.98	.49		

In the experimental group, the CPS was improved in the post-test (M = 3.27, SD = .59) than in the pre-test (M = 2.95, SD = .43). Unlike the control group, the difference between the pre-test and post-test in the experimental group was statistically significant, t = -3.73, p < .01. In all detailed factors, the value of the post-test was improved compared to the pre-test. There was a statistically significant difference in PFA (t = -2.45, p = .02), IG (t = -3.70, p <.01), and PC (t = -3.37, p <.01). However, there was no statistically significant difference in the EP (t = -1.97, p = .05) and EX (t = -1.76, p = .09). These findings confirmed that SMICE had a significant effect on middle school students' CPS, with problem discovery and analysis, idea generation, persuasion, and communication being the main factors driving this outcome. The change in CPS of the experimental group is shown in Table 3.

TABLE Ⅲ
Independent Samples t-test Results in the Experimental Group

	Test	*M*	*SD*	*t*	*p*
PFA	Pre	2.75	.85	-2.45	.02*
	Post	3.08	.87		
IG	Pre	2.76	.60	-3.70	.00*
	Post	3.16	.70		
EP	Pre	3.29	.71	-1.97	.05*
	Post	3.54	.77		
EX	Pre	2.72	.78	-1.73	.09
	Post	2.97	.81		
PC	Pre	3.41	.72	-3.37	.00*
	Post	3.79	.68		
Total	Pre	2.95	.43	-3.73	.00*
	Post	3.27	.59		

*p< .05

The CPS of the experimental group (M = 2.98, SD = .49) was higher than that of the control group (M = 3.27, SD = .59), and the difference between the two groups was statistically significant, t = -3.34, p < .01. In the pre-test results, there was no difference between the control group and the experimental group, and the change in CPS appeared only in the experimental group. This indicates that SMICE was effective in improving CPS for middle school students.

The experimental group's CPS exhibited higher values in all detailed factors than the control group. However, the factors that showed statistically significant differences were PFA (t = -2.64, p = .01), IG (t = -3.18, p < .01), and EP (t = -2.10, p = .04), and PC (t = -2.42, p = .02); there was no significant difference in EX (t = -1.66, p = .10). In the experimental group, significant changes were found only in PFA, IG, and PC. Given the limit in interpreting the significant difference in the EP as an effect of SMICE, these findings suggest that SMICE exerted a significant effect on the PFA, IG, and PC factors as indicators of the creative problem-solving abilities of middle school students. Middle school students' CPS in pre- and post-test is shown in Fig. 1.

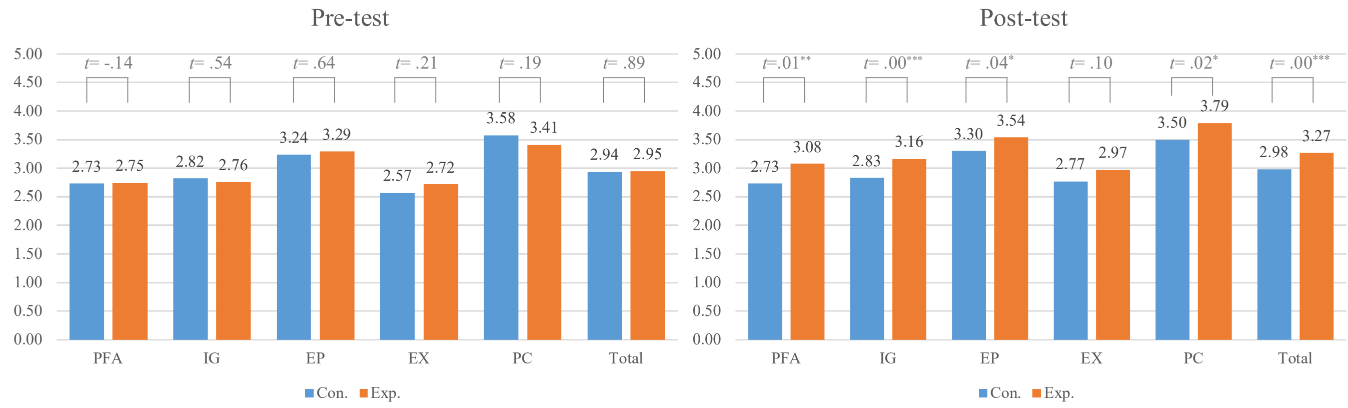

Fig. 1 Middle school students' CPS in pre- and post-test

B. *Discussion*

By executing SMICE, the creative problem-solving abilities of middle school students were improved. However, improvements were only significant in PFA, IG, and PC.

