Ed Process Int J | www.**edupij**.com
ISSN 2147-0901 | e-ISSN 2564-8020
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EDUCATIONAL PROCESS
INTERNATIONAL JOURNAL

RESEARCH ARTICLE

Assessing Algorithmic Thinking Skills in Relation to Gender in Early Childhood

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ARTICLE HISTORY
Received *March 22, 2021*
Accepted *May 10, 2022*
Published Online *June 28, 2022*

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How to cite: *Kanaki, K., & Kalogiannakis, M. (2022).* Assessing Algorithmic Thinking Skills in Relation to Gender in Early Childhood. *Educational Process: International Journal, 11(2): 44-59.*

ABSTRACT

Background/purpose – In terms of computational thinking core facets, algorithmic thinking is a key competency applicable not only in Computer Science but also in aspects of daily life. Considering the global phenomenon of gender stereotypes with regards to the academic and professional orientation in STEM fields, we focused on investigating the level of students' algorithmic thinking skills by gender in early childhood. This article provides evidence of research implemented under the umbrella of quantitative methodology, employing an innovative assessment tool constructed to meet the requirements of the study. The findings obtained could facilitate researchers and policymakers to support equity in learning opportunities, starting from the first stage of compulsory education.

Materials/methods – The study aligns to the principles of quantitative research methodology. Its backbone is a digital platform of multidisciplinary, play-based, and constructivist character, which we implemented from scratch in order to satisfy the requirements of our research.

Results – The findings of the study revealed that algorithmic thinking skills are not related to students' gender in early childhood.

Conclusion – The findings of the study bring out that, at very young ages, the effect of gender stereotypes is not observable as far as students' algorithmic thinking skills are concerned. The implications of the study highlight the need to focus on the schooling stages that follow early childhood in order to tackle the gender gap in STEM fields.

Keywords – computational thinking, algorithmic thinking, gender, early childhood, game-based learning

To link to this article– https://dx.doi.org/10.22521/edupij.2022.112.3

1. INTRODUCTION

In recent years, emerging trends have brought to the fore the perspective of developing computational thinking (CT) skills within the context of Science, Technology, Engineering, and Mathematics (STEM) fields (Lee et al., 2020; NGSS Lead States, 2013; Weintrop et al., 2016). Recent literature on educational techniques for introducing CT skills in K-12 teaching proposes game-based learning environments not only because of their capacity to create learning experiences that are both effective and engaging (Emerson et al., 2020; Lin et al., 2020), but also because of their distinctive feature to improve overall learning interest and performance (Lin et al., 2020). In particular, game-based learning activities build up students' interest in computer programming, as well as in STEM fields (Chatzopoulos et al., 2020; Kastriti et al., 2022; Nikolopoulou, 2022; Santos, 2020; Tselegkaridis & Sapounidis, 2022).

As far as the evaluation of CT skills is concerned, relevant studies have shown that the subject remains open as a research challenge (Poulakis & Politis, 2021; Tang et al., 2020). This is an exceptionally important issue that needs to be addressed, because the absence of valid and reliable assessment tools jeopardizes the successful integration of CT into the educational scene, putting it in serious danger of vanishing as a structure, albeit it merits serious consideration (Román-González et al., 2019).

Exploring the plethora of approaches to CT as a skillset, we notice that algorithmic thinking is one of its fundamental competencies (Kallia et al., 2021; Román-González et al., 2019).

The main purpose of the current study is to investigate students' algorithmic thinking skills in relation to their gender within the context of an Environmental Study course applied during early childhood. We steered towards the first years of schooling since the subject of CT evaluation at this sensitive juncture in developmental terms for students remains an area largely subjected to minimal scientific investigation (Clarke-Midura et al., 2021; Poulakis & Politis, 2021; Tang et al., 2020), despite the need for being introduced even from kindergarten age (Relkin et al., 2021). An important factor that holds back the development of age-appropriate CT assessment tools for kindergarten children is that they are primarily learning reading and writing, and, thus, their CT skills could not be expressed via standard forms of computer-based or paper-and-pencil elicitation techniques (Clarke-Midura et al., 2021). Towards this end, we propose a novel evaluation tool of constructivist, multidisciplinary, and play-based nature, which is developmentally appropriate for young children. The proposed tool aims to cater to the need of having methods of measuring CT competencies that do not require prior knowledge of computer programming (Relkin et al., 2020). Still, it exposes students to fundamental object-oriented programming concepts and principles, even though no direct reference is made to them, giving prominence to the stance that the first contact with programming is better to be enacted through the object-oriented paradigm (Ferrari et al., 2016; Janke et al., 2015).

The significance of the study concerns the fact that the research field on the acquisition of CT skills, such as algorithmic thinking, in compulsory education presents contradicting evidence (Guggemos, 2021; Shute et al., 2017) hampering their effective development. We believe that investigating the role of the students' gender in the algorithmic thinking skills development is of vital importance since it will provide leads that researchers and policymakers could exploit in order to overturn the status quo of the underrepresentation of females in the STEM professional arena (Ampartzaki et al., 2022).

2. LITERATURE REVIEW

2.1 Computational thinking

In recent years, there has been increasing interest in attempts to incorporate CT across all stages of schooling (Huang & Looi, 2021), as a set of competencies aimed at everyone, not only reserved for those studying or working in computer sciences (Wing, 2006; Zhao et al., 2022), and as a means to supporting the cultivation of thinking skills and digital literacy (Angeli & Giannakos, 2020). In fact, stakeholders increasingly believe that investment in computer science education and bolstering CT development helps to equip students with essential competencies in today's world, which is increasingly shaped by computers and digital technologies (Huang & Looi, 2021; Lin & Weintrop, 2021), and in order to formulate a well-trained citizenry and workforce capable of confronting intricate problems that are otherwise difficult or even impossible to be resolved in the absence of CT skills.

