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Effectiveness Analysis of Computer Science Textbooks focusing on Digital Therapeutics☆

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ABSTRACT

Digital therapy has emerged as a novel treatment modality, propelled by advancements in information and communication technology. In the last five years, there has been a substantial surge in research publications addressing digital therapeutics (DTx) interventions, signaling a sustained upward trajectory in this field. The dynamic nature of computer science, marked by continuous innovation and development, underscores the need for agile adaptation to rapid changes. Consequently, computer science education is compelled to offer students insights into the latest trends. This research endeavors to contribute to the evolving landscape by developing textbooks that impart knowledge about DTx, an integration of information technology. The study focuses on the application of these textbooks to elementary and middle school students in South Korea. The instructional materials have been carefully organized to enable students to learn about the principle of Attention Deficit Hyperactivity Disorder (ADHD) DTx at the elementary level and the DTx that can prevent and address the digital drama at the middle school level. Based on the application of the textbook, students who received instruction using the textbook showed statistically significant improvements in all subcategories of creative problem-solving ability, including idea modification, visualization, task focus, analogy, idea generation, and elaboration ($p<.01$). Additionally, there were statistically significant changes in students' self-efficacy before and after using the textbook, with negative efficacy decreasing, and positive efficacy and social efficacy increasing ($p<.001$).

☞ keyword : Digital Therapeutics, Computer Science Textbook, Creative Problem-Solving, Self-Efficacy, Attention Deficit Hyperactivity Disorder, Digital Drama

1. Introduction

Digital Therapeutics (DTx) represents the third generation of therapeutics, significantly reducing the potential for toxicity and side effects while facilitating the collection and management of patient data. In contrast to first-generation therapeutics, which are small-molecule compounds in the form of pills or capsules, and second-generation therapeutics composed of antibodies, proteins, or cells, DTx marks a transformative approach[1].

Literature related to DTx outside of Republic of Korea first emerged in 1999, with only 1 or 2 publications per year until 2015. The number increased to 4 in 2016, and by 2021, it had risen to 113[2]. In Republic of Korea, there were no related papers until 2019, with a starting point of 9 in 2020, growing to 16 in 2021[1]. Considering the relatively low global volume of related research, the concept of DTx can be regarded as an early-stage technology and field, with research in its infancy.

The field of study within computer science is highly extensive, and its content undergoes more rapid changes than almost any other discipline[3]. This is attributed to the expanding use of computers in our society and the continuous development of new technologies through integration with other fields. Moreover, the skills demanded by future societies are evolving over time, making it essential to reflect these changes in educational curricula[4]. To secure and cultivate a high-quality software workforce early on, it is crucial to provide students with the latest trends in computers through computer science education, aiding them in acquiring digital literacy.

We live in an era where technology undergoes rapid changes even within a day, with the emergence of artificial intelligence and new computing technologies. However, it is

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a challenging task to revise government-approved textbooks developed over several years whenever there is a technological change. However, the cultivation of digital literacy, an essential skill in the age of artificial intelligence, would be challenging without a grasp of the concepts and principles of digital technologies. While education programs teaching programming languages to students, such as coding or programming education, have become increasingly prevalent, finding education programs focusing on information technology principles for students remains challenging. Specifically, textbooks teaching the principles of digital therapeutics to students are globally scarce.

In this study, we aimed to develop brief textbooks that support computer science education, designing short-duration lessons (3-4 hours) for easy implementation by teachers. By analyzing the results of applying these materials to students, we sought to explore the potential utility of this instructional resource.

The academic contributions of this paper are as follows:

- The textbooks can supplement aspects not covered in regular educational curricula to enhance understanding of rapidly evolving information technology.
- Teachers can readily apply the textbooks to students, and through the use of applications, conduct lessons in a remote learning environment using mobile devices.
- Creative problem-solving skills of elementary and middle school students improved through the utilization of the textbooks in their lessons.
- Positive changes in self-efficacy were observed among elementary and middle school students who utilized the textbooks during their lessons.

2. Literature Review

2.1 Computer Science Education

Computer literacy focused on acquiring the minimum computer usage skills necessary to live as a member of a knowledge-based society. It was akin to education in industrial society that implemented literacy in reading, writing, and arithmetic as basic skills, aiming to acquire them. In the information society, education was carried out from the perspective of overcoming illiteracy[5]. For example, education on the use of electronic commerce systems could be considered as such. This differed significantly from educational methods in other countries at the time.

