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Key factors influencing initial learning in computer programming

Factores clave que influyen en el aprendizaje inicial de la programación de computadoras

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ABSTRACT

Learning computer programming has become an essential skill in the digital age, presenting significant challenges and opportunities for students. This study examined the levels of motivation and perceived self-efficacy as factors in the initial learning of computer programming and their possible correlation with the academic performance of Computer Science students at a university in Puerto Rico. The approach was quantitative, using a survey research design (cross-sectional), with a self-administered online questionnaire. Evidence of validity related to content, response process, and internal structure was collected, and a non-probability convenience sampling was employed. The data were processed using the SPSS statistical package. The results showed a significant positive Spearman correlation between the items of the self-efficacy and motivation subscales with the academic performance reported by the participants in the introductory programming course. The study concluded that the self-efficacy and motivation of programming learners positively affect academic performance, contributing to the development of higher-order thinking skills such as problem-solving and creativity, highlighting them as fundamental factors in the initial learning of computer programming.

Keywords: academic performance; computer science; higher-order thinking; motivation; self-efficacy

RESUMEN

El aprendizaje de programación de computadoras se ha convertido en una habilidad esencial en la era digital, presentando desafíos y oportunidades significativas para los estudiantes. Este estudio examinó el nivel de motivación y autoeficacia percibida como factores en el aprendizaje inicial de programación de computadoras y su posible correlación con el rendimiento académico de estudiantes de Ciencia de Cómputos en una Universidad de Puerto Rico. El enfoque fue cuantitativo, utilizando un diseño de investigación por encuesta (transversal), con un cuestionario autoadministrado en línea. Se recopilaron evidencias de validez relacionadas con el contenido, proceso de respuesta y estructura interna, y se empleó un muestreo no probabilístico por conveniencia. Los datos fueron procesados con el paquete estadístico SPSS. Los resultados mostraron una correlación de Spearman positiva significativa entre los ítems de las subescalas de autoeficacia y motivación con el rendimiento académico informado por los participantes en el curso de fundamentos de la programación. El estudio concluyó que la autoeficacia y la motivación de los aprendices de programación inciden favorablemente en el rendimiento académico, contribuyendo al desarrollo de habilidades de pensamiento superior como la resolución de problemas y la creatividad, destacándose como factores fundamentales en el aprendizaje inicial de la programación de computadoras.

Palabras clave: autoeficacia; ciencia de cómputos; rendimiento académico; motivación; pensamiento de orden superior

1. INTRODUCTION

Computer programming has become a fundamental skill in higher education and the contemporary job market. However, learning programming poses significant challenges for many students, reflected in high dropout rates and low academic performance in introductory programming courses (Luxton-Reilly et al., 2018). This issue is especially relevant in Latin America, where the demand for technology professionals is increasing, but the supply of computer science graduates does not meet this need (Tekios, 2024).

Addressing this problem is crucial due to the growing importance of programming skills in various professional fields and the need to develop a competent workforce in technology. Success in introductory programming courses is essential for retaining students in computer science programs (Figueiredo & García-Peñalvo, 2020).

Various research studies have addressed the methodologies and pedagogical strategies that can improve academic performance and knowledge retention in programming students (Ibarra-Zapata et al., 2021; Vera Mosquera & Argüello Fiallos, 2019). In this context, our study focuses on motivation and self-efficacy, two key psychological factors influencing the academic success of computer science students.

Motivation, both intrinsic and extrinsic, has been extensively studied from the perspective of self-determination theory. Ryan & Deci (2020) highlight that intrinsic motivation, driven by interest and enjoyment in the activity itself, is a significant predictor of academic success. This approach is particularly relevant in learning programming, where problem-solving and creativity play crucial roles. Ling et al. (2021) have demonstrated that teaching the Python programming language can significantly enhance motivation and learning effectiveness due to its accessible syntax and wide applicability in various technological areas.