In response to this viewpoint, CT and coding have become significant and constituent parts of compulsory education curricula in recent years, and in many countries all over the world (Angeli & Giannakos, 2020; Bers, 2018). CT skills are strongly related and reinforced by dispositions and attitudes, such as creativity (Kalogiannakis & Papadakis, 2022; Román-González et al., 2019), self-confidence in handling complexity, persistence when dealing with demanding problems, tolerance for ambiguity, the ability to address open-ended problems, and the ability to collaborate with others in order to accomplish a common objective (Barr et al., 2011; Román-González et al., 2019).

Algorithmic thinking. When Wing (2006) coined the term CT, she encompassed algorithmic thinking in the set of fundamental CT components. Algorithmic thinking is a set of advanced intellectual operations that involve ability to understanding the core dimensions of a problem, problem-solving skills, competencies for exploring solutions from the perspective of their accuracy and efficiency, and skills to clearly present the process of step-by-step problem resolution (Güler, 2021).

Algorithmic thinking is an essential ability that is applicable not only in computer science, but also as part of everyday life (Figueiredo et al., 2021), since it lays the foundation for comprehending how to accomplish goals by defining an adequate sequence of steps, moving forwards, and backwards in combination as and where required (Vujičić et al., 2021). Since more than one correct and sufficient method may often exist, namely, algorithms to solve a problem, the cultivation of algorithmic thinking skills entails, among others, the ability to detect the most appropriate sequence of steps to accomplish predefined objectives (Vujičić et al., 2021).

2.2 STEM and gender

With the aim being to investigate the potential correlation between gender and algorithmic thinking skills in early childhood, we examined the existing literature regarding the gender effect on the educational achievements in STEM fields, since CT is accepted to be one of the basic STEM practices in compulsory education (NGSS Lead States, 2013).

Gender segregation in terms of academic and professional orientation is a global phenomenon, with females being generally underrepresented in STEM fields (Ampartzaki et al., 2022; Liou et al., 2020; Makarova et al., 2019; Raabe et al., 2019; Stoet & Geary, 2018). In fact, paradoxically, the higher the national level of gender equality, the larger the gap in enrolling in STEM fields becomes (Stoet & Geary, 2018).

A relevant research study presents the educational and professional progress of a representative sample of students nationwide in the United States (Radford et al., 2018). The sample, constituted of ninth-grade students from 2009 whose academic progress was studied through until 2016. The results of the study were then used 1 year later in another study, which highlighted the gender-related preferences of students admitted to college (Charlesworth & Banaji, 2019). More specifically, the preferences of female students for STEM fields appeared to have reduced, in contrast to their strong preference for health- and education-related fields.

These results were confirmed by a recent study conducted in Ontario, Canada, according to which the probability of 11th-grade males to enroll in physics and mathematics fields was found to be significantly higher than females. In the opposite direction, the same study reported the increased intention of female students to enroll in biology courses (Card & Payne, 2021).

However, the differing attitudes of students towards STEM fields according to their gender was found to be evident much earlier than at high school (Charlesworth & Banaji, 2019). In fact, prior to starting high school, more than twice as many males as females were planning to take up jobs related to science or technology (Legewie & DiPrete, 2012). These attitudes were also shown to be maintained at the high school level, and especially in courses relevant to computer science, engineering, and other related fields (Cunningham et el., 2015).

Based on the aforementioned research, it is clear that the preferences of school-age students, in terms of their involvement in scientific domains, are related to their gender, with males having the lead over females. However, does this mean that the learning performance of male students in STEM fields is better than that of their female peers?

A recent study of high school students (eighth and ninth grade) in China found that male and female students performed equally well in student-centered science classrooms (Jiang et al., 2021). The same study also reported that female students responded better to their teachers' instructions than did their male counterparts. This may be explained by social stereotyping that promotes household care as the primary responsibility of adult females (Normile, 2006; Saujani, 2017), cultivating in females the tendency to keep a low profile when doing tasks. Thus, when compared to males, female students are perhaps more likely to cooperate with their teachers and, therefore, react better to their instruction (Jiang et al., 2021). However, this finding did not appear to imply any differing performance level in science-based courses for female students (Jiang et al., 2021).

The pertinent literature has highlighted factors that influence the attitudes of both youth and young adult females towards STEM fields. A study conducted in Pittsburg and the Bay Area of the United States with a sample of 2,900 sixth- and eighth-grade students examined the interaction of endogenous and exogenous factors that motivate youth and young adult females to pursue a career in science fields (Vincent-Ruz & Schunn, 2017). The results showed that females, despite their willingness to participate in scientific discussions and to experience science, lack sufficient support from their environment. This means that they must have strong faith in their own abilities in order to successfully engage in scientific fields (Vincent-Ruz & Schunn, 2017).

The study of Vincent-Ruz and Schunn (2017) revealed an underrepresentation of adult females in STEM professions, as well as their reduced intention to engage in related fields, due perhaps to social stereotyping. However, it has been recognized that no difference in their ability to meet the requirements of STEM fields has been found. In fact, when starting out at school, females are not disadvantaged at all compared to males in their STEM field performance. However, at some point during the first 4 years of school life, male students' skills in STEM fields appear to increase compared to those of their female peers (Kahn & Ginther, 2017).

3. METHODOLOGY

The research study discussed in the current article took place under the umbrella of a robust ethical framework (Cohen et al., 2013; Petousi & Sifaki, 2020) and with permission granted by the Greek Ministry of Education. The study was conducted during the 2018-2019 school year on the Greek island of Crete and, more specifically, within Heraklion city, which is the fourth largest city in Greece.

The thematic unit of the Environmental Study course which was selected to conduct the current research was the eating habits of animals, based on children's attention to animals, even when tempting toys are available as a potential distraction (LoBue et al., 2013).

Seeking to draw conclusions for the wider population of Heraklion city's first- and second-grade students, we adopted the cluster sampling method, as the probability sampling method that would best serve our research needs (Acharya et al., 2013). This method is employed when the target population cannot be examined in its entirety as it is simply too large or widely dispersed. In such cases, the researcher can apply geographical criteria in order to divide the study population into clusters, and to then choose some of them for the study (Elfil & Negida, 2017; Etikan & Bala, 2017), either by simple random sampling or systematic random sampling (Acharya et al., 2013). All of the individuals within the selected clusters then participate in the formation of the sample (Cohen et al., 2013; Etikan & Bala, 2017).