In the United States, programming was taught in mathematics courses for logical education, while engineering-related technologies were taught in science courses. Additionally, in countries like the UK, Canada, and Israel, information and computer science education was adopted as a formal subject in high schools, integrated into science subjects such as mathematics, physics, and chemistry. Computer science education in these countries was designed not only for acquiring basic computer usage skills but also for fostering problem-solving abilities through logical thinking, reasoning, and information control abilities as part of scientific education.

As of now, South Korea has begun revising its educational curriculum starting from 2022, and it is scheduled to be implemented from the first and second grades of elementary school in 2024. Therefore, the curriculum revised in 2015 is still in effect. In the 2015 revised curriculum, the core concepts of information education include information society, information ethics, representation of data and information, analysis of data and information, abstraction, algorithms, programming, and the operating principles of computing systems, all of which are organized into the areas of information culture, data and information, problem-solving and programming, and computing systems.

On the other hand, in South Korea's revised educational curriculum for 2022, the information education curriculum is designed to enhance core competencies such as knowledge information processing, creative thinking, collaborative communication, and community capacity. It aims to strengthen curriculum competencies in computing thinking, digital cultural literacy, and artificial intelligence literacy to foster these core competencies. The content structure is divided into computing systems, data, algorithms and programming, artificial intelligence, and digital culture. The digital culture education includes aspects such as digital society, professions, and ethics, but education specifically related to understanding of the latest information technology is not explicitly mentioned. Therefore, it suggests the need

to add education on promising future information technologies to provide students with a broader perspective for career choices in the digital society.

2.2 Effectiveness of Textbook in Education

Recently, teaching and learning materials utilizing information technology such as digital textbooks and artificial intelligence-based instructional tools have been developed and utilized in education[6]. However, the importance of physical textbooks remains very high in education. This is because the provision of online and digital resources is still designed to support traditional learning materials.

Certainly, traditional textbooks can be more effective when complemented by software and web-based instructional materials. Low-performing students in the group that solely used textbooks during self-directed learning showed notably lower test scores compared to their counterparts in groups that utilized learning support software tools or a combination of textbooks and software tools[7]. This indicates that learning support software stimulates learning motivation and aids comprehension. These research findings underscore the importance, in our rapidly evolving learning environments, of employing diverse resources to enhance students' focus and maximize learning outcomes, rather than relying solely on conventional physical textbooks.

In teacher education targeting educators, the effectiveness of textbooks is also evident. A study found that the development and implementation of textbooks utilizing action learning for elementary and middle school teachers contributed to the enhancement of problem-solving skills, cooperative learning abilities, democratic citizenship, and knowledge processing competencies, thus improving the capacity of teachers[8]. Analyzing the effectiveness of textbooks involves controlling various factors, and even if there is an educational effect, it is difficult to attribute it solely to the textbook as a single factor. Nonetheless, the steady publication of papers on the effectiveness of textbooks indicates their significant role in education.

3. Methods

This paper aims to develop textbooks containing principles of digital therapeutics, a convergence of information technology and biotechnology within the broad field of computer science, and to analyze the results of its application to students. Initially, the textbook development was centered around the ASSURE model[9]. This model, named after its mnemonic acronym Analyze learners, State objectives, Select methods, media, and materials, Require learner participation, Evaluate and revise, was chosen as the framework for textbook development. The reason for adopting this model as a model for textbook development is based on research citing the appropriateness of the ASSURE model as a reference for textbook development for information education[10]. This model provides a framework for instructors to design various media to be utilized according to different situations during lectures.

Meanwhile, to ascertain whether the textbooks developed according to this model for elementary and middle school levels could be effectively utilized in school settings, we recruited teachers willing to use the textbooks for their classes. We provided these teachers with guidance on how to integrate the textbooks into their teaching. Subsequently, these trained teachers implemented the digital therapeutics textbooks in their respective schools. Teachers have implemented the textbooks at school from August to November 2021. Teachers conducted classes using the textbooks with their students at their respective schools. While most teachers utilized the textbooks during face-to-face classes, some teachers conducted classes remotely using mobile learning platform due to the prevailing circumstances of the infectious disease outbreak at that time.

The research samples collected for the study consisted of 189 elementary school students and 205 middle school students, totaling 394 participants. Among the participating students, there were 88 fifth graders and 101 sixth graders, totaling 189 elementary school students. Additionally, there were 55 first-year middle school students, 103 second-year middle school students, and 47 third-year middle school students. Among them, responses from 176 diligent

elementary school students and 181 diligent middle school students were analyzed.

