J. Korean Soc. Math. Ed. Ser. D. (2024) 27(2), 223–239 ISSN 1226-6191
https://doi.org/10.7468/jksmed.2024.27.2.223 Online ISSN 2287-9943

RESEARCH ARTICLE

Effect of coding integrated mathematics program on affective mathematics engagement

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Received: May 3, 2024 / Revised: June 6, 2024 / Accepted: June 22, 2024

Abstract

The integration of coding and mathematics education, known as coding-integrated mathematics education, has received much attention due to the strength of Artificial Intelligence-based Science, Technology, Engineering, Arts, and Mathematics (AI-based STEAM) education in improving students' affective domain. The present study investigated the effectiveness of coding-integrated mathematics education on students' development of affective mathematics engagement. Participants in this study were 86 middle and high school students who attended the coding-integrated mathematics program. Surveys of students' affective mathematics engagement were administered before and after the intervention period. The results showed that students' affective mathematics engagement was statistically significantly improved through coding-integrated mathematics education. In particular, students exhibited increased positive affective mathematics engagement in terms of mathematical attitude, emotion, and value. These findings indicate the positive influence of coding-integrated mathematics education on students' learning in mathematics.

Keywords: affective mathematics engagement, affect, attitude, emotion, value, coding, STEAM education

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I. INTRODUCTION

In school mathematics education, affective characteristics are gaining attention as one of the crucial factors for students' mathematical learning success. The United States (U.S.) organizations National Research Council (NRC, 1994) and National Council of Teachers of Mathematics (NCTM, 1989, 2000, 2018) argued that students' positive affective characteristics in mathematics correlated with their mathematical achievement and suggested efforts to enhance these characteristics through students, teachers, curriculum, and instructional environments.

International comparative studies like The Programme for International Student Assessment (PISA) and Trends in International Mathematics and Science Study (TIMSS) consistently show that Korean students' affective achievement in mathematics is significantly lower compared to other countries. Korean students ranked low in affective domains in TIMSS 2007, 2011, 2015, and 2019, as well as in PISA 2012, 2015, and 2022. As a result, there has been increasing interest in strategies to improve students' affective characteristics in mathematics in Korea (Kim et al., 2013; Kim et al., 2023; Seo et al., 2023).

To support students' success in mathematics learning, it is essential to diagnose and develop instructional methods for both cognitive and affective engagement. In this regard, the national academic achievement assessments in Korea have added items to measure students' affective domains in mathematics since 2016 (Park, et al., 2016). From a curriculum perspective, since the 5th curriculum revision (Ministry of Education [MOE], 1987), there has been a continuous focus on cultivating mathematical affects. The 2015 revised mathematics curriculum emphasizes fostering students' interest and confidence in mathematics, as well as cultivating desirable attitudes and practical abilities (MOE, 2015, p. 5). It also sets curriculum competencies related to affective domains and emphasizes creating suitable instructional environments to nurture these competencies (MOE, 2015, p. 37). The revised mathematics curriculum of 2022 also considers attitude and values as crucial elements in constructing a mathematical content framework (MOE, 2022). The ministry of education stated the importance of affects in mathematics as below.

> Mathematics education is a curriculum aimed at fostering the ability and attitude to comprehend mathematical concepts, principles, and laws, observe and interpret various phenomena in the surroundings mathematically, think logically, and solve problems rationally…… Through mathematics learning, students can comprehend mathematical knowledge, develop mathematical thinking processes and skills, recognize the value of mathematics, and cultivate desirable mathematical attitude, thereby enhancing their competence in mathematics education (MOE, 2022, p. 6)

Science, Technology, Engineering, Art, and Mathematics(STEAM) education, an interdisciplinary curriculum integrating various subjects, can be utilized as a strategy to enhance students' affective characteristics (Jung et al., 2016). Coding integrated STEAM education, which has gained attention in recent years, can serve as a practical approach to mathematics education. In particular, we can expect improvements in students' affective characteristics by incorporating coding into mathematics instruction. Investigating the impact of coding integrated mathematics education on students' affective mathematics learning participation can provide valuable insights for current and future mathematics education using digital devices and software. However, there is still a lack of specific research on this potential.