In order to strengthen the representativeness of the sample of our research study, we selected schools from different areas of Heraklion city, aiming at reaching a sample of students from various socioeconomic strata. This decision was based on literature findings according to which the socioeconomic status of a family has been shown to play a key role in the parental involvement and contribution in terms of students' learning performance, as well as in the beliefs and attitudes that children develop about the learning process and their participation within it (Bempechat & Shernoff, 2012; Tan et al., 2020).

The final sample in the current study consisted of 435 first- and second-grade primary school students. Applying the Cochran (2007) formula revealed that the sample was sufficient in size for the intended research. Moreover, it was balanced according to both gender and grade, with 210 females (48.28%) and 225 males (51.72%) having participated in the study, of which 218 were first-graders (50.11%) and 217 were second-graders (49.89%).

The backbone of the research study was the PhysGramming (an acronym derived from Physical Science Programming) digital platform, which we implemented from scratch to satisfy the requirements of the proposed assessment method of algorithmic thinking skills (Kanaki et al., 2020; Kanaki & Kalogiannakis, 2018, 2019). PhysGramming is of the game-based, multidisciplinary, and constructivist character, and is aligned with good practices that empower the usability of applications designed for young learners (Darejeh & Singh, 2013). PhysGramming is compatible with common operating systems (Windows, Ubuntu, Android, etc.) and can be run not only on personal computers, but also on smart mobile devices too, exploiting the advantages of adopting the use of smart mobile devices in today's compulsory education (Criollo-C et al., 2021; Kanaki et al., 2022).

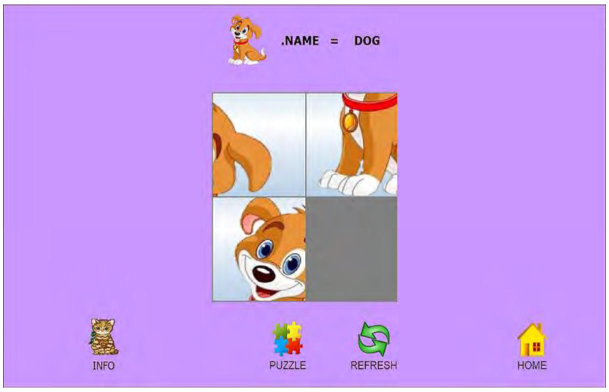

Figure 1. Four-piece dog puzzle

Figure 2. Six-piece dog puzzle

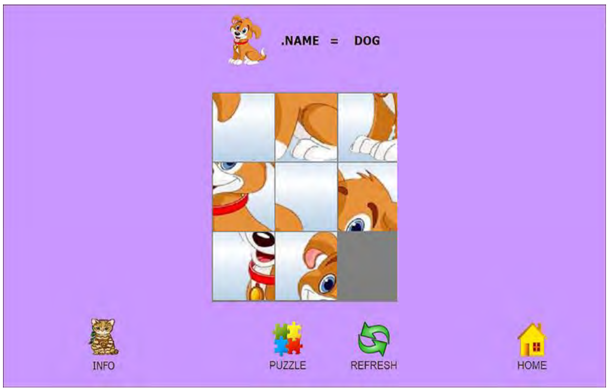

Figure 3. Nine-piece dog puzzle

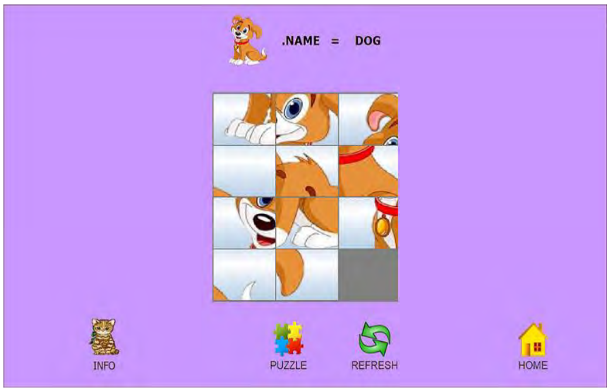

Figure 4. 12-piece dog puzzle

Furthermore, PhysGramming is considered to be developmentally appropriate for students in early childhood, providing them with the opportunity to play digital games that they constructed themselves (Kanaki et al., 2020; Kanaki & Kalogiannakis, 2018). For example, young students may paint, capture, or retrieve pictures embedded within PhysGramming, which enables them to create their own puzzles of varying difficulty level i.e., four-piece (see Figure 1), six-piece (see Figure 2), nine-piece (see Figure 3), and 12-piece puzzles (see Figure 4).

In order to solve a puzzle, students have to rearrange its pieces. Each piece can be moved horizontally, vertically, or diagonally, as long as its adjacent target cell is empty. As the number of puzzle pieces increases, the number of pieces that do not have an empty adjacent cell and, thus, cannot be rearranged, also increases. Therefore, solving puzzles with a higher number of pieces becomes more demanding and requires more advanced algorithmic thinking skills.

In order to estimate the level of students' algorithmic thinking skills we examined the most difficult puzzle they managed to solve, employing as evidence the number of its constituent pieces. This information was derived from the log files of the PhysGramming digital gaming platform. The proposed scale consisted of four grades: Basic (four-piece puzzle), Medium (six-piece puzzle), Satisfactory (nine-piece puzzle), and Excellent (12-piece puzzle).

In order to decide on the maximum number of puzzle pieces that PhysGramming would provide, we took into account the nature of our intended study, as well as relevant studies in the early childhood literature that have employed jigsaw-type puzzles (Doherty et al., 2021; Nieto-Márquez et al., 2020). Two factors led us to the decision that 12 would be the maximum number of puzzle pieces used within PhysGramming. First, typical jigsaw puzzles' pieces can only interlock to the appropriate adjacent pieces, making the solving process easier. Second, in the case of the current study, the participant students, while being assessed, had to explore the functionality of PhysGramming and familiarize themselves with the logic of solving its puzzles since they were only introduced to the platform the same day that the research was conducted in the classroom.

