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Analysis of The on-Site Implementation Effects of Textbooks for Operating a Creative Convergence it Education Program

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ABSTRACT
Information Technology (IT) exerts significant influence across societies and is regarded as a key driver of the Fourth Industrial Revolution. The aim of this paper is to present the results of applying the creative convergence information education program materials developed by the Creative Education Center of Jeju National University in school settings. The developed materials comprise 20 types, including 7 related to humanities in artificial intelligence (AI), 8 to forensic science, and 5 to digital therapeutics. These materials were administered to 701 elementary and secondary students nationwide, with an overall satisfaction rate of 4.25, indicating a high level of contentment. Additionally, prior to and after applying the materials, students' creativity and core competencies were assessed. Both elementary and secondary students demonstrated statistically significant improvements in creativity and core competencies ($p<.001$). Through this paper, we hope to offer insights into educational strategies for teaching intricate ITs in an engaging and accessible manner to elementary and secondary students within the public curriculum.

Keywords: IT Education, Creativity, Core Competency, satisfaction survey, Textbook Development

1. INTRODUCTION

In the face of increasing uncertainty and volatility in future societies, there is an imperative for students to cultivate problem-solving skills rooted in creativity. Furthermore, the ability to integrate knowledge from disparate fields and a foundational understanding of Information Technology (IT) become paramount (Choi et al., 2022; Choi & Park, 2021; Burgsteiner et al., 2016). Among these, IT stands out, having profound implications across sectors, and is deemed a crucial driver of the Fourth Industrial Revolution. Hence, it's not solely the realm of higher education to impart IT knowledge; it is essential to nurture elementary and secondary students with the principles of IT, equipping them with the capacity for creative problem-solving from early on.

In contemporary society, information education plays an essential role in addressing and solving unpredictable challenges (Priemer et al., 2020). As digital technology is anticipated to play a pivotal role in an increasing number of domains, it's imperative for elementary and secondary students to grasp the principles of information technology and develop the acumen to utilize it (Kim & Park, 2012). In South Korea, since the 6th curriculum, middle schools introduced computer subjects, and during the 7th curriculum, high schools initiated courses on the information society and computers (Sung, 2022). Subsequently, in 2014, recognizing software as the future's backbone, the South Korean government emphasized software education as a strategy to realize a software-centric society. This included computer education, information and communication technology utilization, coding, and computational thinking. Furthermore, as of 2023, seeing the need for digital proficiency not only in specialized digital fields but also in everyday life, there's a drive to bridge the digital divide by aiming to nurture a million digital talents, accelerating the development of talents at elementary, secondary, and advanced levels (Choi & Shin, 2022). This paper analyzes the effects of distributing textbooks, designed for easy implementation of integrated information education tied with creativity in real-life settings, to educators and applying them to students in South Korea.

2. LITERATURE REVIEW

Similar to all other disciplines in education, nurturing creativity is of paramount importance in information education. Moreover, the significance of fostering creative thinking in information education is underscored by

the fact that the ultimate objective of information education extends beyond the acquisition of computational thinking and computer science knowledge. It necessitates the application of these skills to real-world problem-solving scenarios.

An illustrative case of fostering creative information education is found in Germany's MINT education model, an acronym encompassing Mathematics, Computer Science, Natural Science, and Technology. This educational paradigm amalgamates information education with mathematics, natural science, and technology, aiming to cultivate a skilled workforce imbued with creativity and a diverse skill set, catering to the evolving needs of German society. MINT education receives comprehensive support through active collaboration among sectors spanning education, research, the economy, politics, and industry. This concerted effort results in a wide spectrum of programs ranging from K-12 education to field training, with the overarching goal of nurturing a workforce characterized by advanced competencies (Fraser et al., 2013). Similarly, the United States responded to economic uncertainties and concerns about skilled labor shortages by initiating STEM education. Evolving from the concept of Mathematics, Science, Technology (MST) education introduced in the 1940s, STEM incorporates Engineering and, with the subsequent addition of Arts, evolves into STEAM education. This approach advocates for the integration of scientific, technological, engineering, mathematical, and artistic knowledge to address societal challenges and create innovative, human-centric technological solutions (Radziwill et al., 2015).