Self-efficacy, defined as the belief in one's ability to execute specific tasks, has also been identified as a determining factor in learning programming. Korkmaz & Altun (2014) and Kovari & Katona (2023) have shown that students with high self-efficacy in programming tend to exhibit better academic performance and greater persistence in facing challenges. Arévalo Mercado et al. (2018) and Rossi et al. (2020) found that self-efficacy and collaborative work can have a positive impact on the performance of novice programming students.

The systematic review by Jiménez-Toledo et al. (2019) emphasizes the evolution of educational approaches in programming, highlighting the importance of adapting methodologies to the current needs of students. Rojas-López & García-Peñalvo (2020) explored the assessment of computational thinking, proposing tools to measure and improve programming skills in higher education.

Despite these advances, there are significant challenges in teaching programming, especially concerning the integration of effective pedagogical approaches and the accurate assessment of competencies. Figueiredo & García-Peñalvo (2020) and De Giusti et al. (2019) suggest that a gamification-based approach and the evolution towards multi-paradigm methodologies can be beneficial. However, the practical implementation of these strategies requires continuous evaluation and adaptations based on empirical evidence.

Moreover, there is a gap in the literature regarding how the interaction between motivation and self-efficacy specifically affects academic performance in introductory programming courses in Puerto Rico. Most existing studies have been conducted in Anglo-Saxon or European contexts, leaving a gap in understanding these factors in Latin American environments.

The purpose of this research is to analyze how motivation and self-efficacy affect the academic performance of computer science students at a university in Puerto Rico. This study aims to fill the gap in the literature by providing empirical evidence on the relationship between these psychological factors and academic success in programming in a Latin American context.

Using an experimental design and quantitative analysis, this study seeks to identify pedagogical strategies that can improve these psychological dimensions and ultimately contribute to the academic success of students. This study will not only enrich the existing literature on programming education but also provide practical recommendations for educators and academic administrators in implementing more effective study programs.

2. MATERIALS AND METHODS

The study was conducted at a university in Puerto Rico, specifically in the Faculty of Natural Sciences. The research method employed was quantitative in nature, using a cross-sectional survey research design. According to Creswell (2008), survey studies aim to describe trends in data rather than offering causal explanations, as this type of design does not involve the manipulation of variables like experimental designs do.

The choice of this design was due to its ability to collect necessary information to examine the perception of Computer Science program students, specifically those who have taken the Introduction to Computer Programming course, in relation to internal factors such as the level of motivation and perceived self-efficacy in learning computer programming.

The study population consisted of 35 students from the Computer Science program of the Faculty of Natural Sciences at a university in Puerto Rico. Of these, 27 (77.1%) were men and 8 (22.9%) were women.

For data collection, an online self-administered questionnaire was designed using Google Forms. The questionnaire included closed questions and was structured into six sections: Part I (aspects about course content), Part II (environments where programming is learned), Part III (usefulness of learning resources), Part IV (motivation for learning programming), Part V (self-efficacy for learning programming), and Part VI (sociodemographic aspects) (gender, type of previous school, age, grade obtained in the introductory programming course, and previous experience in learning computer programming).

Part IV, Motivation for Learning Programming, was based on Ryan & Deci's (2020) Self-Determination Theory (SDT), focusing on the three basic needs outlined by SDT (autonomy, relatedness, and competence) as determining factors for the development of intrinsic motivation.

Part V, Self-Efficacy for Learning Programming, was based on Bandura's (1997) self-efficacy theory, defining self-efficacy as the perception Computer Science students have of their own ability to learn computer programming. Some items in this section were included after conducting a literature review and obtaining authorization from the corresponding authors to use textual or adapted items.