PFA has a high correlation with curiosity, flexibility, and originality and refers to the ability to define problems by analyzing new problems from multiple directions in unstructured situations (such as real-life) [22], [23], [24]. SMICE is designed for students to experience the process of understanding the problem, structuring the problem, and extracting the core concepts in the problem situation based on real-life topics [17], [18]. Since SMICE uses topics that can be encountered in real life, it can induce interest, participation, and motivation for learning, unlike existing classes [5], [19], [22]. Also, SMICE delivers the contents of the CS based on the knowledge of the SS previously studied, and the process of defining problems is based on the learned contents. The learner experiences the process of core concepts from problems using real-life topics and defining problems by using the learned content. Therefore, cognitive structures are developed with new knowledge based on already learned knowledge. This process is more effective in expanding the learner's cognitive structure than learning a single subject, which can promote the learner's experience of generating new ideas through the convergence of their knowledge by learning [22]. Thus, learners can develop curiosity, flexibility, and originality based on real-life topics [23], [24]. The findings of this study showed that the PFA of middle school students improved through SMICE.

IG is related to fluency and originality and refers to the ability to generate various ideas [22], [24]. Park et al. [25] posited that IG is related to convergence literacy that can be developed when multiple subjects are converged. Han [26] confirmed that convergence literacy does not develop even with mathematics subject-centered convergence education. Unlike previous studies, this study showed an improvement in IG, indicating an improvement in convergence literacy. In this study, science, mathematics, and informatics, which are adjacent subjects, were converged, and convergence education was conducted by deriving the common competencies of the three subjects. These results confirmed that, unlike the existing convergence education, SMICE has an effect on the development of convergent literacy when the education is conducted using the common competencies of the three subjects.

Moreover, fluency and originality, which are the factors for IG, also constitute creativity [24]. According to Lee et al. [17], convergence education effectively improves creativity and problem-solving ability. PFA and IG are related to the sub-factors of creativity. Improvements in PFA and IG demonstrated that SMICE is also effective in developing creativity. This observation is consistent with other studies that showed that experiencing the process of solving problems by the convergence of multiple subjects is effective for the development of creativity [5], [27], [28].

PC develops by elaborating one's thoughts, embodying learned knowledge, and obtaining feedback on the results of EX [18], [29]. In SMICE, the output according to the input of the self-produced program is assessed in the 'evaluating' stage. Learners experience the process of inferring the relationship between inputs and outputs, confirming new facts based on previously learned content, debugging programs, or applying them to new problems. Debugging or application in programming provides the learner with reflection. In the programming learning process, reflection provides learners with elaboration and clarification of knowledge [13], [14], [21]. Therefore, PC was developed through activities conducted in the 'evaluating' stage.

PC includes communication and the ability to persuade others to empathize. The core competencies pursued in Korea's convergence education are convergence, creativity, communication, and caring [5]. Our results showed improved communication, indicating an improvement of PC [18]. Thus, SMICE is effective in developing competency aimed at the existing convergence education [5], [25].

Unlike other factors, there was no significant improvement in EP and EX. The necessary knowledge is collected in EP to make a practical plan, and the collected knowledge is compared and confirmed. Therefore, EP shows a high correlation with factors such as efficiency and knowledge in creative motivation [18], [22], [30]. Previous studies have shown that learners' cognitive burden increases in the convergence of knowledge of various subjects [7], [8]. Science, mathematics, and informatics subjects have similar problem-solving processes, but in SMICE, learners proceed with solving problems using knowledge of each subject [31]. As stated earlier, although it is effective to combine the three subjects in the process of learning knowledge and analyzing problems, the process of designing algorithms and programming to solve problems acted as a cognitive burden on learners [7], [8]. In this study, a block-based programming language was used in consideration of the learner's cognitive level. However, students actually had a lot of difficulties in learning the programming language [13], [14], [21]. In situations where difficulties exist in the programming learning process, utilizing and converging the knowledge of the three subjects' places more cognitive burden on the learner.