Affective mathematics engagement during tasks in specific mathematics learning environments (Lee et al., 2019; Wang & Degol, 2014) can change rapidly depending on instructional situations and contexts. While students' mathematical affect is less sensitive to short-term changes and harder to improve quickly, affective mathematics engagement can be addressed by focusing on task-centered improvement strategies. Therefore, this study examined changes in students' affective mathematics engagement tendencies following coding integrated mathematics education. This study analyzed the level of improvement in affective mathematics engagement among middle and high school students to provide implications for the implementation of coding in mathematics education and improvements in students' affective mathematics engagement.

II. RELATED LITERATURE

Affective Mathematics Engagement

The affective characteristics of a learner towards mathematics can be described as the learner's comprehensive feelings about mathematical learning (McLeod, 1988; Sinclair, 1985). Affective engagement is considered one factor within the affective domain (Epstein et al., 2010; Grootenboer & Marshman, 2016). Epstein et al. (2010) defined engagement structure, as corresponding to an individual's internal affective structure in mathematical learning. Affective engagement structure in mathematical learning includes emotional feelings and follows affective pathways, which interact with each other or with cognition. Goldin et al. (2011) suggested that affective engagement structures in mathematical learning are associated with beliefs, providing nine examples: (1) Get the Job Done (GTJD), (2) Look How Smart I Am (LHSIA), (3) Check This Out (CTO), (4) I'm Really into This (IRIT), (5) Don't Disrespect Me (DDM), (6) Stay Out of Trouble (SOOT), (7) It's Not Fair (NF), (8) Let Me Teach you (LMTY), and (9) Pseudo Engagement (PE).

Affective mathematics engagement refers to the learner's situational affective orientation during specific mathematical learning tasks (Wang & Degol, 2014). Situational affect is influenced by individual perceptions based on various social influences (Kim, 2010), implying that affective mathematics engagement is more susceptible to short-term influences from the learning environment compared to general affect towards mathematics. While affect towards mathematics is generally resistant to change, affective mathematics engagement is sensitive to social and emotional changes occurring during learning situations. For instance, a student with a general lack of interest or negative attitude towards mathematics might show interest in specific learning situations.

Positive affective mathematics engagement during learning activities stimulates interest and enthusiasm for tasks, enabling sustained learning over extended periods (Bong et al., 2012). In addition, affective mathematics engagement correlates with cognitive engagement, facilitating meaningful and detailed learning, content retention, and effective learning (Im & Lim, 2007). Thus, affective mathematics engagement has been found to correlate highly with students' academic persistence and achievement. The positive affective attributes towards mathematics and consequent sustained cognitive achievement can ultimately elevate students' academic performance (Choe et al., 2013).

Grootenboer and Marshman (2016) identified mathematical beliefs, attitudes, emotions, and dispositions as important factors influencing the characteristics and degree of mathematical engagement. These affective factors can be considered as sub-factors constituting affective mathematics engagement (Debillis, 1997; Debillis & Goldin, 2006; Furinghetti & Morselli, 2009).

A research team at Rutgers University developed the Rutgers University Mathematical Engagement Structure Inventory (RUMSEI) to measure sub-factors of engagement structures in mathematical learning, which has been widely utilized in subsequent research (e.g., Craft & Capraro, 2017; Epstein et al., 2010; Goldin et al., 2011). Lee et al. (2019) further developed the Measurement of Affective Mathematics Engagement (MAME) based on 37 items extracted from RUMSEI by Craft & Capraro (2017), confirming that these 37 items consist of four constructs. They also integrated existing studies on affective aspects related to mathematics and proposed that attitudes, emotions, self-acknowledgement, and values could be sub-factors constituting affective mathematics engagement (Lee et al., 2019).

Table 1. Affective mathematics engagement framework objectives subscales (Lee et al., 2019)

Framework	Subscales	Number of Items
Mathematical Attitude	Get the Job Done (GTJD)	5
	Pseudo Engagement(PE)	2
Mathematical Emotion	Stay Out of Trouble (SOOT)	5
	Don’t Disrespect Me (DDM)	6
Mathematical Self-Acknowledgement	Check This Out (CTO)	4
	I’m Really into This (IRIT)	3
Mathematical Value	Let Me Teach you (LMTY)	4
	Look How Smart I Am (LHSIA)	8

Mathematical engagement tendencies can shift in either positive or negative directions. Affective mathematical engagement tendencies formed in specific situations can influence the individual's affective characteristics towards mathematics in the long term, making it a concept that should be treated with importance (Dossey et al., 1988). Furthermore, affective mathematical engagement not only affects students' affective characteristics but also their cognitive characteristics. Therefore, research on practical teaching methods that can foster these affective characteristics is necessary.

