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INTEGRATING COMPUTATIONAL THINKING IN PHYSICAL EDUCATION: A PATHWAY TO 21ST-CENTURY COMPETENCIES

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Abstract

Introduction: Computational thinking aligns with the competency needs of the 21st century. **Objectives**: To understand the application of Computational Thinking (CT) in Physical Education (PE), at what educational levels CT can be applied in PE, and how CT in PE is related to 21st-century competencies. **Method**: This article applied a Systematic Literature Review with the PRISMA Model. **Results**: Out of 535 articles, only 10 could be analyzed according to the content of CT and PE. **Findings:** CT in PE can be implemented by promoting CT in PE learning through physical activities, integrative learning, and applications. Promoting CT in PE has been carried out at all educational levels, contributing to achieving 21st-century competencies. It has the potential to be further developed through physical activities and games.

Keywords: 21st Century, Computational Thinking, Learning, Physical Education.

INTRODUCTION

During learning, we can also introduce Computational Thinking (CT). CT transfers broad 21st-century competency skills (Lodi & Martini, 2021), although it influences explicitly critical thinking and problem-solving abilities (Wong & Cheung, 2020). Several subjects have applied CT, such as Mathematics (Lv et al., 2023), Language (Hsu et al., 2023), and Physics (Hutchins et al., 2020).

Science, Technology, Engineering, and Mathematics (STEM) still dominate the application of CT (Tekdal, 2021); theoretically, other subjects outside of STEM can promote CT widely (Li et al., 2020). In physical education, learning is still challenging to find. The theme of applying computational thinking in the context of physical education learning offers exciting opportunities to develop students' critical, analytical, and problem-solving skills.

Integrated with physical education, applying computational thinking concepts opens the gap to using technology-based strategies and a model of thinking that implements physical activity and health.

The application of computational thinking in physical education learning is not limited to using technology in lessons; integrating technology with CT promotion provides opportunities for collaboration between friends and is more fun (Schmidthaler et al., 2022). Apart from that, the ability to formulate problems, solve problems with algorithms, create abstractions, and create patterns or models in physical activities and sports.

Through this approach, students can learn to view physical activity, body movement, and health as problems that can be described, analyzed, and solved using computational principles. For example, in sports, students can use computational thinking to understand and design strategies in soccer games (Marcelino et al., 2020), analyze athlete performance data (Robertson, 2020), or even design measurable training programs (Dagenais et al., 2023).

Meanwhile, in health and fitness, computational thinking concepts enable students to understand data related to their health. Make data-based decisions regarding physical activity and other healthy lifestyle patterns through digital applications (García-Fernández et al., 2020; Parker et al., 2021; Schwarz et al., 2020). We are enabling them to become more skilled at making informed decisions and increasing their awareness of the importance of health and fitness.

Another important thing is the opportunity to develop skills that are very valuable in facing the challenges of today's digital era, where technology plays a vital role in almost all areas of life: economy (Novakova, 2020), environment (Liu et al., 2022), education (Hallström, 2022), and other sectors.

Thus, incorporating computational thinking concepts into physical education learning promises a holistic learning experience, expanding students' understanding of the importance of technology (Gawrisch et al., 2020), health (Teraoka & Kirk, 2022), and physical activity in achieving an overall fit lifestyle (Filgueira et al., 2021). However, we must explore how this can be implemented theoretically by reviewing previous practices.

This article explores three main things: How can CT be applied in PE? At what educational levels can CT be applied in PE? and How does CT in PE affect 21st-century competencies?

METHOD

The method used in this research is a systematic literature review using the PRISMA model. We use the keywords "Computational Thinking" AND "Physical Education" from databases originating from two engines: Databases (Google Scholar) and Registres (Scopus). Data was taken up to 2022; the result was that 535 data were found when we accessed October 1, 2022.

From the results of the data we found, we have carried out checks to obtain data results in the form of articles that comply with the criteria we set through the PRISMA guidelines (see Figure 1). We have taken several steps based on previous research by Gates and March: identification, screening, suitability, and inclusion (Gates & March, 2016).

In the screening section, 370 data were excluded because they included the excluded criteria (Non-PE, Non-CT, No Original Research, and No Open Access). The criteria specified are CT, PE, English Article, Credible Source, Original Research, and Open Access.