4. FINDINGS

Construct Validity

Table 1. Distribution of relative frequencies

Algorithmic thinking levels	Relative frequency %	
	Male	Female
Excellent	9.20	9.66
Satisfactory	19.08	13.56
Medium	19.08	18.85
Basic	4.37	6.21

Before delving into the examination of the correlation under investigation, let us first look at the graphical representation of the research results (see Figure 5). Table 1 presents the relative frequencies of occurrence of each algorithmic thinking level in relation to gender.

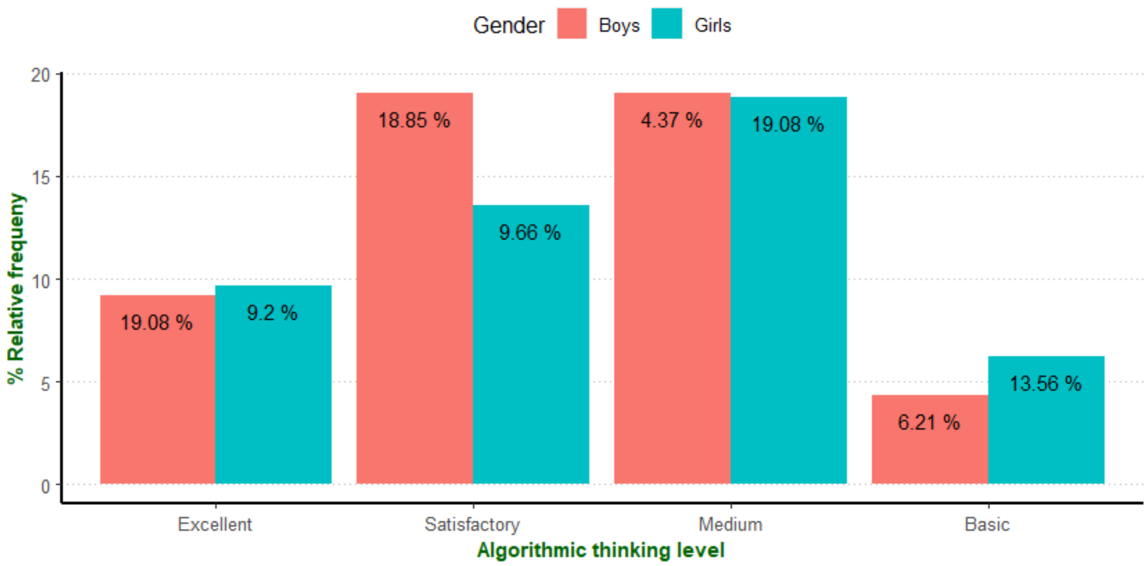

Figure 5. Relative frequencies of algorithmic thinking levels in relation to gender

In order to investigate the potential correlation between the algorithmic thinking skills of young learners in their first and second grade and their gender, we assessed the hypothesis, "The algorithmic thinking levels of students in the first two grades of primary school are not related to their gender."

Table 2. Contingency table of observed frequencies of algorithmic thinking levels according to gender

Algorithmic thinking \ Gender	Male	Female	Total
Excellent	40	42	82
Satisfactory	83	59	142
Medium	83	82	165
Basic	19	27	46
Total	225	210	435

Based on the study's results, we constructed a contingency table of the observed frequencies of algorithmic thinking levels in relation to the participant students' gender (see Table 2).

We then employed the contingency table of observed values (Table 2) to calculate the relevant contingency table of expected frequencies (see Table 3).

Table 3. Contingency table of expected frequencies for algorithmic thinking levels according to gender

Algorithmic thinking \ Gender	Male	Female	Total
Excellent	42.41	39.59	82
Satisfactory	73.45	68.55	142
Medium	85.34	79.66	165
Basic	23.79	22.21	46
Total	225	210	435

Based on the contingency tables, the chi-square was calculated as being 4.9912, the degrees of freedom as $df = 3$, and with a p-value of .1724. Since $p > .05$, we were able to uphold the hypothesis. Thus, we accept that algorithmic thinking skills in early childhood are not related to students' gender.

5. DISCUSSION

The literature includes studies that have discussed the gender effect on the development of CT skills. Notwithstanding, other studies have reported that males and females are equally benefited by activities aimed at cultivating CT.

In a recent study by Angeli and Valanides (2020), 5 and 6-year-old students were asked to implement educational activities employing Bee-Bot, with the aim of developing their CT skills and, more precisely, their algorithmic thinking, sequencing, decomposition, and debugging skills. The same study reported a statistically significant increase in learning achievements between the initial and final assessment of young learners' CT skills, with both males and females having benefited from techniques employed to cultivate CT. However, a statistically significant effect was found between gender and the techniques applied. More specifically, it was shown that males benefited most when working alone, in the context of spatial planning-related activities, while females benefited more from collaborative writing activities (Angeli & Valanides, 2020).

In another study, Relkin et al. (2020) focused on examining the CT skills of early-grade primary school students, employing the innovative assessment tool ThechCheck. The study endorsed the value of unplugged CT assessment methods, underlining the importance of constructing age-appropriate assessment tools that do not require any prior programming knowledge. In total, 758 students aged between 5 and 9 years' old from eight primary schools in the same school district in Virginia, United States, participated in the study. The research findings revealed the absence of any significant difference between the students' gender as far as exercising their CT skills was concerned. Moreover, they proved that gender was not a predicting factor for CT competencies (Relkin et al., 2020).

