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Learning programming: exploring the relationships of self-efficacy, computational thinking, and learning performance among minority students

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This study investigated minority students' learning in programming. The variables, including self-efficacy, computational thinking, and learning performance were the focus of this study. This study explored the relationships of creative self-efficacy, learning self-efficacy, computational thinking, and learning performance among minority undergraduate students. The influence of creative self-efficacy, learning self-efficacy, and computational thinking on learning performance was explored. The participants were minority students from a HBCU institution in the southeastern United States. Quantitative approaches were performed to analyze the collected data. The results indicated that self-efficacy, learning self-efficacy, and computational thinking were positively correlated with learning performance. Learning self-efficacy and computational thinking were significant predictors of learning performance among minority students.

KEYWORDS

learning self-efficacy, creativity self-efficacy, computational thinking, computer programming, learning performance, minority students

1 Introduction

With computing being influential in all areas of life, programming is recognized as an essential competency that people should possess to resolve real-world problems in the 21st century (Kuo and Kuo, 2023; Calderon et al., 2024; Chao, 2016). Programming education is considered important in all levels of education, from K-12 education to higher education (Kuo et al., 2026; Avci, 2022). Through programming education, students not only learn the basic concept of programming, but also develop programming competencies, computational thinking, and abilities for problem solving through implementing programming applications (Li et al., 2021; Tran, 2018). Programming skills that used to be regarded as professional capabilities specific to computer science majors have now become essential in many other professions, including both STEM and non-STEM fields (Tsai et al., 2019).

The skills associated with computer programming are essential ones for STEM careers (Lee and Cheng, 2011). Due to the call for more skilled STEM/CS professionals, it is important to equip students with qualified programming skills through education (Lee and Cheng, 2011; Tsai et al., 2019). To respond to the STEM/CS shortage in the United States, higher education institutions have raised consciousness in providing computer programming initiatives in STEM/CS education (Tran, 2018). In higher education, computer programming courses are commonly offered in computer science. In the field of engineering, some programs offer introductory programming courses or courses that may require the knowledge of programming, depending on students' specialization (Avci, 2022). In the society of the ever-changing digital technology, there are many benefits of learning programming (Li et al., 2021). However, on the other hand, learning programming is often considered difficult, especially for those who are novices or new to programming (Avci, 2022). The challenges that novice learners may encounter include learning or using a specific programming language, memorizing syntax or functions, editing or writing computer codes in the coding platform or environment, applying computer science concepts to solve problems, etc. (Avci, 2022; Calderon et al., 2024; Wei et al., 2021).

Although the benefits of learning programming have been recognized, the challenges or difficulties that undergraduate students experienced have led to high dropout and failure rates in undergraduate computer programming courses (Alturki, 2016; Cheah, 2020). Especially for non-CS majors, they would need to put more effort into learning programming than expected, which gradually lowers their motivation to learn programming and in turn increases their chances of dropping out of a programming class (Kinnunen and Malmi, 2006). Self-efficacy (Bandura, 1977), which is deemed to be critical to students' academic learning experience, is an important variable in programming learning (Gunbatar, 2018; Tsai et al., 2021). It is associated with students' programming experiences and performance (Kuo and Kuo, 2023; Gunbatar, 2018). Learning programming requires students' continuous work and practice in solving programming problems to achieve a desired goal (Ke, 2014). Students with sufficient self-efficacy generally have higher confidence in overcoming encountered programming problems, resulting in higher persistence or academic performance in programming learning (Wei et al., 2021).

In computer game development, students are required to create games through programming. Students' creative self-efficacy may play an important role in the game development process. Creative self-efficacy is critical to the emergence of creative behaviors and the facilitation of development in creative endeavors (Christensen-Salem et al., 2021). Computational thinking that addresses one's thought processes and techniques for problem solving is essential to programming (Barr and Stephenson, 2011; Tsai et al., 2021; Wing, 2006). Programming is one of the approaches to enhancing an individual's computational thinking skill (Calderon et al., 2024).

Achievement gaps have been reported to exist between white and minority groups, according to the American Council on Education (Espinosa et al., 2019) and Stanford Center for Education Policy Analysis (2025). In computing fields, Kargarmoakhar et al. (2020) raised concerns about minority groups (e.g., African Americans, Hispanics, etc.) showing higher dropouts and lower learning persistence, compared to white groups, due to discrimination and biases. Minority or underrepresented students' low achievement in computing/computer programming or relevant fields remains an issue that educators and researchers have attended to (Alford et al., 2017; Alford and Deorio, 2019; Kuo et al., 2025; Kargarmoakhar et al., 2020).