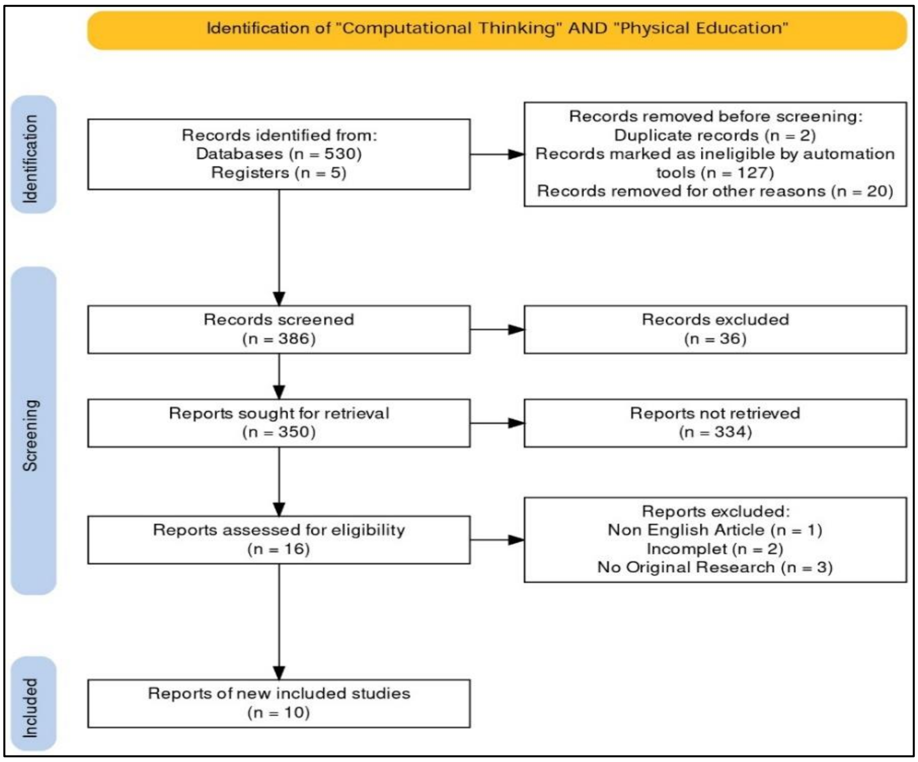

Figure 1: Implementation of PRISMA

RESULTS

The results of this research were ten selected articles for analysis with the support of theoretical studies. The selected articles were published during the 2017-2022 range, and we see a significant increase in 2022, according to the graph (figure 2).

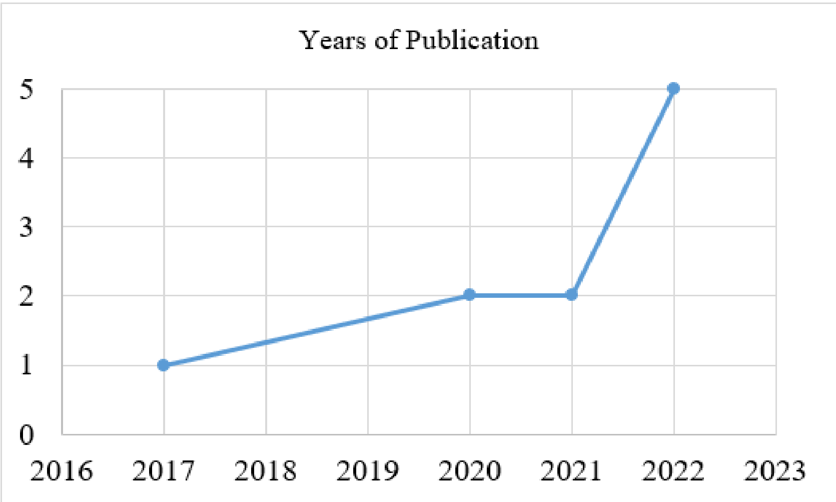

Figure 2: Distribution of Articles by Year

Even though the selected articles are relatively minimal, based on the existing data results, only three still need to be indexed by Scopus. We can find out by referring to Table 1. What is interesting is that we find the use of varied research methods (qualitative, quantitative, and mixed methods).