Prior to receiving instruction using the textbooks, we assessed their creative problem-solving abilities and self-efficacy. After the instruction, we utilized the same assessment tools to conduct post-test.

The research tool for assessing creative problem-solving comprises factors including idea modification, visualization, task focus, analogy, idea generation, and elaboration[11]. The Cronbach's α for this tool was found to be 0.82 on average, indicating the reliability of the assessment tool.

Regarding the measurement tool for self-efficacy, we employed the self-efficacy assessment, which subdivides self-efficacy into categories such as negative self-efficacy, positive self-efficacy, and social self-efficacy[12]. This tool also demonstrated reliability with a Cronbach's α of 0.89.

Both research instruments were constructed using a 5-point Likert scale. The analysis of the research results involved conducting pre-post t-tests and utilizing SPSS 24.0 software for analysis. Considering that the sample size was over 30, normality was assumed, and normality tests were not conducted prior to conducting t-tests.

4. Results

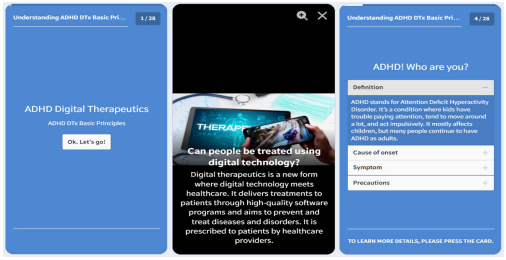
4.1 Textbook Development

For the first step of the ASSURE model, which involves learner analysis, data from the Ministry of Education's 2020 survey on elementary and middle school career education status were utilized. Among the top 10 desired professions among elementary school students nationwide, none were directly related to intelligent information technology, and middle school students expressed relatively low interest in such careers. These results underscored the urgent need for education and textbooks related to intelligent information technology.

The second step is setting objectives. The primary goal of this textbook was to enhance educators' future information technology teaching capabilities, while also aiming to contribute to students' growth as individuals who meet the demands of future society.

The third step involves selecting instructional methods, media, and materials. This textbook selected EdApp as an online customized learning tool and incorporated gamification to increase engagement. Additionally, it adopted unplugged education techniques to prepare for various educational environments and included educational materials containing the latest information.

The fourth step is utilizing media and materials. Figure 1 shows a partial screen from the first session of a class developed using EdApp, one of the media selected in the third step. EdApp is a mobile learning management system designed to enable students to learn with tablets, smartphones, and similar devices even without the presence of a teacher in the same space. We have migrated paper-based textbooks into a web format using the application. Students can engage in lessons within this application by touching the screen and inputting text, similar to playing games. This approach is designed to facilitate the utilization of textbooks by teachers and students in a remote learning environment.



(Figure 1) (Digital Resource using EdApp)

The fifth step involves encouraging learner participation. This textbook aimed to increase student engagement and participation by focusing on the relatively unfamiliar concept of digital therapeutics.

The final step is evaluation and revision. Evaluation tools were developed in the form of creativity assessment, self-assessment, peer assessment, and reflection journals, which teachers could utilize when implementing the textbook in their classes.

4.1.1 Computer Science Textbook for Elementary School Level

This textbook can be used in physical education classes for 3rd and 4th graders and in Korean, science, and practical

arts classes for 5th and 6th graders. It is associated with achievement standards codes [4PE03-08], [6KOR01-01], [6SCI01-01], and [6PRA04-03]. The proposed lessons in this textbook consist of four sessions.

In the first session, the topic focuses on understanding the basic principles of ADHD digital therapeutics, followed by a debate on the pros and cons of using games for ADHD treatment.

Sessions 2 and 3 focus on the application of ADHD digital therapeutics. In the second session, students explore difficulties in communication, one of the symptoms of ADHD, and learn methods to improve communication skills in daily life, regardless of whether they have ADHD. The third session involves experiencing attention-enhancing games and engaging in learning games to understand the principle of Brain-Computer Interface (BCI) used in the development of ADHD digital therapeutics. Students are divided into "Brain Team" and "Computer Team," based on the concept of assisting humans, where the team that accurately remembers and communicates the agreed-upon signals wins.

In the fourth session, the topic revolves around the future of ADHD digital therapeutics, encouraging students to utilize artificial intelligence tools to envision their own future ADHD treatments. The key contents for each session are outlined in Table 1.