Another study focused on the evaluation of coding skills and the development of CT for learners aged 8 to 17 years' old, with the aim of highlighting differences in their coding depending on their gender. Objective measurements were used (monitoring the learners' gaze), which were triangulated with qualitative data (interviews and observation), in order to achieve a deeper understanding of the learners' perspectives and practices. The study's findings revealed that the influence of gender on implementing coding activities was a multifactorial phenomenon. According to the quantitative data analysis results, no difference was found between the male and female participants in terms of their performance. In contrast, the qualitative data and the evaluation of the digital toys that the learners constructed revealed differences in the strategies and practices that they applied whilst coding, as well as in their perceptions regarding the related activities. We conclude, therefore, that female learners do not lack coding skills compared to their male counterparts, but just approach coding activities in different ways (Papavlasopoulou et al., 2020).

On the other hand, Román-González et al. (2017) conducted a study in which a tool was developed for the evaluating of CT, and the authors reported a statistically significant difference in favor of males when measuring CT levels. The survey was conducted in Spain and its sample consisted of 1,251 students in the fifth to 10th grades. According to their study, gender differentiation starts becoming statistically significant in the seventh and eighth grades, while intensifying in the ninth and 10th grades. On the contrary, in the fifth and sixth grades, there was no significant gender differentiation reported in terms of the participant students' academic performance (Román-González et al., 2017).

Jenson and Droumeva (2016), in their study which explored the development and the evaluation of CT skills through coding activities, reported that gender differences in attitudes toward computers and coding were established, with males exhibiting slightly higher self-esteem and academic performances. The research sample in their study consisted of 60 students in their sixth grade, who were each asked to construct digital games using GameMaker (Jenson & Droumeva, 2016).

Finally, other studies have presented gender as a predicting factor of CT skill levels, within the context of its correlation with the computer sciences (Angeli & Giannakos, 2020; Angeli & Valanides, 2020; Durak & Saritepeci, 2018). The most notable reason put forwards for this assertion was the influence of gender roles on attitudes toward technology (Stein, 2004).

The results of the various research studies discussed in this section can be said to be in line with the findings of the current research, in that gender is not a predicting factor of algorithmic thinking levels in early childhood learners. Regarding the research studies that established an association between CT levels and the learners' gender, it is important to note that the studies included samples with older aged students, rather than young learners in their first or second grade.

5.1 Limitations and future directions

Reflecting on the limitations of the current study, we recognize that the research population was spatially limited since it consisted of students only from the city of Heraklion, Crete. In order to address this limitation, we plan to extend our research to a national level in the future.

Another limitation pertains to conducting the research study amid one thematic unit of an Environmental Study course, i.e., animals' eating habits. Our perspectives include the conducting of a future largescale research study with the ultimate goal of confirming the results of the current study within the context of other thematic units of the same Environmental Study course.

6. CONCLUSION

Intrigued by the fact that females are insufficiently represented in STEM-related domains, the current study explored the correlation between algorithmic thinking skills and the gender of first- and second-grade students, within the context of an Environmental Study course. The study's results indicated the absence of any correlation between the investigated fields, verifying the existing relevant literature which has shown that in the first years of school, female learners have yet to form any negative attitude towards STEM fields and, thus, gender was not found to be a predicting factor for CT skills such as algorithmic thinking.

The current study adds to the efforts of eliminating the different opportunities that students face in becoming dynamically involved in STEM fields based on their gender alone (Ampartzaki et al., 2022; Master et al., 2016; Sax et al., 2017). Furthermore, it supports the establishment of CT as a worldwide applicable competency set within the contemporary digital era, and contributes to the scientific and instructional area of elaborating on gender equity plans for the efficient introduction of CT into compulsory education.

DECLARATIONS

Author contributions Each step of the research was conducted by the authors together, based on an understanding of common responsibility.

Conflicts of interest The authors declare no conflict of interest.

Funding No external funding was received for the study.

Data availability statement The data of the study are available upon reasonable request from the corresponding author.

REFERENCES

Acharya, A. S., Prakash, A., Saxena, P., & Nigam, A. (2013). Sampling: Why and how of it. *Indian Journal of Medical Specialties*, *4*(2), 330-333.

Ampartzaki, M., Kalogiannakis, M., Papadakis, S., & Giannakou, V. (2022). Perceptions About STEM and the Arts: Teachers', Parents' Professionals' and Artists' Understandings About the Role of Arts in STEM Education. In St. Papadakis & M. Kalogiannakis (Eds.), *STEM, Robotics, Mobile Apps in Early Childhood and Primary Education. Lecture Notes in Educational Technology* (pp. 601-624). Springer https://doi.org/10.1007/978-981-19-0568-1_25

Angeli, C., & Giannakos, M. (2020). Computational thinking education: Issues and challenges. *Computers in Human Behavior*, *105*, Article 106185. https://doi.org/10.1016/j.chb.2019.106185

Angeli, C., & Valanides, N. (2020). Developing young children's computational thinking with educational robotics: An interaction effect between gender and scaffolding strategy. *Computers in Human Behavior*, *105*, Article 105954. https://doi.org/10.1016/j.chb.2019.03.018

Barr, D., Harrison, J., & Conery, L. (2011). Computational thinking: A digital age skill for everyone. *Learning & Leading with Technology*, *38*(6), 20-23. https://www.learningandleading-digital.com/learning_leading/20110304?pm=2&pg=22#pg22

Bempechat, J., & Shernoff, D. J. (2012). Parental influences on achievement motivation and student engagement. In S. L. Christenson, A. L. Reschly, & C. Wylie (Eds.), *Handbook of research on student engagement* (pp. 315-342). Springer. https://doi.org/10.1007/978-1-4614-2018-7_15

Bers, M. U. (2018). Coding and computational thinking in early childhood: the impact of ScratchJr in Europe. *European Journal of STEM Education*, *3*(3), Article 8. https://doi.org/10.20897/ejsteme/3868

Card, D., & Payne, A. A. (2021). High school choices and the gender gap in STEM. *Economic Inquiry*, *59*(1), 9-28. https://doi.org/10.3386/w23769