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Table 1: Methods and Journal Indexing

Methods with Publication Rating (Scimago)	Count
Mixed Methods	**1**
Q2	1
Qualitative	**4**
Not Grade	2
Q2	1
Q3	1
Quantitative	**5**
Not Grade	1
Q1	3
Q2	1
Grand Total	**10**

We have summarized the results of the resulting data analysis comprehensively in the following table. CT has been applied to PE, even from preschool to college (see Table 2).

Table 2. Research Findings

Code	Titles	Subjects	Findings	Source
3	Possibility of improving computational thinking through activity-based learning strategy for young children	Preschool	CT is a key life skill that can be developed through activity-based learning on related topics.	(Cho & Lee, 2017)
14	Serious game as support for the development of computational thinking for children with hearing impairment	Elementary school	All children with hearing problems were highly motivated to play the MECONESIS game, which develops CT.	(Cano et al., 2020)
46	Patterns of Computational Thinking Development While Solving Unplugged Coding Activities Coupled with the 3S Approach for Self-Directed Learning	Secondary school	CT development progresses from initial to partial and then to complete stages, influenced by different abilities to apply computer science concepts using various CT skills; the 3S self-directed learning strategy, which includes scaffolding, paired self-check, and paired self-debug, supports this development.	(Threekunprapa & Yasri, 2020)
52	Project movesmart: Integrating Physical Activity and Computer Science Learning in Elementary School Classrooms	Elementary school	The finding is that by implementing Movesmart in elementary schools, computer science and physical activity can be taught at the same time.	(Fritz et al., 2022)
72	Exploring Factors That Influence Computational	Elementary school	The intrinsic motivation and perceived competence significantly enhance learning	(Stewart et al., 2021)

	Thinking Skills in Elementary Students' Collaborative Robotics		and enjoyment, and problem-solving skills accurately indicate CT abilities, suggesting that collaborative robotics could improve classroom learning outcomes.	
13	Connecting Science, Design Thinking, and Computational Thinking through Sports.	Middle school	Students' attitudes toward science improved with their knowledge, skills, and self-efficacy in science, sports, and various thinking disciplines.	(Galoyan et al., 2022)
20	The Effect of Gender, Grade, Time and Chronotype on Computational Thinking: Longitudinal Study	Secondary school	CT abilities vary mainly by grade level, not by gender, time, or chronotype.	(Demir-Kaymak et al., 2021)
21	Exploring the relationship between computational thinking and learning satisfaction for non-STEM college students	College	CT and enjoyment significantly boost digital self-efficacy and self-exploration, which strongly correlate with learning satisfaction.	(Liao et al., 2022)
53	Effects of a Computational Thinking Intervention Program on Executive Functions in Children Aged from 10 to 11	Elementary school	The intervention significantly impacted executive functions associated with the dorsolateral cortex and anterior prefrontal cortex, while the orbitofrontal area remained unaffected.	(Robledo-Castro et al., 2023)
99	PE: Exploring Opportunities for Connecting Computer Science and Physical Education in Elementary School	Elementary school	These exercises motivate pupils' interest and develop new perspectives on them, CS, and their teachers.	(Worsley, 2022)

DISCUSSION

CT practice can be done through physical learning activities adapted to relevant topics (Cho & Lee, 2017). The practice is separate between CT and PE. However, it can also be done integratively. Computer science can be integrated into PE (Fritz et al., 2022; Worsley, 2022) so that CT can be developed through application development (moveSMART) (Fritz et al., 2022). Recalling, CT is a science that was born with a constructivist view, building new knowledge by connecting current experience with past knowledge (Papert, 1980). Therefore, it is agreed that CT can be born by integrating other subjects with PE, producing new learning experiences.

Even though CT means computational thinking, using computer media is not necessarily mandatory. CT does not mean solving problems using computer media but rather a way of thinking and solving problems following the flow of thinking in computer science (Cheung Kong & Abelson, 2019).