Self-efficacy and computational thinking play an important role in programming learning (Gunbatar, 2018; Kanaparan et al., 2013; Lishinski and Yadav, 2021). Although the positive impact of learning self-efficacy on performance is prominent in prior research, it is not clear about how creative self-efficacy and computational thinking would influence programming performance (Kuo et al., 2014; Kuo and Kuo, 2023; Walker et al., 2024). There is a lack of such studies for minority students. Therefore, this study aims to explore the relationships of self-efficacy, computational thinking, and learning performance among minority students.

2 Literature review

2.1 Self-efficacy

The concept of self-efficacy was first introduced by the psychologist, Albert Bandura (1977). He defined self-efficacy as "the belief in one's capabilities to organize and execute the courses of action required to manage prospective situations" (Bandura, 1995, p. 2). Rooted in the core belief that drives individuals to take actions to make a difference or for a desired outcome, self-efficacy is the foundation of human motivation, performance accomplishments, and emotional well-being (Bandura, 1997). Self-efficacy has an influence on many aspects of behavior that include the amount of time or effort an individual is willing to spend, a specific behavioral change that an individual anticipates to achieve, or the thought process that an individual carries out to enact the behavior (Bandura, 2006; Gerald and Mangan, 2008). There are four main sources of influence through which an individual develops his or her self-efficacy beliefs, including mastery experiences, vicarious experience, verbal persuasion, and emotional and physiological states (Bandura, 1994).

Self-efficacy is an important component in evaluating individual or program outcomes (Gerald and Mangan, 2008). Research has indicated the connection of self-efficacy to outcome variables in various fields, including education, business, science, information technology, medical education, etc. (Kuo et al., 2025, 2026; Correa-Rojas et al., 2024; Peteros, 2024; Tutar et al., 2024; Walker et al., 2024). Individuals with a higher level of self-efficacy tend to accomplish more and persist longer with a given task, compared to those with lower levels of self-efficacy (Barned et al., 2021). People with higher self-efficacy are more likely to have better coping strategies to handle a difficult situation, and show more resilience when encountering frustrations or problems (Holzer et al., 2023; Stoutenberg et al., 2016; Yang and Tu, 2024).

2.1.1 Learning self-efficacy

Learning self-efficacy refers to an individual's confidence in his or her ability to carry out the necessary actions to complete required tasks or assignments in the learning process (Yang and Tu, 2024). It plays an important role in facilitating learners' successful learning experience (Kuo et al., 2014; Tang et al., 2022). There is a relationship between learning self-efficacy and learning behaviors (Bandura, 1997; Tang et al., 2022). Research has indicated that learning self-efficacy is related to learning motivation, engagement, performance, persistence, etc. (Alemayehu and Chen, 2021; Kuo et al., 2020; Chan et al., 2025; Tang and Osman, 2022; Tang et al., 2022). Tang and Osman (2022) conducted a large-scale study that included over one thousand students from a vocational college of science and technology, and found that there was a positive correlation between learning self-efficacy and learning motivation. Alemayehu and Chen (2021) investigated undergraduate students from multiple higher education institutions in Taiwan, and found that students' learning self-efficacy was significantly correlated with their motivation and learning engagement in online learning environments.

2.1.2 Creative self-efficacy

Creative self-efficacy refers to individuals' belief in their ability to creatively perform a task for a desired outcome (Tierney and Farmer, 2002). It also indicates individuals' judgment about their own creative capabilities or potential to make decisions or efforts, find solutions, generate new ideas, or reflect on the progress of work, to achieve innovative outcomes (Beghetto, 2013; Shaw et al., 2021; Unal and Taşar, 2021). Creative self-efficacy is rooted in Bandura's (1977) general concept of self-efficacy (Tierney and Farmer, 2002). With its important role in the creative process, creative self-efficacy provides an understanding of how an individual intends to pursue or avoid some types of creative assignments or tasks over others (Tierney and Farmer, 2002). Creative self-efficacy can change over time, depending on an individual's experiences or the environment (Tierney and Farmer, 2011). It is considered as a critical motivation factor that has an impact on individuals' creative performance or novelty tendency (Christensen-Salem et al., 2021; Karwowski et al., 2015; Yuan et al., 2023). Individuals with high creative self-efficacy are more motivated to exert creativity or make efforts on creative endeavors than the individuals with low creative self-efficacy (Cervone et al., 2011).