To cultivate students' affective characteristics toward mathematics, opportunities should be provided for students to perceive the practicality of mathematics (Kim et al., 2008; Park & Sang, 2017). Particularly considering the situational affective characteristics inherent in affective mathematical engagement, teaching and learning methods that demonstrate the situational relevance of the usefulness of learning content in real life can be crucial factors in enhancing students' affective mathematical engagement. Moreover, considering the short-term changes in affective mathematical engagement, possibilities can be explored through various media like computers, teaching aids, or integrated education with other subjects (Hidi & Harackiewicz, 2000; Kim & Yoon, 2004; Lee et al., 2019).

Coding Integrated Mathematics Education

Recently, there has been a growing interest in integrating STEAM education with coding to enhance students' affective characteristics through interdisciplinary approaches (Ministry of Education, & Korea Foundation for the Advancement of Science and Creativity, 2016). Affective changes can motivate students towards sustained mathematical learning (Mueller et al., 2011) and positively influence students' STEAM-related career choices (Ketelhut et al., 2010). Indeed, many studies have reported that students participating in STEAM education tend to choose STEAM-related majors and careers more than those who do not (e.g., Graham et al., 2013; Tyson et al., 2007).

Recently, coding integrated STEAM education has garnered attention as an effective practice in mathematics education. Coding integrated STEAM education in mathematics encourages learners to actively engage in the learning process by finding and applying mathematical problem-solving strategies, allowing them to self-regulate their learning (Kwon et al., 2024). Such participation fosters students to become autonomous agents in their learning, actively constructing knowledge rather than passively receiving it (Yackel & Cobb, 1996). Through this, students realize and utilize their cognitive potential in mathematical problem-solving (Kamii, 1985), fostering a sense of achievement, confidence, and self-efficacy, as well as positive affect, attitudes, self-concept, and values towards mathematics (Kwon et al., 2024; Lee et al., 2019; Mueller et al., 2011; Stefan, 2017; Yackel & Cobb, 1996). Therefore, there is a need to develop approaches that can positively transform students' affective characteristics towards mathematics through coding integrated STEAM education.

In mathematics education, the application of software is shifting from merely learning programming or utilizing Information and Communications Technology (ICT) to teaching computational thinking for solving real-world problems, indicating a reinforcement in coding education (Kwon, 2017; Chang, 2017). Computational thinking aims to combine mathematical and engineering thinking, involving understanding human behavior through designing systems and solving problems using basic concepts of computer science (Wing, 2006). In coding integrated STEAM education, learners can develop comprehensive computational thinking skills through data practices, modeling and simulation, computational problem-solving, and systems thinking (Weintrop et al., 2016). These computational thinking skills align with the mathematical thinking skills targeted in mathematics education (Wing, 2006). Moreover, analytical reasoning, problem-solving abilities (Liu et al., 2011), geometric thinking, and metacognition (Keren & Fridin, 2014) emphasized in mathematics education are also enhanced through coding-mathematics integration education. Thus, integrating coding education into mathematics lessons not only improves students' coding skills but also enhances their mathematical knowledge and thinking abilities (Chang, 2017).

Programming languages used in coding integration education are referred to as Educational Programming Languages (EPL). EPLs can be categorized into text-based EPL and block-based EPL. In text-based coding education using text-based EPL, learners use advanced programming languages like Java, Ruby, Visual Basic, C, C++, and Python, which are commonly used in real-world computer programming. For instance, the Arduino program, a physical computing tool based on microcontroller boards and open-source software, uses text-based programming languages like C/C++. Students can configure circuits with components like Light Emitting Diodes(LEDs) and motors and control them through coding. While this method allows learners to learn languages used in real-world programming, it requires them to understand various commands and functions, which can be challenging. To address this, block-based EPLs have been developed. Representative block-based EPLs include Hour of Code, Scratch, and Entry. Block-based EPLs provide commands in the form of blocks, reducing the burden of learning individual commands. However, the range of usable commands is limited in block-based EPLs.