Within the context of information and computer education fostering creativity, Roberts et al. (2018) proposed an active learning framework for creative computing education utilizing explanatory visualizations. This framework is divided into three stages. The first stage involves selecting algorithms for learning and presentation, followed by acquiring various techniques for visually expressing ideas in the second stage. The third stage culminates in the development of explanatory visualizations, coupled with reflective evaluation. Student engagement in this educational approach resulted in the creation of personal explanatory visualizations, fostering creativity and enhancing communication skills (Roberts et al., 2018). In a similar vein, Payne et al. (2021) developed a platform that empowers learners to provide artistic experiences using data science and computing. This platform integrates a Domain Specific Language (DSL) with declarative syntax and reactive behaviors, a media player featuring pose detection and classification capabilities, and a web-based IDE. Participants leveraged this platform during remote learning camps to engage in creative coding inspired by artistic expression (Payne et al., 2021). Additionally, Kim et al. (2019) introduced data visualization education employing Google Sheets. Elementary students engaged in real-world problem-solving using data visualization techniques, leading to a significant enhancement in fluency, resistance to hasty conclusions, abstraction, creativity, and overall proficiency (Kim et al., 2019). Moreover, Koo and Woo. (2018) put forward a creative computing education program centered around Micro:bit. This innovative program incorporated educational activities involving a single sensor or operational device per class session. The program was meticulously designed to seamlessly integrate with various subjects, encompassing activities such as LED manipulation coding, pedometer creation through accelerometer sensor utilization, and sound programming for music composition (Koo et al., 2018).

Table 1 provides a comparative analysis of diverse instances of creative information education programs, both on a domestic and international scale. While many of these programs involve coding or programming for problem-solving or project-based learning, educational approaches explicitly addressing future information technologies remain somewhat limit.

Table 1: Comparative analysis of creative information education cases

	Contents	Characteristics	Educational Effect
Roberts et al. (2017)	Algorithm learning for explanatory visualization development	Contribution to structured learning through proposed educational framework	Top 80% of students use higher-level verbs in bloom's taxonomy
Payne et al. (2021)	Expression of cultural artistic dance through data science	Integration with stem education possible via self-developed platform	Participants engage in creative coding by crafting artistically inspired code
Kim et al. (2019)	Data visualization education using google sheets	Designing real-life problem-solving solutions via data visualization based on computational thinking	Increased fluency, resilience to hasty conclusions, abstraction, average creativity, and creativity index among participants
Koo and Woo (2018)	Micro:bit-based creative computing education program	Instructional design allowing activity engagement using a single sensor or operational device per session	-

3. RESEARCH METHODOLOGY

The instructional materials proposed in this study were developed based on the ASSURE model by Heinich et al.

(1996), which Kim et al. (2018) suggested as a framework for reference in the development of instructional materials for information education. The ASSURE model is an acronym derived from the initial letters of its stages: Analyze learners, State objectives, Select methods, media, and materials, Utilize media and materials, Require learner participation, and Evaluate and revise (Heinich et al., 1996).

In this research, a novel focus was directed towards instructional design for information education based on the ASSURE model, which was originally devised for lesson planning involving digital tools, as presented by Kim et al. (2018). The first step of the ASSURE model, learner analysis, was conducted based on the 2020 survey data of approximately 15,000 primary and secondary school students in South Korea, as reported by the Ministry of Education (Ministry of Education (South Korea), 2021). The comparison of the top 10 desired occupations by age group revealed that elementary school students showed minimal interest in IT-related careers. For middle school students, IT careers were ranked 10th in 2018, 9th in 2019, and even dropped from the list of preferences in 2020. These results indicate that students in South Korea do not have a significantly higher preference for IT-related occupations compared to other job categories. In the second step, the objective statement, we set the goal for our instructional materials. Instead of aiming to provide students with highly specialized skills in applied intelligence technology, our materials aimed to convey an understanding of IT principles and foster creativity for solving diverse problems through innovative teaching methods involving various instructional and learning activities and the utilization of artificial intelligence (AI). The third step, selection of instructional methods, media, and materials, involved collecting information education methods from literature analysis that are suited to various instructional situations. Methods like flipped learning, cooperative learning, problem-based learning, project-based learning, blended learning, and web-based learning were collected. Based on expert opinions, quantum learning, blended learning, and AI-assisted teaching methods were selected among these various methods. In the fourth step, utilization of media and materials, we conceptualized the transformation of class materials into micro-learning formats that can be easily applied in lessons using mobile learning authoring tools. In the fifth step, learner engagement, we devised methods to enhance students' concentration and participation in instructional activities. Active learner participation was considered a crucial value in this study. Accordingly, we aimed to provide students with opportunities to engage actively in learning, moving beyond conventional lecture-style instruction. Finally, in the sixth step, evaluation and revision, we designed plans to observe the effects of the instructional materials in real educational settings, particularly focusing on changes in creativity and core competencies. The data collected from these observations would guide future revisions of the instructional materials.