2.2 Computational thinking

Computational thinking is a fundamental skill that everyone should possess, not just for computer scientists or computer engineers (Barr and Stephenson, 2011; Tsai et al., 2021; Wing, 2006; Zhou et al., 2024). Emerging from the field of computer science (CS), it refers to a way of thinking for problem-solving, system design, and the understanding of human behavior (Wing, 2006). Drawn on the concepts of CS, Wing (2006) emphasized the importance of CT in deconstructing complicated problems into manageable elements. Computational thinking includes processes such as decomposition, pattern recognition, abstraction, and algorithmic thinking (Yadav et al., 2016). According to Brennan and Resnick (2012), there are three dimensions of computational thinking, including concepts, practices, and perspectives.

CT is inherent in the process of computer programming (Atmatzidou and Demetriadis, 2016; Zhou et al., 2024). It can be carried out through the principles or practices, such as sequences, loops, conditionals, events, debugging, modularization, etc. (Brennan and Resnick, 2012; Jeon and Kwon, 2024; Zhou et al., 2024). Programming education is critical to the development of CT skills (Tsarava et al., 2022). Working on programming activities, assignments, or tasks helps to enhance an individual's cognitive or higher-order thinking skills, such as CT skills (Zhou et al., 2024).

2.3 Learning performance

Learning performance refers to learners' ability to engage in the learning process through adapting, making changes or choices, or learning from their own mistakes (Feldman et al., 2016). It is often measured by the scores or grades students obtain from tests, quizzes, or other forms of testing or evaluation (Kuo et al., 2020; Kuo and Kuo, 2023; Tordet et al., 2024). As an important indicator of learners' academic outcomes, research has indicated learning performance is related to a number of factors, such as peer feedback, self-efficacy, motivation, etc. (Kuo et al., 2025; Brummer et al., 2024; Walker et al., 2024; Zhao et al., 2024). Self-efficacy is deemed to be a critical factor of learning performance in various learning settings (Alosaimi, 2021; Wang et al., 2017). Computational thinking, which is associated with problem-solving processes, is considered to be an important thinking approach or skill in learning programming (Lye and Koh, 2014; Shin et al., 2025; Zhou et al., 2024). This study presumes the influential role of self-efficacy and computational thinking on minority students' learning performance in programming.

3 Research questions

1. What are minority students' creative self-efficacy, learning self-efficacy, and computational thinking, and learning performance?
2. What are the correlations among creative self-efficacy, learning self-efficacy, and computational thinking, and learning performance?
3. Do minority students' creative self-efficacy, learning self-efficacy, and computational thinking predict their learning performance?

4 Methods

4.1 Participants

The undergraduate students participating in this study were 56 minority students enrolled in two game design courses. All students responded to the online survey. The responses from 55 students were used for data analysis, with one incomplete response removed. Both courses were offered through an engineering program at a HBCU (Historically Black Colleges and Universities) university in the United States. They are face-to-face courses, and taught by the same instructor. Among the participants, there were more male students (60%) then female students (40%). Most of them aged 20 years old or older (96.4%), and one student (3.6%) who was 19 years old. Almost all of the students were African Americans, except for two who were Hispanic Americans (96.4%). As for their grade levels, about 85.5% were juniors, and 14.5% seniors. In terms of their programming skill, most of the students indicated having a basic (65.5%) or medium level (30.9%) of programming. One student reported no programming skills, and one student determined possessing a high skill level of programming. Table 1 provides an overview of the student information.

4.2 Data collection

An online survey was developed to collect the responses from the undergraduate students in this study. The researcher received the approval of the study from the university's Institutional Review Board (IRB), and obtained informed consent forms from the students, where students indicated their willingness to participate in the study by filling out the online survey. To encourage students'

TABLE 1 Student information.

Characteristic	*N* (%)
Gender	
Male	33 (60%)
Female	22 (40%)
Age	
19	2 (3.6%)
20	29 (52.7%)
21	15 (27.3%)
22	4 (7.3%)
23	5 (9.1%)
Ethnicity	
African-American	53 (96.4%)
Hispanic	2 (3.6%)
Grade level	
Junior	47 (85.5%)
Senior	8 (14.5%)
Programming skill	
None	1 (1.8%)
Basic level	36 (65.5%)
Medium level	17 (30.9%)
High level	1 (1.8%)

participation, the instructor provided extra points to the students who volunteered to participate in the online survey. The online survey was conducted after the IRB approval. The online survey was provided to students at the end of the course. The survey questionnaire has five sections (see Table 2), including student background information, creative self-efficacy, learning self-efficacy, computational thinking, and learning performance in programming.