Charlesworth, T. E., & Banaji, M. R. (2019). Gender in science, technology, engineering, and mathematics: Issues, causes, solutions. *Journal of Neuroscience*, *39*(37), 7228-7243. https://doi.org/10.1523/jneurosci.0475-18.2019

Chatzopoulos, A., Kalogiannakis, M., Papoutsidakis, M., Psycharis, S., & Papachristos, D. (2020). Measuring the Impact on Student's Computational Thinking Skills Through STEM and Educational Robotics Project Implementation. In M. Kalogiannakis, & S. Papadakis (Eds.), *Handbook of Research on Tools for Teaching Computational Thinking in P-12 Education* (pp. 234-284). IGI Global. https://doi.org/10.4018/978-1-7998-4576-8.ch010

Clarke-Midura, J., Silvis, D., Shumway, J. F., Lee, V. R., & Kozlowski, J. S. (2021). Developing a kindergarten computational thinking assessment using evidence-centered design: the case of algorithmic thinking. *Computer Science Education*, *31*(2), 117-140. https://doi.org/10.1080/08993408.2021.1877988

Cochran, W. G. (2007). *Sampling techniques*. Wiley.

Cohen, L., Manion, L., & Morrison, K. (2013). *Research methods in education*. Routledge.

Criollo-C, S., Guerrero-Arias, A., Jaramillo-Alcázar, Á., & Luján-Mora, S. (2021). Mobile learning technologies for education: Benefits and pending issues. *Applied Sciences, 11*(9), Article 4111. https://doi.org/10.3390/app11094111

Cunningham, B. C., Hoyer, K. M., & Sparks, D. (2015). Gender Differences in Science, Technology, Engineering, and Mathematics (STEM) Interest, Credits Earned, and NAEP Performance in the 12th Grade. Stats in Brief. NCES 2015-075. *National Center for Education Statistics*. https://nces.ed.gov/pubs2015/2015075.pdf

Darejeh, A., & Singh, D. (2013). A review on user interface design principles to increase software usability for users with less computer literacy. *Journal of Computer Science*, *9*(11), 1443-1450. https://doi.org/10.3844/jcssp.2013.1443.1450

Doherty, M. J., Wimmer, M. C., Gollek, C., Stone, C., & Robinson, E. J. (2021). Piecing together the puzzle of pictorial representation: How jigsaw puzzles index metacognitive development. *Child Development*, *92*(1), 205-221. https://doi.org/10.1111/cdev.13391

Durak, H. Y., & Saritepeci, M. (2018). Analysis of the relation between computational thinking skills and various variables with the structural equation model. *Computers & Education*, *116*, 191-202. https//:doi.org/10.1016/j.compedu.2017.09.004

Elfil, M., & Negida, A. (2017). Sampling methods in clinical research; an educational review. *Emergency*, *5*(1), e52. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5325924/.

Emerson, A., Cloude, E. B., Azevedo, R., & Lester, J. (2020). Multimodal learning analytics for game-based learning. *British Journal of Educational Technology*, *51*(5), 1505-1526. https://doi.org/10.1111/bjet.12992.

Etikan, I., & Bala, K. (2017). Sampling and sampling methods. *Biometrics & Biostatistics International Journal*, *5*(6), 215-217. https://doi.org/10.15406/bbij.2017.05.00149

Ferrari, A., Poggi, A., & Tomaiuolo, M. (2016). Object oriented puzzle programming. *Mondo Digitale*, *15*, 64. https://mondodigitale.aicanet.net/2016-3/DidamaticaSessioni/Programmazione/paper_39.pdf

Figueiredo, M. P., Amante, S., Gomes, H. M. D. S. V., Gomes, C. A., Rego, B., Alves, V., & Duarte, R. P. (2021). Algorithmic Thinking in Early Childhood Education: Opportunities and Supports in the Portuguese Context. In L. Gómez Chova, A. López Martínez, & I. Candel Torres (Eds.), *EduLearn 2021 Proceedings. 13th International Conference on Education and New Learning Technologies* (pp. 9339-9348). IATED. https://doi.org/10.21125/edulearn.2021.1885

Guggemos, J. (2021). On the predictors of computational thinking and its growth at the high-school level. *Computers & Education*, *161*, Article 104060. https://doi.org/10.1016/j.compedu.2020.104060

Güler, Ç. (2021). Algorithmic thinking skills without computers for prospective computer science teachers. *Kuramsal Eğitimbilim Dergisi [Journal of Theoretical Educational Science]*, 14(4), 570-585. http://doi.org/10.30831/akukeg.892869

Huang, W., & Looi, C.-K. (2021). A critical review of literature on "unplugged" pedagogies in K-12 computer science and computational thinking education. *Computer Science Education*, *31*(1), 83-111. https://doi.org/10.1080/08993408.2020.1789411

Janke, E., Brune, P., & Wagner, S. (2015). Does outside-in teaching improve the learning of object-oriented programming? In *2015 IEEE/ACM 37th IEEE International Conference on Software Engineering* (Vol. 2, pp. 408-417). IEEE. https://doi.org/10.1109/icse.2015.173

Jenson, J., & Droumeva, M. (2016). Exploring media literacy and computational thinking: A game maker curriculum study. *Electronic Journal of e-Learning*, *14*(2), 111-121. https://academic-publishing.org/index.php/ejel/article/view/1748

Jiang, T., Chen, J.-G., & Wu, Y.-Y. (2021). Impact Of Instruction On Science Performance: Learning Initiative As A Mediator And Gender As A Limited Moderator. *Journal of Baltic Science Education*, *20*(1), 50-66. https://doi.org/10.33225/jbse/21.20.50

Kahn, S., & Ginther, D. (2017). *Women and STEM* (No. w23525). National Bureau of Economic Research. https://www.nber.org/papers/w23525

Kallia, M., van Borkulo, S. P., Drijvers, P., Barendsen, E., & Tolboom, J. (2021). Characterising computational thinking in mathematics education: a literature-informed Delphi study. *Research in Mathematics Education*, *23*(2), 159-187. https://doi.org/10.1080/14794802.2020.1852104