III. METHODS

Lesson Plan

The purpose of this study is to explore the enhancement of learners' affective characteristics through coding integrated mathematics education. Therefore, the mathematical content knowledge difficulty of the coding-mathematics lesson program was set at a level understandable by middle school students or above. The curriculum content was selected based on topics in geometry, probability, and statistics, which can be effectively integrated with coding learning. We designed a coding-mathematics lesson program targeting students who have never received coding education before. Hence, we initially used block-based educational programming languages, which are simpler to use than text-based programming languages, to help students easily get acquainted with coding. As the lessons progress, we gradually incorporate text-based educational programming languages to offer higher-level opportunities for mathematics learning activities using coding.

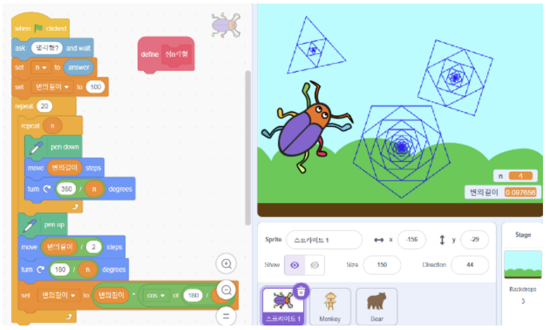
The coding-mathematics lesson program designed in this study consists of a total of 10 sessions as shown in Table 2. Sessions 1-3 focus on geometry-centered mathematics lessons using block-based educational programming languages. In these sessions, students are required to create a storybook using Scratch based on given conditions (Figure 1). The code for creating the storybook should be more than 50 lines and include two characters, four different shapes, and three or more motions. This session is designed to help students understand various properties such as shapes, lengths, sizes, measurement units, and angles through activities where they use code to draw on their own. Additionally, by moving the shapes they drew while coding, students can understand the position and movement of shapes on the coordinate plane.

Table 2. Contents of coding-mathematics STEAM education program

Lesson	Mathematical Content	Summary	Coding Tool
1-3 lessons	• Angles, shapes • Movement of shapes on the coordinate plane • Conversion of measurement units such as the metric system	1) A situation where two characters engage in dialogue. 2) Four different shapes. 3) Three or more types of motion. 4) Creating a storybook using over 50 lines of code.	Scratch
4-6 lessons	• Flowcharts • Number of cases • Understanding and calculation of probability • Permutations	1) Counting the number of letters in a word. 2) Considering the number of challenges to provide to the problem solver. 3) Creating a word guessing game.	Python
7-10 lessons	• Number of cases • Combinations • Permutations	1) Construct an electrical circuit using multiple LED bulbs and RGB LED bulbs on a breadboard. 2) Utilize code in an Arduino program to make LED bulbs of various colors light up in different sequences.	Microcontroller

Sessions 4-6 focus on probability-centered mathematics lessons using Python, a text-based educational programming language. Students are tasked with creating a word-guessing game using Python (Figure 1). For this, they are given conditions such as the number of letters the word should contain and must create a program with limited attempts. Through this coding activity of creating a word guessing game, the lessons are structured to help students think about and understand concepts related to permutations based on the number of letters given and probabilities based on the number of attempts.

Sessions 7-10 utilize Arduino, a program based on text-based programming languages C/C++. In this lesson, students use a microcontroller to make LEDs of various colors light up in different sequences. They construct an electrical circuit using LED bulbs and RGB LED bulbs and create a program on Arduino to light up the bulbs according to certain conditions. For instance, if they want the red and yellow bulbs to light up, students can code to have the lights come on in either 'red-yellow' or 'yellow-red' order. As the number of bulbs increases, the number of permutations students need to consider also increases. The lessons are structured in such a way that students naturally acquire concepts of permutations and combinations through this process.



```python
name = input("""What is your name?""")

print("Hello, " + name)
print("Let's play!")
w = 0
if 0 == 0:
    one = "_"
    two = "_"
    three = "_"
    four = "_"
    five = "_"

#Start of loop

    while 0 == 0:
        print(one + two + three + four + three + five + four)
        guess = input("""Guess a letter""")
        if guess == "s":
            one = "s"
        elif guess == "t":
            two = "t"
        elif guess == "e":
            three = "e"
        elif guess == "a":
            four = "a"
        elif guess == "m":
            five = "m"
        else:
            w = int(w + 1)
            r = str(6-w)
            print("That letter isn't in the word")
            print(r + " guesses remaining")
        while w == 6:
            print("Try again")
        if one == "s":
            if two == "t":
                if three == "e":
                    if four == "a":
                        if five == "m":
                            while 0 == 0:
                                print("You win")
```