Content-related validity evidence was collected. For this purpose, the instrument was subjected to expert judgment, including an expert in measurement and instrument construction, a professor from the Bachelor's Program in Computer Science at a university in Puerto Rico, a professional in the field of Psychology or Counseling knowledgeable about Motivation and Self-Efficacy theories, and an expert in Learning Technology. Additionally, evidence based on the response process was collected. For this purpose, five students from the Computer Science program participated to explore the cognitive demands of the questionnaire and response processes (Medina-Díaz, 2010).

Internal consistency was determined by calculating the Cronbach's Alpha reliability coefficient. This coefficient is used in instruments where there is no right or wrong answer for each item (McMillan, 2004). The categories proposed by Gliem & Gliem (2003) were used as a reference.

The results of this research were analyzed using the Statistical Package for the Social Sciences (SPSS) version 23. Descriptive statistics, such as measures of central tendency, frequencies, and percentages, were used to examine responses and their distribution according to the questionnaire items. A Spearman correlation analysis was also performed to establish the relationship between students' motivation and

their academic performance in the Introduction to Computer Programming course, as well as between self-efficacy and academic performance in the same course.

3. RESULTS AND DISCUSSIONS

In the sections of the questionnaire corresponding to motivation and self-efficacy, a Likert scale was used with the response categories: Completely Agree (CA), Agree (A), Neutral (N), Disagree (D), and Completely Disagree (CD). Table 1 highlights the items that were most relevant. For this, the response options CA were grouped with A, and D with CD.

3.1. Motivation for learning programming

Table 1 highlights the items that were most relevant, grouping the response options CA with A and D with CD.

Table 1.
Aspects related to motivation for learning programming

Item	CA *f (P)*	A *f (P)*	N *f (P)*	D *f (P)*	CD *f (P)*
1	17(48.6)	14(40)	1(2.9)	2(5.7)	1(2.9)
2	11(31.4)	17(48.6)		6(17.1)	1(2.9)
3	9(25.7)	19(54.3)	2(5.7)	4(11.4)	1(2.9)
4	3(8.6)	8(22.9)	1(2.9)	18(51.4)	5(14.3)
5	8(22.9)	17(48.6)	3(8.6)	5(14.3)	2(5.7)
6	12(34.3)	16(45.7)	3(8.6)	4(11.4)	
7	1(2.9)	10(28.6)	3(8.6)	20(57.1)	1(2.9)
8	1(2.9)	6(17.1)	1(2.9)	20(57.1)	7(20)
9	1(2.9)	6(17.1)	2(5.7)	17(48.6)	8(22.9)
10	15(42.9)	16(45.7)		3(8.6)	1(2.9)
11	5(14.3)	6(17.1)	2(5.7)	12(34.3)	10(28.6)
12	2(5.7)	3(8.6)	4(11.4)	16(45.7)	10(28.6)
13	8(22.9)	17(48.6)	3(8.6)	6(17.1)	1(2.9)
14	10(28.6)	13(37.1)	1(2.9)	8(22.9)	2(5.7)
15	3(8.6)	4(11.4)	2(5.7)	14(40)	12(34.3)
16	12(34.3)	15(42.9)	3(8.6)	3(8.6)	2(5.7)
17	3(8.6)	3(8.6)	3(8.6)	17(48.6)	9(25.7)
18	7(20)	19(54.3)	2(5.7)	6(17.1)	1(2.9)

Notes: f = frequency. P = percentage. Instances where percentages do not total 100% are due to rounding errors. Items in bold have a negative statement.

Regarding motivation, 31 participants (88.5%) were CA or A with items 1 and 10, which inquire about motivation to achieve good grades and to strive for a good job. This finding is consistent with Ryan & Deci's (2020) self-determination theory, which highlights the importance of intrinsic motivation in learning.

Additionally, 80% of participants were CA or A with items 2 (feeling accepted by classmates), 3 (ability to learn everything required in programming), and 6 (successfully completing difficult tasks). These results align with previous studies indicating that social acceptance and perceived competence are critical factors in motivation for learning programming (Luxton-Reilly et al., 2018; Arévalo Mercado et al., 2018).