To verify the effectiveness of the developed set of 20 textbooks, a pre-post matched-sample t-test was conducted using IBM SPSS 24.0 software. This assessment involved providing students with creativity and core competency questionnaires before implementing the textbook-based lessons. Subsequently, after the lessons, the same questionnaires were administered alongside a satisfaction survey. The responses were collected immediately following the lessons. This procedure aimed to analyze the effectiveness of the textbooks.

4. RESULT AND DISCUSSION

4.1. Creative IT Education Program Textbooks

We constructed textbooks based on innovative instructional methods, including non-face-to-face blended learning, dynamic quantum learning, and AI-based teaching methods, focusing on the topics of AI Humanities, Forensic Science, and Digital Therapeutics. The detailed structure of the textbooks was designed in collaboration with researchers from Jeju National University's Creative Education Center and field teachers, connecting instructional methods and IT educational content. The blended learning method is associated with AI Humanities and Forensic Science, while the dynamic quantum method is linked to Forensic Science, and the AI-based teaching method is connected to digital therapeutics. These divisions were arbitrarily made to facilitate teachers' easy application in classes; however, they can be recombined with the desired teaching methods and topics without any issues.

Firstly, for the AI Humanities-related textbook topics, we covered ‘Support Vector Machines’, ‘Convolutional Neural Networks’, ‘AI Ethics’, ‘Overfitting and Underfitting’, ‘Classification and Regression’, ‘Robot Programming’, and ‘Expert Systems’. Among these, ‘Robot Programming’ and ‘Expert Systems’ are aimed at middle school students, while the rest are targeted at elementary school students.

Secondly, for the Forensic Science-related textbook topics, we included ‘Principles of Scientific Investigation’, ‘Fingerprint Analysis Techniques’, ‘Excavating the Remains of the 6.25 War Victims’, ‘Forgery and Tampering’, ‘Hacking and Information Security’, ‘Digital Footprints’, ‘Anti-Forensics’, and ‘Virtual Ecosystem Implementation’. Among these, ‘Digital Footprints’ and ‘Anti-Forensics’ are designed for middle school students, ‘Virtual Ecosystem Implementation’ for high school students, and the remaining topics for elementary school students.

Lastly, for the Digital Therapeutics textbook topics, we covered ‘ADHD Digital Therapeutics’, ‘Corona Blue

Digital Therapeutics', 'Circadian Rhythm Balance', 'Holistic Mind-Body Health Care', and 'Digital Drama'. Among these, 'Digital Drama' is intended for middle school students, while the others are developed for elementary school students.

All textbooks are structured for direct application to the South Korean curriculum and are mostly organized into 3-4 class sessions. Table 2 provides detailed descriptions of the developed textbooks.

Table 2: Configuration of creative IT education textbooks

Teaching Methods	Target	Program	
Blended Learning	Elementary School	AI Humanities	Support vector Machine
			Convolution Neural Network
			Artificial Intelligence Ethics
			Overfitting and Underfitting
			Classification and Regression
	Middle School		Robot Programming
			Expert Systems
Quantum Learning	Elementary School	Forensics Science	Principles of Scientific Investigation
			Fingerprint Analysis Techniques
			Excavating the Remains of the 6.25 War Victims
			Forgery and Tampering
			Hacking and Information Security
	Middle School		Digital Footprints
			Anti-Forensics
	High School		Virtual Ecosystem Implementation
AI-based Learning	Elementary School	Digital Therapeutics	ADHD Digital Therapeutics
			Corona Blue Digital Therapeutics
			Circadian Rhythm Balance'
			Holistic Mind-Body Health Care
	Middle School		Digital Drama

4.2. Analysis of the Effects of Textbooks Implementation

The developed textbooks were implemented from June to December 2022 for a total of 701 elementary, middle, and high school students nationwide. Among them, 603 students diligently responded to the satisfaction survey, and the overall satisfaction level was recorded as 4.25 points, indicating a high level of overall satisfaction. The survey questionnaire used for the satisfaction survey was provided by the Korea Science Foundation. Table 3 presents the results of the satisfaction survey by item.