Table 2 shows the information of scales that were used in this study. The creativity self-efficacy that has 3 items was adopted from Tierney and Farmer (2002). The self-efficacy scale that has 8 items was adopted from Pintrich and De Groot (1990). The computational thinking scale that has 19 items was adopted from Tsai et al. (2021). The learning performance scale that consists of 39 items was adopted from the scale developed by Kuo et al. (2025). It assessed students' perceived programming skills learned from the class. Both creative self-efficacy and learning self-efficacy scales are a 7-point Likert scale. Computational thinking and learning performance are a 5-point Likert scale. The reliability of these four scales is good, with all Cronbach's alpha above 0.9.

4.3 Context

The game design course required students to learn computer programming to develop games. It took a semester of 15 weeks to complete. The course was delivered through the combined slide-based lectures and demonstrations using the Unity (a game development software) in the computer classroom. By the end of the semester, the students were required to create their own computer games by integrating what they had learned throughout the semester.

TABLE 2 Instruments.

Scales	Number of items	Range	Cronbach's alpha
Creative self-efficacy	3	1–7	0.934
Learning self-efficacy	8	1–7	0.932
Computational thinking	19	1–5	0.938
Learning performance in programming	39	1–5	0.970

4.4 Data analysis

The data collected from the survey were analyzed using quantitative approaches. These quantitative approaches included descriptive analysis, correlation and regression analyses. SPSS 27 was used to perform the data analysis. Statistical assumptions for regression were checked and there were no violations.

5 Results

5.1 RQ1: what are minority students' creative self-efficacy, learning self-efficacy, and computational thinking, and learning performance?

Table 3 shows the results of descriptive analyses from the undergraduate students. The average score of students' creativity self-efficacy was moderately high ($M = 5.64$, $SD = 0.98$). The average score of students' learning self-efficacy ($M = 5.27$, $SD = 1.02$) was above the mid-point score 3.5. Students' average score of computational thinking was moderately high, with a mean of 4.05 ($SD = 0.55$). Students had a moderate average score ($M = 3.65$, $SD = 0.65$), slightly above 3, in their learning performance for programming.

5.2 RQ2: what are the correlations among creative self-efficacy, learning self-efficacy, and computational thinking, and learning performance?

Table 4 shows the correlations of students' creative self-efficacy, learning self-efficacy, computational thinking, and learning performance in programming. Creative self-efficacy ($r = 0.38$, $p < 0.01$), learning self-efficacy ($r = 0.76$, $p < 0.01$), and computational thinking ($r = 0.48$, $p < 0.01$) were positively correlated with learning performance in programming at a significant level. Creative self-efficacy ($r = 0.75$, $p < 0.01$) and learning self-efficacy ($r = 0.42$, $p < 0.01$) were positively correlated with computational thinking.

TABLE 3 Descriptive information.

Scales	*M*	*SD*
Creative self-efficacy	5.64	0.98
Learning self-efficacy	5.27	1.02
Computational thinking	4.05	0.55
Learning performance in programming	3.65	0.65

TABLE 4 Correlations among Variables.

Variables	Creative self-efficacy	Learning self-efficacy	Computational thinking	Learning performance
Creative self-efficacy	–	0.43*	0.75**	0.38**
Learning self-efficacy		–	0.42**	0.76**
Computational thinking			–	0.48**
Learning performance				–

** $p < 0.01$.

TABLE 5 Multiple regression model.

Variables	*B*	*SE*	*β*	*t*	*p*
Creative self-efficacy	0.109	0.084	0.165	1.30	0.200
Learning self-efficacy	0.466	0.059	0.731	7.94	0.000***
Computational thinking	0.355	0.149	0.301	2.38	0.021*

* $p < 0.05$; *** $p < 0.001$.

TABLE 6 Multiple regression model.

Variables	*B*	*SE*	*β*	*t*	*p*
Creative self-efficacy	0.123	0.094	0.180	1.31	0.198
Learning self-efficacy	0.467	0.065	0.710	7.13	0.000***
Computational thinking	0.346	0.166	0.284	2.08	0.043*

* $p < 0.05$; *** $p < 0.001$.

TABLE 7 Multiple regression model.

Variables	*B*	*SE*	*β*	*t*	*p*
Creative self-efficacy	0.105	0.088	0.157	1.19	0.239
Learning self-efficacy	0.451	0.061	0.700	7.34	0.000***
Computational thinking	0.382	0.156	0.320	2.458	0.018*

* $p < 0.05$; *** $p < 0.001$.