(Table 1) Curriculum of the DTx Textbook for Elementary School

Topic	Class	Contents
Understanding ADHD DTx Basic Principles	1/4	• ADHD and DTx concepts • How to treat neuro developmental disorders through digital technology and gaming with Selective Stimulus Management Engine
Application of ADHD DTx	2/4	• ADHD DTx cases • Effective communication skills using sandwich methods
	3/4	• Three dimensional multi object tracking principles • BCI as a game to explore cognitive improvements
Future of ADHD. DTx	4/4	• Prospect of development of ADHD DTx • Effective ways to treat ADHD

4.1.2 Computer Science Textbook for Secondary School Level

The digital drama digital therapeutics textbook targeting middle school teachers can be utilized in information, Korean, and ethics classes for 1st to 3rd graders. The related achievement standards codes are [9INFO01-03], [9INFO02-01], [9KOR02-01], and [9ETH02-07]. The proposed lessons in this textbook consist of three sessions.

In the first session, the topic focuses on understanding digital therapeutics corresponding to digital dramas. Students learn to differentiate between digital dramas and cyberbullying, understand the basic concepts of digital therapeutics, and grasp the principle of treating digital drama victims using digital technology.

The second session revolves around developing digital drama therapeutic interventions. Utilizing artificial intelligence platforms, students create educational videos to prevent digital dramas or engage in webtoon creation activities if time is limited. Platforms such as AI STUDIOS, OnAir Studio, and TypeCast ai can be used for video production, while Storyboard That and Tooning are suitable platforms for webtoon creation. Since video production may require significant time, it may be assigned as a task or an additional class session may be scheduled.

In the third session, the topic is proposing strategies to address digital dramas. Students share the videos created in the previous session and discuss effective strategies to respond to digital dramas. The key contents for each session are outlined in Table 2.

(Table 2) Curriculum of the DTx Textbook for Secondary School

Topic	Class	Contents
Understanding DTx Against Digital Drama	1/3	• Differences between digital drama and cyberbullying • DTx concepts
Development of DTx Against Digital Drama	2/3	• DTx cases to prevent cyberbullying • Examples of DTx that treat victims of digital drama or prevent digital drama
Proposal for Digital Drama Response Plan	3/3	• Production of digital drama prevention education video using artificial intelligence platform • Discuss ways to effectively respond to and prevent digital dramas

4.2 Textbook Application

4.2.1 Analysis of Creative Problem-Solving Test Results

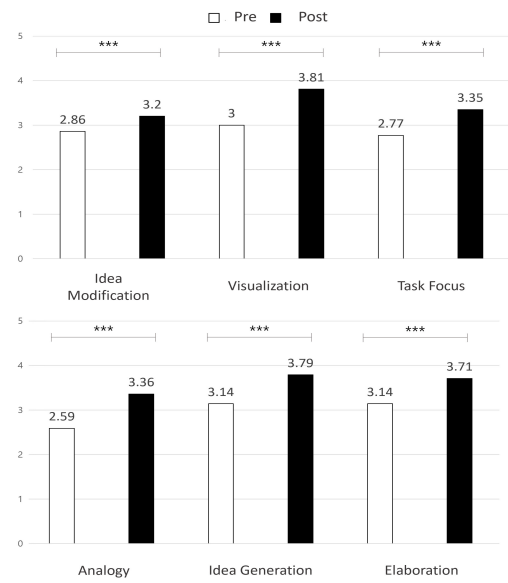
Since normality was satisfied, paired samples t-tests were conducted to examine the pre-post verification results of elementary students' creative problem-solving ability. The test results indicated that idea generation (mean=3.14, standard deviation=0.707) and elaboration factor (mean=3.14, standard deviation=0.916) were the highest pre-test averages, while the imagery factor showed the highest post-test mean (mean=3.81, standard deviation=0.880). The metaphor factor had the lowest pre-test mean (mean=2.59, standard deviation=0.695), and the idea modification factor had the lowest post-test mean (mean=3.20, standard deviation=0.778).

In all factors, the mean of creative problem-solving ability increased post-test compared to pre-test, and the change in all factors showed a statistically significant improvement (p<.001). Table 3 and Figure 2 demonstrate the pre- and post-capacity changes in creative problem-solving ability among elementary school students who received instruction using the ADHD digital therapeutics textbook.