Table 3: Satisfaction Survey Results (N=603)

Variable	Min.	Max.	Mean	Standard Deviation
Class Satisfaction	1	5	4.30	0.81
The Degree of Interest in the Content of the Class	1	5	4.29	0.80
Understanding of the Class Subjects	1	5	4.23	0.81
Teacher's Kind Guidance	1	5	4.33	0.79
Ensuring the Time of Sharing Opinions	1	5	4.27	0.86
Improving Problem-solving Skills	1	5	4.12	0.91
Cultivating a Variety of Perspectives on Problems	1	5	4.11	0.90
Improving Convergence Capacity	1	5	4.15	0.87
Learning Contents and Real-life Transitions	1	5	4.07	0.90
Willingness to Participate Programs in the Future	1	5	4.22	0.85

To validate the empirical evidence and effectiveness of the developed textbook, changes in creativity and core competencies were observed among elementary and middle school students before and after the application of the textbook.

For elementary school students, a self-developed questionnaire was employed, and creativity was subdivided into sensitivity, elaboration, originality, fluency, and flexibility. Core competencies were categorized into subfactors such as self-management, knowledge information processing, creative thinking, aesthetic sensitivity, cooperative communication, and community competence. The item reliability analysis showed that the Cronbach's alpha coefficient for the creativity questionnaire was 0.943, while for the core competencies questionnaire, it was 0.952, indicating a satisfactory reliability of the items. The analysis of creativity effects was conducted using responses from 210 participants who earnestly participated in the survey. To confirm the program's effectiveness, changes in the pre-post creativity total scores were analyzed, and the patterns of these differences were examined.

A t-test was conducted on the pre-post creativity total scores, and the results are presented in Table 4. The pre-test creativity total score had an average of 3.35 (Standard Deviation=0.68), and the post-test score was 3.93 (Standard Deviation =0.68), indicating an increase of approximately 0.58. In other words, according to the t-test results, the creativity total scores of the program participants improved after the program implementation, and this improvement was statistically significant (p<.001). Furthermore, all factors except sensitivity showed statistically significant improvements (p<.001).

Table 4: Elementary School Students' Creativity T-test Results(N=210)

		Mean	Standard Deviation	*t*	*p*
Sensitivity	Pre	3.68	0.75	-1.81	.071
	Post	3.82	0.73		
Elaboration	Pre	3.41	0.79	-6.15***	.000
	Post	3.89	0.75		
Originality	Pre	2.83	0.66	-16.06***	.000
	Post	3.95	0.74		
Flexibility	Pre	3.36	0.80	-6.94***	.000
	Post	3.90	0.78		
Fluency	Pre	3.51	0.81	-5.46***	.000
	Post	3.92	0.77		
Total	Pre	3.35	0.68	-8.47***	.000
	Post	3.93	0.68		

***p < .001

To examine the pattern of change in core competencies among elementary school students, the responses of 239 diligent participants were analyzed using t-tests, and the results are presented in Table 5. The pre-assessment average for overall core competencies was 3.59 (Standard Deviation=0.58), and it increased to 3.92 (Standard Deviation=0.50) post-assessment, indicating an increase of approximately 0.33. The t-test results revealed a

statistically significant difference (p<.001), indicating that the overall core competencies of program participants increased after the program was implemented. Moreover, all factors except creative thinking and aesthetic sensitivity showed statistically significant improvement (p<.001).

Table 5: Elementary School Students' Core Competency T-test Results(N=239)

		Mean	Standard Deviation	*t*	*p*
Self-Management	Pre	3.34	0.66	-8.62***	.000
	Post	3.88	0.67		
Knowledge Information Processing	Pre	3.69	0.66	-6.46***	.000
	Post	4.02	0.65		
Creative Thinking	Pre	3.49	0.71	-1.51	.132
	Post	3.52	0.71		
Aesthetic Sensibility	Pre	3.74	0.65	-1.84	.067
	Post	3.86	0.64		
Cooperative Communication	Pre	3.67	0.71	-5.59***	.000
	Post	4.04	0.65		
Community	Pre	3.65	0.67	-5.95***	.000
	Post	4.02	0.63		
Total	Pre	3.59	0.58	-6.91***	.000
	Post	3.92	0.50		

***p < .001

For assessing creativity in middle school students, the Kaufman Domains of Creativity Scale (K-DOCS) was adapted and utilized, encompassing sub-factors of everyday, academic, behavioral, mechanical-physical, and artistic creativity (Kaufman, 2012). The assessment tool employed for core competencies was developed by Baek et al. (2017) and consists of sub-factors like self-management, knowledge and information processing, creative thinking, aesthetic sensitivity, cooperative communication, and community competency. The reliability analysis of items revealed a high level of consistency, with Cronbach's alpha coefficient of 0.956 for creativity and 0.964 for core competencies.