Creative self-efficacy ($r = 0.43$, $p < 0.01$) was positively correlated with learning self-efficacy.

5.3 RQ3: do minority students' creative self-efficacy, learning self-efficacy, and computational thinking predict their learning performance?

The multiple regression model (see Table 5) was significant, $F(3, 51) = 32.46$, $p < 0.001$. The model explained 64% of the variance in learning performance. There is no multicollinearity detected. Creative self-efficacy did not significantly predict learning performance ($\beta = 0.165$, $p > 0.05$). Learning self-efficacy ($\beta = 0.731$, $p < 0.001$) and computational thinking ($\beta = 0.301$, $p < 0.05$) are significant predictors of learning performance. Learning self-efficacy was a stronger predictor than computational thinking.

The learning performance in programming in this study measures three types of programming skills (i.e., understanding of programming, application of programming, and problem-solving of programming) students learned in the course. We performed regression analyses to look further into how creative self-efficacy, learning self-efficacy, and computational thinking predicted understanding of programming, application of programming, and problem-solving of programming (see Tables 6–8). There is no multicollinearity detected. In understanding of programming,

TABLE 8 Multiple regression model.

Variables	*B*	*SE*	*β*	*t*	*p*
Creative self-efficacy	0.100	0.089	0.147	1.13	0.263
Learning self-efficacy	0.479	0.062	0.728	7.75	0.000***
Computational thinking	0.337	0.157	0.277	2.15	0.037*

*$p < 0.05$; ***$p < 0.001$.

learning self-efficacy ($\beta = 0.710$, $p < 0.001$) and computational thinking ($\beta = 0.284$, $p < 0.05$) are significant predictors (see Table 6). As for application of programming, learning self-efficacy ($\beta = 0.700$, $p < 0.001$) and computational thinking ($\beta = 0.320$, $p < 0.05$) are significant predictors (see Table 7). Similarly, learning self-efficacy ($\beta = 0.728$, $p < 0.001$) and computational thinking ($\beta = 0.277$, $p < 0.05$) significantly predicted problem-solving of programming (see Table 8). Creativity self-efficacy did not significantly predict understanding of programming ($\beta = 0.180$, $p > 0.05$), application of programming ($\beta = 0.157$, $p > 0.05$), and problem-solving of programming ($\beta = 0.147$, $p > 0.05$).

6 Discussion

This section summarizes major results from data analyses and provides discussions on these findings through explanations and synthesis. According to the descriptive analysis, minority students were moderately confident in their self-efficacy for creativity and learning during their attendance of the game design course. Their computational thinking and learning performance in programming showed an adequate average, slightly higher than the midpoint score.

According to the correlation analysis, positive correlations were found among creative self-efficacy, learning self-efficacy, computational thinking, and learning performance. Creative self-efficacy, learning self-efficacy, and computational thinking were found to significantly and positively correlated with learning performance. It suggests a trend of higher creative or learning self-efficacy, or computational thinking being linked to higher performance in learning programming, and vice versa, among the minority students. In previous studies, a positive relationship between self-efficacy and learning performance was found (Kuo et al., 2020; Bandura, 1997; Chan et al., 2025).

Based on the regression analysis, the impact of creative self-efficacy, learning self-efficacy, and computational thinking on learning performance in programming was examined. The results indicated the significant roles of learning self-efficacy and computational thinking in predicting learning performance in programming. They suggest that minority students who were confident in learning or being creative, were more likely to perform better in learning programming. Similarly, minority students who were more computational thinking oriented were more likely to succeed in learning programming. As indicated in prior research, learning self-efficacy is critical to students' successful learning experience, and it contributes to students' academic performance (Alemayehu and Chen, 2021; Kuo et al., 2020; Chan et al., 2025). Self-efficacy plays an important role in enhancing STEM education (Bandura, 1997; Wu et al., 2023). In programming learning, self-efficacy is critical to student performance and was often found to have a significant influence on student performance (Kanaparan et al., 2013; Lishinski and Yadav, 2021). Computational thinking plays an important role in STEM education (Cheng et al., 2023). The integration of computational thinking is beneficial to students in STEM disciplines as computational thinking was found to have a significant effect on STEM learning outcomes (Cheng et al., 2023). In the context of programming, computational thinking was recognized as an essential skill to learning programming (Atmatzidou and Demetriadis, 2016; Lye and Koh, 2014; Tsai et al., 2021; Zhou et al., 2024). This study provides evidence to the significant impact of computational thinking on programming performance, specifically for minority undergraduate students.