(Table 3) Analysis of Changes in Elementary Students' Creative Problem-Solving Ability(N=176)

Factor		M	SD	t	p
Idea modification	Pre	2.86	0.69	-4.49***	.000
	Post	3.20	0.78		
Visualization	Pre	3.00	0.95	-8.66***	.000
	Post	3.81	0.88		
Task focus	Pre	2.77	0.78	-6.47***	.000
	Post	3.35	0.80		
Analogy	Pre	2.59	0.70	-10.05***	.000
	Post	3.36	0.70		
Idea generation	Pre	3.14	0.70	-7.49***	.000
	Post	3.79	0.80		
Elaboration	Pre	3.14	0.92	-6.46***	.000
	Post	3.71	0.78		

***p<.001



(Figure 2) Comparison of Changes in Elementary Students' Creative Problem-Solving Ability (N=176)

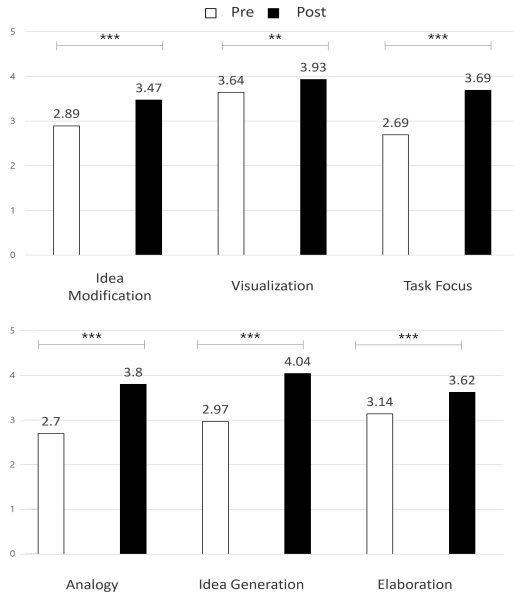
The paired samples t-test results for the pre-post verification of middle school students' creative problem-solving ability indicated that the imagery factor had the highest score in the pre-test (mean=3.64, standard deviation=0.960), while in the post-test, the idea generation factor showed the highest score (mean=4.04, standard deviation=0.788). On the other hand, the task concentration factor had the lowest score in the pre-test (mean=2.69, standard deviation=0.764), while in the post-test, it was the idea modification factor (mean=3.47, standard deviation= 0.866).

Similarly, for middle school students, improvement in creative problem-solving ability was observed post-test compared to pre-test in all factors. The idea modification, task concentration, metaphor, idea generation, and elaboration factors showed the most statistically significant improvement (p<.001). Additionally, the imagery factor also exhibited a significant improvement in post-test mean compared to pre-test (p<.01). Table 4 and Figure 3 depict the patterns of changes in creative problem-solving ability before and after secondary school students received instruction from the digital drama digital therapeutics textbook.

(Table 4) Analysis of Changesin Secondary Students' Creative Problem-Solving Ability(N=181)

Factor		M	SD	*t*	*p*
Idea modification	Pre	2.89	0.68	-7.16***	.000
	Post	3.47	0.87		
Visualization	Pre	3.64	0.96	-3.45**	.001
	Post	3.93	0.89		
Task focus	Pre	2.69	0.76	-11.28***	.000
	Post	3.69	0.96		
Analogy	Pre	2.70	0.68	-14.4***	.000
	Post	3.80	0.74		
Idea generation	Pre	2.97	0.73	-14.66***	.000
	Post	4.04	0.79		
Elaboration	Pre	3.14	0.75	-6.34***	.000
	Post	3.62	0.67		

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



(Figure 3) Comparison of Changes in Secondary Students' Creative Problem-Solving Ability (N=181)

4.2.2 Analysis of Self-Efficacy Test Results

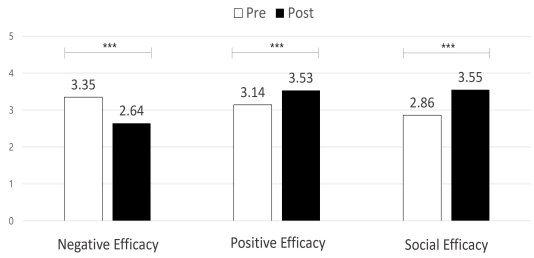
Self-efficacy consists of negative, positive, and social factors, with the social factor composed of negatively phrased questions, which were reverse-scored for analysis.