The validation of creativity in middle school students involved analyzing responses from 170 diligent participants. Pre-and post-assessment overall creativity scores were measured and subjected to t-tests, and the results are presented in Table 6. The pre-assessment average for overall creativity was 3.51 (Standard Deviation=0.63), which increased to 3.64 (Standard Deviation=0.48) post-assessment, showing an increase of approximately 0.13. Thus, the overall creativity scores of participants significantly increased after the program was implemented (p<.05). Additionally, except for everyday and academic creativity, all other factors demonstrated statistically significant improvement (p<.05).

Table 6: Secondary School Students' Creativity T-test Results(N=170)

		Mean	Standard Deviation	*t*	*p*
Self-Everyday	Pre	3.82	0.58	-.15	.884
	Post	3.82	0.54		
Scholarly	Pre	3.62	0.65	.17	.863
	Post	3.61	0.61		
Performance	Pre	3.31	0.85	-2.67**	.008
	Post	3.52	0.57		
Mechanical/Scientific	Pre	3.20	1.01	-3.46**	.001
	Post	3.51	0.73		
Artistic	Pre	3.57	0.78	-1.99*	.048
	Post	3.72	0.59		
Total	Pre	3.51	0.63	-2.18*	.031
	Post	3.64	0.48		

**p < .05, *p < .01

The validation of core competencies in middle school students was conducted using responses from 191 diligent participants and, similarly, t-tests were performed. The pre-assessment average for overall core competencies was 3.52 (Standard Deviation=0.47), which increased to 3.70 (Standard Deviation=0.50) post-assessment, reflecting an increase of approximately 0.18. The participants' core competencies increased after the program was

implemented, and this increase was statistically significant (p<.001). Additionally, apart from cooperative communication and community competency, all other factors demonstrated statistically significant improvement (p<.01). The analysis results are presented in Table 7.

Table 7: Secondary School Students' Core Competence T-test Results(N=191)

		Mean	Standard Deviation	*t*	*p*
Self-Management	Pre	3.42	0.51	-4.37***	.000
	Post	3.66	0.57		
Knowledge Information Processing	Pre	3.45	0.57	-3.68***	.000
	Post	3.67	0.54		
Creative Thinking	Pre	3.38	0.56	-4.47***	.000
	Post	3.64	0.60		
Aesthetic Sensibility	Pre	3.47	0.56	-2.58*	.011
	Post	3.63	0.61		
Cooperative Communication	Pre	3.62	0.59	-1.86	.065
	Post	3.73	0.56		
Community	Pre	3.77	0.58	-1.87	.062
	Post	3.88	0.58		
Total	Pre	3.52	0.47	-3.67***	.000
	Post	3.70	0.50		

***p < .001, *p < .01

5. CONCLUSION AND FUTURE WORK

The occurrence of powerful pandemics, advancements in AI, the Fourth Industrial Revolution, and more are causing society to undergo rapid and unprecedented changes that we have not experienced before. In light of these transformations, the need for nurturing individuals who can lead us into the future has become more urgent than ever before (Kim & Lee, 2021).

In this paper, we have developed 20 instructional materials that enhance students' creativity and core competencies while also increasing their understanding of IT, in response to these societal changes. Furthermore, we analyzed the effectiveness of these materials in educational settings using pre-post t-tests. The results showed that students using the materials exhibited a high level of satisfaction, and both elementary and middle school students demonstrated statistically significant improvements in creativity and core competencies. However, the materials developed in this study only include one out of the 20 aimed at high school students. Consequently, the effectiveness of the materials for high school students is lacking. Currently, in the education environment of South Korea, high school students are heavily focused on exam preparation for university entrance. It is a fact that education on supplementary knowledge not covered in entrance exams is being passively provided (Cho, 2022). Nevertheless, IT knowledge is essential for high school students, who have less time to enter society compared to elementary and middle school students, and their creativity and core competencies that effectively demonstrate this knowledge should also be nurtured. Therefore, in future research, the development of instructional materials that can be effectively integrated into the curriculum and empirical studies based on this development are anticipated to be necessary. We hope that the results of this paper will contribute to the development of instructional materials and educational model research that can foster the competencies required for the future.

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