Kalogiannakis, M., & Papadakis, S. (2022). Preparing Greek Pre-service Kindergarten Teachers to Promote Creativity: Opportunities Using Scratch and Makey Makey. In K.-J, Murcia, C., Campbell, M.-M. Joubert & S. Wilson (Eds.), *Children's Creative Inquiry in STEM. Sociocultural Explorations of Science Education* (Vol. 25, pp. 347-354). Springer, https://doi.org/10.1007/978-3-030-94724-8_20

Kanaki, K., & Kalogiannakis, M. (2018). Introducing fundamental object-oriented programming concepts in preschool education within the context of physical science courses. *Education and Information Technologies*, *23*(6), 2673-2698. https://doi.org/10.1007/s10639-018-9736-0

Kanaki, K., & Kalogiannakis, M. (2019). Assessing computational thinking skills at first stages of schooling. In *Proceedings of the 2019 3rd International Conference on Education and E-Learning* (pp. 135-139). ACM. https://doi.org/10.1145/3371647.3371651

Kanaki, K., Kalogiannakis, M., Poulakis, E., & Politis, P. (2022). Employing Mobile Technologies to Investigate the Association Between Abstraction Skills and Performance in Environmental Studies in Early Primary School. *International Journal of Interactive Mobile Technologies*, *16*(6), 241-249. https://doi.org/10.3991/ijim.v16i06.28391

Kanaki, K., Kalogiannakis, M., & Stamovlasis, D. (2020). Assessing Algorithmic Thinking Skills in Early Childhood Education: Evaluation in Physical and Natural Science Courses. In M. Kalogiannakis & S. Papadakis (Eds.), *Handbook of Research on Tools for Teaching Computational Thinking in P-12 Education* (pp. 104-139). IGI Global. https://doi.org/10.4018/978-1-7998-4576-8.ch005

Kastriti, E., Kalogiannakis, M., Psycharis, S., & Vavougios, D. (2022). The teaching of Natural Sciences in kindergarten based on the principles of STEM and STEAM approach. *Advances in Mobile Learning Educational Research (AMLER), 2*(1), 268-277. https://doi.org/10.25082/AMLER.2022.01.011

Lee, I., Grover, S., Martin, F., Pillai, S., & Malyn-Smith, J. (2020). Computational thinking from a disciplinary perspective: Integrating computational thinking in K-12 science, technology, engineering, and mathematics education. *Journal of Science Education and Technology*, *29*(1), 1-8. https://doi.org/10.1007/s10956-019-09803-w

Legewie, J., & DiPrete, T. (2012). High School Environments, STEM Orientations, and the Gender Gap in Science and Engineering Degrees. *SSRN*. https://doi.org/10.2139/ssrn.2008733

Lin, S.-Y., Chien, S.-Y., Hsiao, C.-L., Hsia, C.-H., & Chao, K.-M. (2020). Enhancing Computational Thinking Capability of Preschool Children by Game-based Smart Toys. *Electronic Commerce Research and Applications*, *44*, Article 101011. https://doi.org/10.1016/j.elerap.2020.101011

Lin, Y., & Weintrop, D. (2021). The landscape of Block-based programming: Characteristics of block-based environments and how they support the transition to text-based programming. *Journal of Computer Languages*, *67*, Article 101075. https://doi.org/10.1016/j.cola.2021.101075

Liou, P.-Y., Wang, C.-L., Lin, J. J., & Areepattamannil, S. (2020). Assessing students' motivational beliefs about learning science across grade level and gender. *The Journal of Experimental Education,* *89*(4), 605-624. https://doi.org/10.1080/00220973.2020.1721413

LoBue, V., Bloom Pickard, M., Sherman, K., Axford, C., & DeLoache, J. S. (2013). Young children's interest in live animals. *British Journal of Developmental Psychology*, *31*(1), 57-69. https://doi.org/10.1111/j.2044-835x.2012.02078.x

Makarova, E., Aeschlimann, B., & Herzog, W. (2019). The gender gap in STEM fields: The impact of the gender stereotype of math and science on secondary students' career aspirations. In *Frontiers in Education, 2019*(4), Article 60). https://doi.org/10.3389/feduc.2019.00060

Master, A., Cheryan, S., & Meltzoff, A. N. (2016). Computing whether she belongs: Stereotypes undermine girls' interest and sense of belonging in computer science. *Journal of Educational Psychology*, *108*(3), 424-437. http://dx.doi.org/10.1037/edu0000061

NGSS Lead States. (2013). *Next generation science standards: For states, by states*. The National Academies Press. https://nap.nationalacademies.org/catalog/18290/next-generation-science-standards-for-states-by-states

Nieto-Márquez, N. L., Baldominos, A., & Pérez-Nieto, M. Á. (2020). Digital Teaching Materials and Their Relationship with the Metacognitive Skills of Students in Primary Education. *Education Sciences*, *10*(4), Article 113. https://doi.org/10.3390/educsci10040113

Nikolopoulou, K. (2022). Digital Technology in Early STEM Education: Exploring Its Supportive Role. In S. Papadakis and M. Kalogiannakis (Eds.), *STEM, Robotics, Mobile Apps in Early Childhood and Primary Education. Lecture Notes in Educational Technology* (pp. 103-115). Springer. https://doi.org/10.1007/978-981-19-0568-1_6

Normile, D. (2006). Getting women scientists back on the career track in Japan. *Science, 311*(5765), 1235-1236. https://doi.org/10.1126/science.311.5765.1235

Papavlasopoulou, S., Sharma, K., & Giannakos, M. N. (2020). Coding activities for children: Coupling eye-tracking with qualitative data to investigate gender differences. *Computers in Human Behavior*, *105*, Article 105939. https://doi.org/10.1016/j.chb.2019.03.003

Petousi, V., & Sifaki, E. (2020). Contextualizing harm in the framework of research misconduct. Findings from a discourse analysis of scientific publications. *International Journal of Sustainable Development, 23*(3/4), 149-174, https://doi.org/10.1504/IJSD.2020.10037655