A paired samples t-test was conducted to analyze the self-efficacy test results of elementary school students. The analysis revealed that negative self-efficacy had the highest average score in the pre-test (mean=3.35, standard deviation=0.741), while social self-efficacy had the highest average score in the post-test (mean=3.55, standard deviation=0.648). On the other hand, the factor with the lowest average score in the pre-test was social self-efficacy (mean=2.86, standard deviation=0.715), and in the post-test, it was negative self-efficacy (mean=2.64, standard deviation=0.64). It was found that elementary school students exhibited a positive change in self-efficacy after receiving education from the ADHD digital therapeutics textbook (p<.001). Table 5 and Figure 4 display the pre-post analysis results of the average scores of self-efficacy among elementary school students.

(Table 5) Analysis of Changes in Elementary Students' Self-Efficacy(N=176)

Factor		M	SD	*t*	*p*
Negative Efficacy	Pre	3.35	0.741	9.50***	.000
	Post	2.64	0.625		
Positive Efficacy	Pre	3.14	0.712	-4.96***	.000
	Post	3.53	0.82		
Social Efficacy	Pre	2.86	0.72	-9.82***	.000
	Post	3.55	0.65		

***p<.001



(Figure 4) Comparison of Changes in Elementary Students' Self-Efficacy(N=176)

A paired samples t-test was conducted to analyze the results of self-efficacy scores of middle school students before and after receiving digital drama digital therapeutics

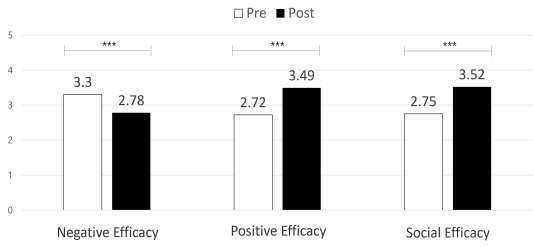
classes. The test results showed that negative self-efficacy had the highest average score in the pre-test (mean=3.30, standard deviation=0.767), while social self-efficacy had the highest average score in the post-test (mean=3.52, standard deviation=0.735). The factor with the lowest average score among middle school students' self-efficacy in the pre-test was positive self-efficacy (mean=2.72, standard deviation= 0.740), while in the post-test, it was negative self-efficacy (mean=2.78, standard deviation=0.602).

Furthermore, it can be observed that all factors of middle school students' self-efficacy underwent statistically significant changes from pre-test to post-test (p<.001). Table 6 and Figure 5 depict the pre- and post-changes in self-efficacy among middle school students.

(Table 6) Analysis of Changes in Secondary Students' Self-Efficacy(N=181)

Factor		M	SD	t	p
Negative Efficacy	Pre	3.30	0.77	7.48***	.000
	Post	2.78	0.60		
Positive Efficacy	Pre	2.72	0.74	-10.41***	.000
	Post	3.49	0.81		
Social Efficacy	Pre	2.75	0.62	-10.69***	.000
	Post	3.52	0.74		

***p<.001



(Figure 5) Comparison of Changes in Secondary Students' Self-Efficacy(N=181)

5. Conclusions

Computer science is a subject characterized by rapid changes both within and outside its field. As the pace of technological advancements accelerates, the areas covered by computer science must also evolve swiftly[13],[14]. This is because future revolutions are expected to center around computers. Globally, new technologies related to computer science are emerging rapidly[15]. It is now a critical juncture where there is a demand for various fragmented yet effective educational topics that can supplement national curricula that have remained unchanged for seven years.

This paper focuses on the promising future topic of Digital Therapeutics (DTx) and presents the development of a computer science textbook suitable for 3-4 session classes. The results demonstrate the application of this textbook to students. Elementary school students who received lessons using the ADHD DTx textbook showed statistically significant improvements in both creative problem-solving skills and self-efficacy. Similarly, middle school students who received lessons using the DTx textbook corresponding to digital dramas also experienced significant enhancements in their creative problem-solving skills and self-efficacy. Moreover, significant improvements were observed in most of the sub-factors belonging to both competencies.

Through this, it was confirmed that the computer science textbooks proposed in this study were effective in developing the ability to cope with unpredictable problems and generating confidence. However, since this study excluded high school students, it is difficult to conclude that the textbook is effective for all secondary school students. Nevertheless, by suggesting digital supplementary materials that can be used in online environments along with physical textbooks, the usability of the textbook was enhanced, and it can be applied integratively to various subject classes. We hope that this study will contribute to the development of computer science textbooks and the cultivation of digital talent.

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