Figure 1. Examples of students' coding activity (Left: Scratch, Right: Python).

Participants

The study participants consisted of a total of 86 middle and high school students, comprising 47 male students and 39 female students, spanning 1st grade of middle school through 2nd grade in high school (Table 3). The participants are enrolled in regular mathematics curricula in either public or private schools. Prior to participating in the coding-mathematics lesson program, none of the students had prior experience with coding education. Students did not participate in any additional programs or classes during the project period.

Table 3. Participants of coding-mathematics lesson program

		Number of Participants	Ratio
Gender	Male	47	54.7
	Female	39	45.3
School Level-Grade	Middle School -1st	14	16.3
	Middle School -2nd	16	18.6
	Middle School -3rd	18	20.9
	High School -1st	22	25.6
	High School -2nd	16	18.6
Total		86	100.0

Data Collection

In this study, we aimed to assess the degree of improvement in students' affective mathematical engagement through coding-mathematics lesson programs in the using pre- and post-tests. The measurement tool for affective mathematical engagement was adapted from Lee et al. (2019)'s MAME. The MAME survey consists of 37 items categorized into attitude (7 items, questions 1-7), emotion (11 items, questions 8-18), self-acknowledgement (7 items, questions 19-25), and value (12 items, questions 26-37). The survey was administered for 10-15 minutes both before and after the implementation of the entire coding-mathematics lesson program. Respondents were asked to indicate their level of agreement with each survey item on a Likert 5-point scale. To examine whether the coding-mathematics lesson brought about changes in students' affective mathematics engagement, we conducted statistical analyses on the survey results before and after the program implementation.

Using SPSS 24, we computed the mean and standard deviation (SD) and performed a paired-sample t-test to compare the differences between pre- and post-test scores (df=85). To address the sensitivity of the p-value to sample size limitations in null hypothesis statistical significance testing, we also provided 95% confidence intervals and effect sizes (Capraro et al., 2019). Therefore, in this study, we calculated 95% confidence intervals and Cohen's d effect sizes. A Cohen's d effect size of 0.2 or less is considered small, 0.5 medium, and 0.8 or more large (Cohen, 1992). By presenting the 95% confidence intervals and effect sizes, we aim to indicate the statistical estimation and power, that is, the degree of precision in statistical analysis (Capraro et al., 2019). Additionally, to effectively represent the complex estimated relationships between pre- and post-test responses, we presented the 95% confidence intervals graphically (Cumming & Finch, 2004).

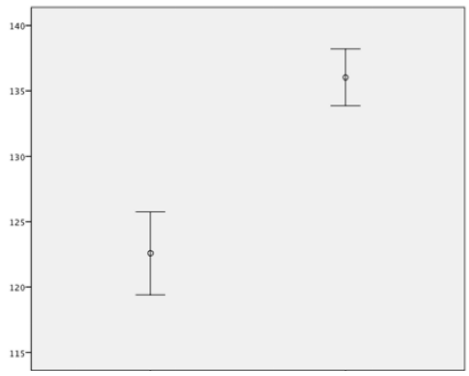
IV. RESULTS

Effect of Coding-Mathematics lesson on Affective Mathematics Engagement

The analysis results of students' affective mathematics engagement before and after the implementation of the coding-mathematics lesson are presented in Table 4. The means for affective mathematics engagement increased from 122.58 in the pre-test to 136.02 in the post-test, with a decrease in SD observed. The 95% confidence intervals for the average responses to affective mathematical engagement due to the coding-mathematics lesson were [119.45, 125.71] for the pre-test and [133.87, 138.17] for the post-test. The difference in mean responses between pre- and post-tests was statistically significant, and the effect size for the difference in pre- and post-test responses was 2.285. This indicates that the effect of the coding-mathematics lesson on affective mathematics engagement is very high. Thus, it can be confirmed that the coding integrated mathematics education program designed in this study positively influenced students' affective mathematics engagement.