In terms of the three areas of learning performance in programming, including understanding of programming, application of programming, and problem-solving of programming, both learning self-efficacy and computational thinking were found to be significant predictors. Corresponding to the suggestions from previous research (Calderon et al., 2024; Chan et al., 2025; Tsai et al., 2021), the important role of learning self-efficacy and computational thinking in predicting students' programming performance was confirmed in this study.

On the other hand, creative self-efficacy, although showing a positive correlation with learning performance, did not predict minority students' learning performance in programming. This result indicated that minority students' confidence level in being creative did not influence how they performed in learning programming. Similarly, creative self-efficacy did not significantly predict the three areas of learning performance, including understanding of programming, application of programming, and problem-solving of programming. It may be due to that the programming process itself does not involve lots of creative work or require a high level of creative thinking, which leads to the non-significant impact of creative self-efficacy on programming performance. Programming using visual programming tools may often involve higher levels of creativity demand, compared to text-based programming without the use of visual programming, which is the case of this study (Kovalkov et al., 2020). In addition, the creativity self-efficacy scale used in this study was not designed specifically for programming learning, which may potentially result in the non-significant influence of creativity self-efficacy on learning performance in programming in this study.

7 Conclusion

This study examined the role of self-efficacy and computation thinking in facilitating undergraduate minority students' learning performance in programming. Overall, students attending the game design course had an adequate level of learning performance in programming. Positive correlations were found among creative self-efficacy, learning self-efficacy, computational thinking, and learning performance in programming. Creative self-efficacy, learning self-efficacy, and computational thinking were significantly correlated with learning performance in programming. Among the three predictors, learning self-efficacy and computational thinking were the significant predictors of minority students' learning performance in programming. The results of this study adds to the limited research on minority students' learning experiences with programming, as well as the importance of self-efficacy and computational thinking in affecting minority students' outcomes in learning programming.

It is suggested that instructors or educators who teach programming for minority students develop strategies to enhance students' confidence in learning programming. Because learning self-efficacy was found to be the strongest predictor, instructors are suggested to focus on mastery experiences or social modeling (Bandura, 1997) to build students' confidence in learning programming. Confidence-building interventions may be especially warranted for underrepresented groups (Steele and Aronson, 1995). For example, collaborative learning approaches that are effective for minority students in learning (Kumi-Yeboah et al., 2017), can be adopted to enhance students' learning self-efficacy by pairing up the students who are more confident in learning programming with the students with low confidence in programming. Individual tutoring or trainings related to programming would help increase students' learning self-efficacy. To enhance students' computational thinking, instructors could consider incorporating CT processes into the design of the course content, activities, and assignments, when teaching programming to minority students. Teaching strategies, such as project-based learning or active learning (Adeyemi et al., 2024), could be applied to improve students' learning self-efficacy, computational thinking, and learning performance in programming. Active learning strategies were found to be beneficial to enhancing minority students' learning outcomes (Adeyemi et al., 2024).

There are several limitations of this study. First, the participants were minority students, with the majority of them being African Americans, and the results of the study may not be generalized to other groups of non-minority groups. The sample size of this study may be slightly small, it is encouraged that researchers implement similar studies with a larger sample size. Second, there are other variables (e.g., motivation, interests, etc.) that may show an impact on learning performance in programming but were not included in this study (Walker et al., 2024; Kuo et al., 2025, 2026). Researchers are encouraged to include them in the future study. Controlling for variables such as gender and grade level could be considered for future research. Third, although in this study, creativity self-efficacy was not found to have a significant role in predicting minority students' learning outcomes in programming, the impact of creativity self-efficacy on learning programming should be re-assessed in future studies by using a creativity self-efficacy scale that is more suitable for programming learning, or developing a new creative self-efficacy scale for the use of programming contexts. Last, the cross-sectional design may have its limitations in inferring causality, and it is suggested that researchers conduct a longitudinal or experimental design (e.g., comparison groups for minority and non-minority groups, etc.) to further evaluate the influence of self-efficacy and computational thinking on performance in programming for minority students. Including qualitative follow-ups may also help to explore how minority students perceive creativity in programming or how computer thinking skills are developed.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by The Institutional Review Board (IRB) at North Carolina A&T State University. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

Y-TK: Writing – original draft, Writing – review & editing. Y-CK: Writing – original draft, Writing – review & editing.

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