In considering the opinions of teachers who actually conducted SMICE, there were many cases where students could not properly recall or did not know the contents of the convergence subject. In SMICE, the CS is learned in class, but the SS is configured to utilize the knowledge previously learned [12], [17]. However, there were indications that the learner felt a lot of cognitive burden in the process of solving the problem. There were many cases where learners had difficulties in activities included in the action plan factors, and additional time was needed to explain the contents related to convergence education [21]. In this study, three hours of treatment were allocated for each subject. However, more time was needed, depending on the level of students. Thus, the development of the EP in middle school students was difficult due to the characteristics of SMICE.

EX is the stage of executing a planned idea and finding the answer to a problem. EX is related to the willingness and confidence to solve a problem and has a high correlation with efficacy [32]. Efficacy refers to the judgment of the ability to organize and execute the actions necessary to perform a task [33]. Since efficacy is a result of recognition, "perceived efficacy" and "belief or expectation of self-efficacy" are inferred [34]. Bandura [34], [35] argued that it is necessary to provide an achievement experience to improve efficacy. When student experiences achievements in various situations, a belief is formed that students can do well on their own. These beliefs improve efficacy so students can solve problems independently [36], [37]. Therefore, it is important to form a belief to improve efficacy. Conviction is the most reliable method of actual achievement experience, and it is necessary to proceed with tasks at a level lower than students' ability for achievement experience [33], [38]. As described earlier, SMICE was found to induce cognitive burden in students [39]. Cognitive burden hinders the learner from forming a belief in problem-solving, and because a belief cannot be formed, a significant improvement in efficacy cannot be achieved [7], [8], [40], [41]. Thus, SMICE did not significantly affect EX, as shown in this study.

IV. Conclusion

This study analyzed the effect of SMICE on the CPS of middle school students. The conclusions obtained through this study are as follows. First, SMICE was effective in improving the CPS of middle school students. The group who received additional treatment of SMICE showed a significant improvement in CPS, observed by the change of pre-test and post-test scores compared to the group receiving only informatics education.

Second, SMICE was effective in achieving the goal of convergence education. Convergence education in Korea aims at convergence, creativity, communication, and caring. In this study, SMICE significantly affected the PFA, IG, and PC components of CPS. PFA (convergence), IG (creativity), and PC (communication and caring) are factors related to the competencies of convergence education. Thus, SMICE is effective in achieving the goal of convergence education.

However, SMICE did not significantly change CPS's EP and EX components. These factors describe the EP of CPS. Convergence education in Korea presents context presentation, creative design, and emotional touch as teaching-learning criteria. SMICE satisfies the presentation of situations by presenting real-life problems. Teaching-learning is constructed for the experience of success or failure (emotional experience) through idea expression and artifacts (creative design). However, there was no significant improvement in EP and EX related to creative design and emotional experience. This problem was due to the cognitive burden in the existing convergence education research. Although SMICE achieves the goal of convergence education, it exhibited the same problems encountered in the existing convergence education. Therefore, in future research, the SMICE program should be improved by adjusting the teaching-learning process, the amount of learning, and the number of hours executing the program.

Given that problem-solving ability is included as the goal of convergence education, this study measured CPS to analyze the effect of SMICE. The educational goals of convergence education include problem-solving skills, interests, and attitudes toward convergence. As new things are created through convergence, analyzing educational effects such as convergence literacy is necessary. Furthermore, investigations on the effects of the core competencies of science, mathematics, and informatics subjects are needed. Therefore, research should be conducted to analyze not only CPS, but also attitude toward convergence, literacy, science, mathematics, and core competencies of informatics subjects.

Acknowledgment

Basic Science Research Program supported this research through the National Research Foundation of Korea (NRF) funded by the Ministry of Education (No. 2019R1I1A3A01060920)

References

[1] J. J. Yoo, E. E. Günay, K. Park, S. Tahamtan, and G. E. Okudan Kremer, "An intelligent learning framework for Industry 4.0 through automated planning," Computer Applications in Engineering Education, no. SE, Jan. 2021.

[2] F. J. Cantú-Ortiz, N. G. Sánchez, L. Garrido, H. Terashima-Marin, and R. F. Brena, "An artificial intelligence educational strategy for the digital transformation," International Journal on Interactive Design and Manufacturing (IJIDeM), vol. 14, no. 4, pp. 1195-1209, Sep. 2020.

[3] D. J. Herr, B. Akbar, J. Brummet, S. Flores, A. Gordon, B. Gray, and J. Murday, "Convergence education—an international perspective," Journal of Nanoparticle Research, vol. 21, no. 11, pp. 1-6, Nov. 2019.