Table 4. A t-test result of pre- and post-tests of affective mathematics engagement

Test	M	SD	t	p	d
Pre	122.58	14.81	10.532	<.001	2.285
Post	136.02	10.15			



Effects of Coding-Mathematics Lesson on Affective Mathematics Engagement Subscales

We examined changes in the mean responses of pre- and post-tests for four subscales related to the affective aspects of mathematics, and analyzed the effect sizes through paired-sample t-tests. The analysis of student reactions before and after applying the coding-mathematics lesson for the four subscales of participation in affective mathematics engagement(i.e., attitude, emotion, self-acknowledgement, and value) is shown in Table 5.

Table 5. t-test results of pre- and post-tests by subscales of affective mathematics engagement

Subscale	Pre-M (SD)	Post-M(SD)	t	p	d
Attitude	26.28 (3.73)	28.84 (3.02)	7.092	<.001	1.538
Emotion	35.34 (5.19)	38.40 (4.51)	6.175	<.001	1.340
Self-acknowledgement	27.12 (4.93)	27.73 (4.29)	1.320	.191	0.286
Value	33.85 (9.75)	41.06 (4.47)	7.018	<.001	1.522

In examining the mean responses of students, it can be observed that the results of the post-test are higher compared to the pre-test for both attitude, emotion, self-acknowledgement, and value related to participation in affective mathematics engagement. Regarding mathematical attitude related to participation in affective mathematics engagement, the mean response increased from 26.28 in the pre-test to 28.84 in the post-test, with a 95% confidence interval of [25.49, 27.07] for the pre-test and [28.20, 29.48] for the post-test. The pre-post test mean difference was statistically significant ($p<.001$), with an effect size of 1.538, indicating a significant effect of coding-mathematics lesson on attitude change. The mean of mathematical emotion in affective mathematics engagement increased from 35.34 in the pre-test to 38.40 in the post-test, with a 95% confidence interval of [34.24, 36.43] for the pre-test and [37.45, 39.35] for the post-test. The pre- and post-tests mean difference was statistically significant ($p<.001$), with an effect size of 1.340, indicating a significant effect of the coding integrated mathematics education on students' affective engagement change.

The mean response for mathematical value increased from 33.85 in the pre-test to 41.06 in the post-test. The 95% confidence interval was [31.79, 35.91] for the pre-test and [40.12, 42.00] for the post-test, suggesting the largest pre- and post-tests mean difference. The pre- and post-tests mean difference was statistically significant ($p<.001$), with an effect size of 1.522, indicating a significant effect of coding-mathematics lesson on value change. The mean response for mathematical self-acknowledgement increased from 27.12 in the pre-test to 27.73 in the post-test, and the 95% confidence interval was [26.08, 28.16] for the pre-test and [26.82, 28.64] for the post-test, indicating a relatively small pre- and post-tests mean difference. The mean difference for mathematical self-acknowledgement was not statistically significant. The effect size was also low at 0.286, indicating that the self-acknowledgement change due to coding-math lesson was lower compared to other factors (attitude, emotion, and value). In particular, it can be observed that the 95% confidence intervals of pre and post-test responses for students' self-acknowledgement are wider than those of other subscales, and the range of overlap between pre-post test responses' 95% confidence intervals is broader. This justifies that the change in students' self-acknowledgement is not statistically significant.

V. DISCUSSION

Affective characteristics of students' mathematics not only positively impact their cognitive achievement but also have a close relationship with their quality of life (Kauchak & Eggen, 2010). Therefore, nurturing the affective characteristic skills is necessary for students to lead a fulfilling school life and a high-quality life in general. In particular, the lower affective achievement of Korean students compared to their high cognitive achievement, as revealed in international comparative studies, indicates the need for proactive efforts in educational aspects to develop both academic achievement and affective characteristic skills. In this study, we designed a coding-mathematics lesson as one program for coding integrated STEAM education in mathematics, and analyzed the extent of change in students' affective mathematics engagement following the implementation of the program.