Poulakis, E., & Politis, P. (2021). Computational Thinking Assessment: Literature Review. In T. Tsiatsos, S. Demetriadis, A. Mikropoulos, & V. Dagdilelis (Eds.), *Research on E-Learning and ICT in Education* (pp. 111-128). Springer. https://doi.org/10.1007/978-3-030-64363-8_7

Raabe, I. J., Boda, Z., & Stadtfeld, C. (2019). The social pipeline: How friend influence and peer exposure widen the STEM gender gap. *Sociology of Education*, *92*(2), 105-123. https://doi.org/10.1177/0038040718824095

Radford, A. W., Fritch, L. B., Leu, K., & Duprey, M. (2018). High School Longitudinal Study of 2009 (HSLS: 09) Second Follow-Up: A First Look at Fall 2009 Ninth-Graders in 2016. NCES 2018-139. *National Center for Education Statistics*. https://nces.ed.gov/pubsearch/pubsinfo.asp?pubid=2018139

Relkin, E., de Ruiter, L., & Bers, M. U. (2020). TechCheck: Development and validation of an unplugged assessment of computational thinking in early childhood education. *Journal of Science Education and Technology*, *29*(4), 482-498. https://doi.org/10.1007/s10956-020-09831-x

Relkin, E., de Ruiter, L. E., & Bers, M. U. (2021). Learning to code and the acquisition of computational thinking by young children. *Computers & Education*, *169*, Article 104222. https://doi.org/10.1016/j.compedu.2021.104222

Román-González, M., Moreno-León, J., & Robles, G. (2019). Combining assessment tools for a comprehensive evaluation of computational thinking interventions. In S.-C. Kong & H. Abelson (Eds.), *Computational thinking education* (pp. 79-98). Springer. https://doi.org/10.1007/978-981-13-6528-7_6

Román-González, M., Pérez-González, J. C., & Jiménez-Fernández, C. (2017). Which cognitive abilities underlie computational thinking? Criterion validity of the Computational Thinking Test. *Computers in Human Behavior*, *72*, 678-691. https://doi.org/10.1016/j.chb.2016.08.047

Santos, P. A. (2020). The Past, Present and Future of Serious Games and Gamification in STEM Learning. In M. Ludwig, S. Jablonski, A. Caldeira, & A. Moura (Eds.), *Research on Outdoor STEM Education in the digiTal Age*. *Proceedings of the ROSETA Online Conference in June 2020* (pp. 147-154). WTM. https://doi.org/10.37626/ga9783959871440.0.18

Saujani, R. (2017). Girl code. *Scientific American, 317*(3), 66-69. https://doi.org/10.1038/scientificamerican0917-66

Sax, L. J., Lehman, K. J., Jacobs, J. A., Kanny, M. A., Lim, G., Monje-Paulson, L., & Zimmerman, H. B. (2017). Anatomy of an enduring gender gap: The evolution of women's participation in computer science. *The Journal of Higher Education*, *88*(2), 258-293. https://doi.org/10.1080/00221546.2016.1257306

Shute, V. J., Sun, C., & Asbell-Clarke, J. (2017). Demystifying computational thinking. *Educational Research Review*, *22*, 142-158. https://doi.org/10.1016/j.edurev.2017.09.003

Stein, C. (2004). Botball robotics and gender differences in middle school teams. In *2004 Annual Conference* (pp. 9.262.1-9.262.10). ASEE. https://doi.org/10.18260/1-2--13534

Stoet, G., & Geary, D. C. (2018). The gender-equality paradox in science, technology, engineering, and mathematics education. *Psychological Science*, *29*(4), 581-593. https://doi.org/10.1177/0956797617741719

Tan, C. Y., Lyu, M., & Peng, B. (2020). Academic benefits from parental involvement are stratified by parental socioeconomic status: A meta-analysis. *Parenting*, *20*(4), 241-287. https://doi.org/10.1080/15295192.2019.1694836.

Tang, H., Xu, Y., Lin, A., Heidari, A. A., Wang, M., Chen, H., Luo, Y., & Li, C. (2020). Predicting green consumption behaviors of students using efficient firefly grey wolf-assisted K-nearest neighbor classifiers. *IEEE Access*, *8*, 35546-35562. https://doi.org/10.1109/ACCESS.2020.2973763.

Tselegkaridis, S., & Sapounidis, T. (2022). A Systematic Literature Review on STEM Research in Early Childhood. In S. Papadakis and M. Kalogiannakis (Eds.), *STEM, Robotics, Mobile Apps in Early Childhood and Primary Education. Lecture Notes in Educational Technology* (pp. 117-134). Springer. https://doi.org/10.1007/978-981-19-0568-1_7

Vincent-Ruz, P., & Schunn, C. D. (2017). The increasingly important role of science competency beliefs for science learning in girls. *Journal of Research in Science Teaching*, *54*(6), 790-822. https://doi.org/10.1002/tea.21387

Vujičić, L., Jančec, L., & Mezak, J. (2021). Development of algorithmic thinking skills in early and preschool education. In L. Gómez Chova, A. López Martínez, & I. Candel Torres

(Eds.), *Proceedings of EDULEARN21 Conference* (Vol. 5). IATED. https://doi.org/10.21125/edulearn.2021.1650

Weintrop, D., Beheshti, E., Horn, M., Orton, K., Jona, K., Trouille, L., & Wilensky, U. (2016). Defining computational thinking for mathematics and science classrooms. *Journal of Science Education & Technology*, *25*(1), 127-147

Wing, J. M. (2006). Computational thinking. *Communications of the ACM, 49*(3), 33-35. https://doi.org/10.1145/1118178.1118215

Zhao, L., Liu, X., Wang, C., & Su, Y.-S. (2022). Effect of different mind mapping approaches on primary school students' computational thinking skills during visual programming learning. *Computers & Education, 181,* Article 104445. https://doi.org/10.1016/j.compedu.2022.104445.

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