[4] S. W. Kim and Y. Lee, "An investigation of teachers' Perception on STEAM education teachers' training Program according to School Level," Indian Journal of Public Health, vol. 9, no. 9, pp. 256-263, 2018.

[5] Y. Back, H. J. Park, Y. Kim, S. Noh, J. Y. Park, Y. Lee, ... and H. Han, "STEAM Education in Korea," The Journal of Learner-Centered Curriculum and Instruction, vol. 11, pp. 149-171, Nov. 2011.

[6] H. J. Park, Y. Kim, S. Noh, J. Lee, J. S. Jeong, Y. Choi, ... & Y. Baek, "Components of 4C-STEAM Education and a Checklist for the Instructional Design," The Journal of Learner-Centered Curriculum and Instruction, vol. 12, no. 4, pp. 533-557, Apr. 2012.

[7] Y. Lim, "Problems and Ways to Improve Korean STEAM Education based on Integrated Curriculum," The Journal of Elementary Education, vol. 25, no. 4, pp. 53-80, Nov. 2012.
[8] J. Sim, Y. R. Lee, and H. K. Kim, "Understanding STEM, STEAM Education, and Addressing the Issues Facing STEAM in the Korean Context," Journal of the Korean Association for Science Education, vol. 35, no. 4, pp. 709-723, Aug. 2015.
[9] S. W. Kim and Y. Lee, "The analysis on research trends in programming based STEAM education in Korea," Indian Journal of Science and Technology, vol. 9, no. 24, pp. 1-11, 2016.
[10] S. W. Kim and Y. Lee, "The analysis on research trends for software education in Korea," Journal of Engineering and Applied Sciences, vol. 13, no. SE2, pp. 2951-2956, 2018.
[11] S. H. Paik, S. W. Kim, and Y. Lee, "A study on teachers practices of STEAM education in Korea," International Journal of Pure and Applied Mathematics, vol. 118(19), pp. 2339-2365, 2018.
[12] W. Jung and Y. Lee, "Content Analysis on the Curriculum Achievement Standards in the Software·Mathematics·Science Convergence Teaching and Learning Material," The Journal of Korean Association of Computer Education, vol. 21, no. 5, pp. 11-23, Sep. 2018.
[13] S. W. Kim and Y. Lee, "A Study Of Educational Method Using App Inventor for Elementary Computing Education," Journal of Theoretical & Applied Information Technology, vol. 95, no. 18, Sep. 2017.
[14] S. W. Kim and Y. Lee, "Development and Application of Arduino-Based Education Program For High School Students'," Journal of Theoretical & Applied Information Technology, vol. 95, no. 18, Sep. 2017.
[15] E. Lee, "Perspectives and Challenges of Informatics Education: Suggestions for the Informatics Curriculum Revision," The Journal of Korean Association of Computer Education, vol. 21, no. 2, pp. 1-10, Mar. 2018.
[16] National Assembly of South Korea (2018), "Enforcement Decree of the Science, Mathematics, and Information Education Promotion Act," Available: http://www.yeslaw.com/lims/front/page/fulltext.html?pAct=view&pLawId=2063
[17] Y. Lee, S. Kim, J. Kim, S. Paik, J. Yoon, K. Lee, ... & Hong, E, SW, Mathematics and Science Convergence Project for Creative Thinking. Seoul, Republic of Korea: Emotionbooks, 2018.
[18] H. Lee, J. M. Pyo, and I. Choe, "Development and Validity of Creative Problem Solving Profile Inventory (CPSPI)," Journal of Gifted/Talented Education, vol. 24, no. 5, pp. 733-755, Dec. 2014.
[19] S. W. Kim and Y. Lee, "The Effects of the TPACK-P Educational Program on Teachers' TPACK: Programming as a Technological Tool," International Journal of Engineering & Technology, vol. 7, no. 3.34, pp. 636-643, 2018
[20] W. C. Hsu and J. Gainsburg, "Hybrid and Non-Hybrid Block-Based Programming Languages in an Introductory College Computer-Science Course," Journal of Educational Computing Research, Jan. 2021.
[21] S. W. Kim and Y. Lee, "An Analysis of Pre-service Teachers' Learning Process in Programming Learning," International Journal on Advanced Science, Engineering and Information Technology, vol. 1, pp. 58-69, 2020.
[22] M. B. Calavia, T. Blanco, and R. Casas, "Fostering Creativity as a Problem-Solving Competence through Design: Think-Create-Learn, a Tool for Teachers," Thinking Skills and Creativity, vol. 39, Mar. 2021.