In contrast, item 4 (effort to please parents) had 65.7% D or CD, and item 7 (effort to please teachers) had 60% D or CD. These findings suggest a lower relevance of extrinsic motivation, consistent with the idea that intrinsic motivation is a stronger predictor of academic performance (Ling et al., 2021).

3.2. Self-efficacy for learning programming

The items in Section V of the questionnaire aimed to understand students' perceptions of self-efficacy for learning programming. Table 2 reports the frequency and percentage of participants' responses to each item regarding perceived self-efficacy.

Table 2.
Aspects related to self-efficacy for learning programming

Item	CA *f (P)*	A *f (P)*	N *f (P)*	D *f (P)*	CD *f (P)*
1	11(31.4)	17(48.6)	2(5.7)	4(11.4)	1(2.9)
2	10(28.6)	18(51.4)	4(11.4)	3(8.6)	
3	12(34.3)	16(45.7)	2(5.7)	4(11.4)	
4	7(20)	21(60)	3(8.6)	3(8.6)	1(2.9)
5	9(25.7)	17(48.6)	2(5.7)	5(14.3)	2(5.7)
6	5(14.3)	23(65.7)	1(2.9)	6(17.1)	
7	11(31.4)	13(37.1)	3(8.6)	8(22.9)	
8	7(20)	16(45.7)	3(8.6)	6(17.1)	3(8.6)
9	14(40)	15(42.9)	1(2.9)	5(14.3)	
10	7(20)	18(51.4)	1(2.9)	9(25.7)	
11	7(20)	19(54.3)	1(2.9)	5(14.3)	2(5.7)
12	13(37.1)	15(42.9)	2(5.7)	3(8.6)	1(2.9)
13	15(42.9)	13(37.1)	1(2.9)	6(17.1)	
14	8(22.9)	19(54.3)		8(22.9)	
15	5(14.3)	16(45.7)	7(20)	4(11.4)	3(8.6)

Notes: f = frequency. P = percentage. Instances where percentages do not total 100% are due to rounding errors.

Item 9 (academic competence) received 82.8% CA or A responses, indicating a high perceived self-efficacy among participants. These results suggest that participants have high perceived self-efficacy, which is important because, according to Bandura (1997), a strong sense of self-efficacy enhances achievements and personal well-being. Items 1, 2, 3, 4, 6, 15, and 13 also showed high levels of perceived self-efficacy, with 80% agreement. These findings align with studies showing that self-efficacy is a crucial factor for success in programming (Kovari & Katona, 2023; Erol, 2020; Arévalo Mercado et al., 2018).

Bandura (1997) emphasizes that a strong sense of efficacy significantly boosts performance and personal well-being. Individuals with high confidence in their abilities view challenging tasks as opportunities for mastery rather than threats to be avoided. In this context, it is promising that participants exhibit high levels of perceived self-efficacy, as this characteristic enables them to tackle complex challenges with the conviction and assurance necessary for success.

3.3. Correlation between motivation and academic performance

Table 3 shows the Spearman correlation analysis (r_s) between motivation items and academic performance (grade received by the participant in the introductory programming course). Academic performance was reported by participants using the following grading scale: A, B, C, D, and F. Significant correlations ($p < 0.05$) were found for items 2, 3, 6, 7, 8, 9, 11, 13, 14, 16, and 18, indicating that motivation positively impacts academic performance.

Tabla 3.
Spearman correlation analysis between motivation and academic performance

Item	Academic performance r_s (*p*)
1	.203 (.242)
2	.647** (.000)
3	.519** (.001)

4	.211 (.223)
5	.316 (.064)
6	.408* (.015)
7	.362* (.032)
8	.648** (.000)
9	.664** (.000)
10	.140 (.421)
11	.621** (.000)
12	.321 (.060)
13	.462** (.005)
14	.392* (.020)
15	.088 (.613)
16	.470** (.004)
17	.247 (.152)
18	.637** (.000)

Notes: ** Correlation coefficients significant at p < 0.01; * correlation coefficients significant at p < 0.05.