As a program for coding integrated STEAM education in mathematics, coding-math lesson designed in this study has been shown to positively change mathematical attitude, emotion, and value in affective mathematics engagement. Participating in coding-math lesson, where students generate ideas through programming and share their ideas with other students, has positively influenced attitude, emotion, and value. In particular, the coding-math lesson has been shown to have a greater impact on the change in value in affective mathematics engagement. Mathematical value involves understanding the importance of sharing mathematical knowledge or ideas with others and the belief that mathematical knowledge or skills can impress others (Goldin et al., 2011; Lee et al., 2019). The program designed in this study appears to have exerted a greater influence on the positive change in mathematical value than on mathematical attitude or emotion, as it involves learners actively engaging in coding, leading to mathematical learning, and collaborative work with other students.

On the other hand, self-acknowledgement in affective mathematics engagement remained statistically unchanged through the coding-mathematics lesson. Mathematical self-acknowledgement involves a focus on aspects such as the psychological reward of conveying understanding or achievements, mathematical comprehension, problem-solving, and the experience of the allure of mathematics (Goldin et al., 2011; Lee et al., 2019). Within the context of participation in affective mathematics engagement, self-acknowledgement seems to be more related to mathematical achievement than to attitude, emotion, or value. This aligns with research suggesting that participation in affective mathematics engagement interacts with cognitive aspects (Im & Lim, 2007). Thus, to enhance affective mathematics engagement, particularly to improve mathematical self-acknowledgement, there is a need for further refinement to ensure clear cognitive understanding of mathematical concepts obtained through the coding process and to develop effective methods for rewarding learners' achievements.

The implications drawn from the research results are as follows. First, the coding-mathematics lesson can serve as a means to enhance students' affective characteristics. The program designed in this study was found to contribute to increasing students' affective mathematics engagement. As participatory coding integrated mathematics learning encompasses concepts related to affective characteristics. Many studies emphasize the importance of students' active participation in mathematical learning environments (Boaler & Greeno, 2000; Gellert, 2004). Through the coding-mathematic lesson, students engage actively in mathematical learning, share opinions with other students, develop positive feelings towards mathematics, and consequently, induce positive changes in affective characteristics such as attitude, emotion, and value. This, in turn, can promote students' sustained mathematical learning and influence their choices regarding STEAM-related majors and careers (Ketelhut et al., 2010; Mueller et al., 2011).

Furthermore, to improve mathematical self-acknowledgement, programs that allow students to experience mathematical achievement need to be provided. It was not statistically significant that the coding-mathematics lesson did not have a significant impact on the change in self-acknowledgement. Self-acknowledgement is closely related to learners' feelings about mathematical cognition and is associated with students' processes of forming mathematical knowledge. Therefore, the results indicating that students lack confidence in the mathematical knowledge they construct during the learning process, leading to their self-acknowledgement not improving compared to other subscales, suggest the need to establish a systematic supportive environment that recognizes and encourages students' cognitive achievements during the learning process to enhance affective mathematics engagement, particularly mathematical self-acknowledgement.

The current study confirmed the potential to positively improve students' affective mathematics engagement through coding-mathematics lesson among middle and high school students. These findings suggest that the expanding coding integrated STEAM education programs in mathematics classrooms could be utilized as a means to improve affective characteristics of students regarding mathematics. This study implemented a robust theoretical framework specifically developed for Mathematics-based STEAM education (Lee et al., 2019). This framework identifies the factors of students' affective engagement that educators should focus on. Also, the coding-mathematics lesson program was developed by integrating three different programs (Scratch, Python, and microcontrollers), whereas many studies focus on only one program (e.g., Rodríguez-Martínez et al., 2020; Song, 2017). This demonstrates that our program genuinely considers coding for mathematics learning without limiting it to a single platform.

In this study, we did not separate students by their grades or school levels. For future research, it could be meaningful to explore how students at different schools or grade levels are influenced by the integration of coding in mathematics learning, particularly in terms of their affective mathematics engagement. A larger sample size might be more beneficial for this purpose. Through these, exploration of the activation of coding integrated mathematics education and the cultivation of affective mathematics engagement can be further pursued.

Acknowledgement

This study was supported by 2023 Research Grant from Kangwon National University.

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