[23] C. Moruzzi, "Measuring creativity: an account of natural and artificial creativity," European Journal for Philosophy of Science, vol. 11, no. 1, pp. 1-20, Oct. 2021.
[24] A. Mróz and I. Ocetkiewicz, "Creativity for Sustainability: How Do Polish Teachers Develop Students' Creativity Competence? Analysis of Research Results," Sustainability, vol. 13, no. 2, pp. 571, 2021.
[25] H. J. Park, Y. Baek, J. Sim, J. S. Jeong, S. Byun, N. Kang, ... & H. Lee, "Research Results Report of STEAM Education Survey and Effectiveness In-depth Analysis in 2015, KOFAC research report, 2016.
[26] H. Han, "The Effects of Mathematics-Centered STEAM Program on Middle School Students' Interest in STEM Career and Integrated Problem Solving Ability," Communications of Mathematical Education, vol. 31, no. 1, pp. 125-147, Mar. 2017.
[27] F. A. U. Anindya and I. U. Wusqo, "The Influence of PjBL-STEAM model toward students' problem-solving skills on light and optical instruments topic," In Journal of Physics: Conference Series, June, 2020, Vol. 1567, No. 4, p. 042054, IOP Publishing.
[28] M. Sanders, "A rationale for new approaches to STEM education and STEM education graduate programs," Paper presented at the 93rd Mississippi Valley Technology Teacher Education Conference, 2006, Nashville, TN.
[29] V. Dolgopolovas and V. Dagienė, "Computational thinking: Enhancing STEAM and engineering education, from theory to practice," Computer Applications in Engineering Education. no. SE, Jan. 2021.
[30] C. Conradty, S. A. Sotiriou, and F. X. Bogner, "How creativity in STEAM modules intervenes with self-efficacy and motivation," Education Sciences, vol. 10, no. 3, pp. 70, 2020.
[31] Y. Nam, J. Yoon, H, Han, and J. Jeong, "x: Comparison of Problem Solving Processes in Science(S), Engineering(E), Mathematic(M), and Computational Thinking(CT)," The Journal of Korean Association of Computer Education, vol. 22, no. 3, pp. 37-54, May 2019.
[32] S. W. Kim and Y. Lee, "Effects of Software Education Using Robots in the Creative Problem-Solving Ability of Middle School Students," The Journal of Korean Association of Computer Education, vol. 23, no. 5, pp. 13-22, Nov. 2020.
[33] A. Kim, "self-efficacy and academic motivation, "The Korean Journal of Educational Methodology Studies, vol. 16, no. 2, pp. 1-38, Feb. 2004.
[34] A. Bandura, "Self-efficacy: toward a unifying theory of behavioral change," Psychological review, vol. 84, no. 2, pp. 191, 1977.
[35] D. L. Webb and K. P. LoFaro, "Sources of engineering teaching self-efficacy in a STEAM methods course for elementary preservice teachers," School Science and Mathematics, vol. 120, no. 4, pp. 209-219, Apr. 2020.
[36] S. W. Kim and Y. Lee, "The Effects of the TPACK-P Education Program on Teaching Expertise of Pre-service Teachers'," Indian Journal of Public Health Research & Development, vol. 9, no. 8, 2018.
[37] C. Conradty and F. X. Bogner, "From STEM to STEAM: How to monitor creativity," Creativity Research Journal, vol. 30, no. 3, pp. 233-240, Sep. 2018.
[38] C. Conradty and F. X. Bogner, "STEAM teaching professional development works: effects on students' creativity and motivation," Smart Learning Environments, vol. 7, no. 1, pp. 1-20, Oct. 2020.
[39] Ľ. Valovičová, J. Ondruška, Ľ. Zelenický, V. Chytrý, and J. Medová, "Enhancing Computational Thinking through Interdisciplinary STEAM Activities Using Tablets," Mathematics, vol. 8, no. 12, pp. 2128, Oct. 2020.
[40] J. A. Kim and H. Kim, "Meta-analysis of researches of STEAM with coding education–in Korea," In International Conference on Computational Science and Its Applications, June 2019, pp. 82-89, Springer, Cham.
[41] H. Hu, Y. Li, Y. Yang, Y. Su, and S. Du, "The Relationship Between STEAM Instruction, Design Thinking and Deeper Learning," International Journal of Engineering Education, vol. 36, no. 5, pp. 1448-1460, 2020.