The significant correlations underscore the importance of fostering motivation among students, as it has a direct impact on their academic performance. This finding is consistent with previous studies highlighting the importance of motivation in learning programming (Jiménez et al., 2019; Rojas & García, 2020).

Although not all items in the motivation subscale showed a significant positive correlation with academic performance in the introductory programming course, it was observed that the items that did correlate corresponded to each of the three basic needs proposed in Ryan & Deci's (2020) self-determination theory. Attention to these needs is a crucial factor for a student to continue their studies (Ryan & Deci, 2020).

These results are consistent with the findings of Park et al. (2019), who indicate that a student's level of motivation is positively related to their learning process in computer programming. Similarly, Kovari & Katona (2023) found that motivation is a key facilitator for learning and academic success. It is considered that motivation acts as a catalyst for educational performance, aligning with Mohanarajah (2018).

3.4. Correlation between self-efficacy and academic performance

Table 4 presents the Spearman correlation analysis (r_s) between self-efficacy items and academic performance. Significant correlations (p < 0.05) were found for items 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 13, and 15, indicating that self-efficacy positively influences academic performance.

Table 4.
Spearman correlation analysis between self-efficacy and academic performance

Item	Academic performance r_s (*p*)
1	.485** (.003)
2	.605** (.000)
3	.417* (.013)
4	.675** (.000)
5	.616** (.000)
6	.731** (.000)
7	.662* (.000)
8	.585** (.000)
9	.351* (.039)
10	.543** (.001)
11	.207 (.233)
12	.471** (.004)
13	.425* (.011)
14	.250 (.147)
15	.594** (.000)

Notes: ** Correlation coefficients significant at p < 0.01; * correlation coefficients significant at p < 0.05.

These findings indicate that high self-efficacy is associated with better academic performance, supporting the importance of strengthening self-efficacy among programming students (Bandura, 1997; Ling et al., 2021). According to Bandura (1997), a strong sense of efficacy enhances human achievements and personal well-being in many ways. People with high confidence in their abilities approach difficult tasks as challenges to be mastered rather than threats to be avoided. Therefore, it is favorable that participants show a high level of perceived self-efficacy, as this allows them to face complex challenges with the conviction and belief that they can overcome them successfully.

Although the findings were significant, this study presents some limitations that should be considered. The sample was relatively small and selected using non-probability convenience sampling, which restricts the ability to generalize the results to the broader population.

CONCLUSIONS

This study confirmed that self-efficacy and motivation are essential determinants of the academic performance of Computer Science students in their initial learning of programming. The observed significant positive correlation between these variables and performance in an introductory course reinforces the importance of fostering these factors from the beginning of the educational process.

The practical implications of these findings are significant. Programming education must go beyond teaching technical skills by incorporating strategies that strengthen students' confidence and interest. By integrating approaches that promote self-efficacy and motivation, such as using playful methodologies and project-based learning, educators can create an environment more conducive to developing higher-order thinking skills, including problem-solving and creativity. This approach will not only improve academic performance but also prepare students to face future technological challenges, contributing to the advancement of knowledge and a more innovative society.

For future research, it is recommended to explore the effectiveness of different pedagogical approaches in strengthening self-efficacy and motivation in programming education. Additionally, it would be valuable to investigate how these strategies impact the long-term development of advanced competencies, such as critical thinking and creativity, and their influence on preparing students for professional roles in an increasingly digital world.

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CONFLICT OF INTEREST

There is no conflict of interest related to the subject matter of the work.

AUTHORSHIP CONTRIBUTION

Conceptualization: Martínez-Mejía, R. D.
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Writing - review and editing: Rodríguez-Villanueva, B. P

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