What needs to be noted is that it still contains integrated CT steps in learning, such as 1) Decomposition, dividing into small parts (Fried et al., 2018), 2) Pattern recognition, looking for similarities in emerging patterns (Agbo et al., 2024), 3) Abstraction, extracting meaningful information (Cansu & Cansu, 2019), 4) Algorithm, compiling logical steps (Cansu & Cansu, 2019). In this finding, the application of CT in PE learning can pay attention to scaffolding, paired self-check, and paired self-debug steps (Threekunprapa & Yasri, 2020).

Promoting CT in PE is not just for students without special needs. Games that develop CT can be given to students with hearing problems (Cano et al., 2020). Previous research found that applying CT to students with special needs has shown promising results in improving their problem-solving skills and navigating the modern world (Castaño et al., 2023). Meanwhile, the results of this study showed a high increase in motivation to learn for students with hearing loss (Cano et al., 2020).

Another finding we can report is that CT ability is not influenced by gender but needs to be considered by grade at the educational level (Demir-Kaymak et al., 2021). In previous research, it was explained about the influence of CT at the 10th-grade level (Ramaila & Shilenge, 2023) and 9-12 (Gok & Karamete, 2023); in this study, it was also found at the same level as research at the secondary school level (Demir-Kaymak et al., 2021; Threekunprapa & Yasri, 2020). Another finding in this research is that CT can be promoted at all other levels of education, preschool (Cho & Lee, 2017), elementary school (Cano et al., 2020; Fritz et al., 2022; Robledo-Castro et al., 2023; Stewart et al., 2021; Worsley, 2022), middle school (Galoyan et al., 2022), and university (Liao et al., 2022).

Teachers play an important role as leaders in helping their students achieve 21st-century competencies: collaboration, communication, critical thinking, problem-solving, and creativity (Naidoo, 2021). It not only plays a pedagogical role but also guides and accompanies learning in the digital era (Lim et al., 2022).

The role of teachers in the 21st century is increasingly complex, required to deal with increasingly diverse students, and demands increasingly higher quality of education and standards of processes and results (Loeneto et al., 2022). One thing teachers can do to support the achievement of 21st-century competencies is to implement CT. Through CT, students are supported to think critically (Kules, 2016; Smith, 2021; Voskoglou & Buckley, 2012), solve problems (Ayuso et al., 2020; Hufad et al., 2021), and show creativity (Agbo et al., 2024). In this study, data was found that supports these things.

The practice of CT in several PE learning activities impacts achieving 21st-century competencies. Some of them are: Using AppInventor helps students learn computational thinking, improve problem-analysis skills, critical thinking, and problem-solving, and also helps students understand themselves (Liao et al., 2022), the pre-production section in the MECONESIS game pays attention to the achievement of several aspects and one of them is the communication aspect in the serious game section (Cano et al., 2020), students engage in intensive games to communicate their original ideas (Fritz et al., 2022).

In addition, existing findings show factors that influence computational thinking (Stewart et al., 2021), improving and developing CT (Cano et al., 2020; Cho & Lee, 2017), unplugged parts of CT development in problem-solving (Threekunprapa & Yasri, 2020), its integration into PE and several other sciences (such as computer science and sports) (Fritz et al., 2022; Galoyan et al., 2022), its influence on learning (Demir-Kaymak et al., 2021; Liao et al., 2022; Robledo-Castro et al., 2023), and opportunities for its development in elementary school level PE (Worsley, 2022).

Another finding that can be reported is the use of play activities to promote CT in PE. These activities are through the MECONESIS game (Acronym in Spanish, MEtodología para CONcepción de juEgos Serios para nIños con discapacidad auditiva) (Cano et al., 2020), introducing coding in PE (Silly Game, Juggling Challenges, and Warm-up Game) (Worsley, 2022), and moving smartly with the moveSMART game (Fritz et al., 2022).

If we relate it to existing theory, the application of this game is in line with CT promotion efforts using various combinations of methods: plugged (Wing, 2011), unplugged (Agbo et al., 2024; Caeli & Yadav, 2020; Hufad et al., 2021; Threekunprapa & Yasri, 2020; Zapata-Ros, 2019), or a combination of both (Jiang & Wong, 2019; Saxena et al., 2020). Apart from that, the application of games in PE learning has been proven to have a positive impact; previous research shows the effects of games: increasing students' learning motivation and cooperative attitudes (Astutik et al., 2023; Pamungkas et al., 2024) and innovative competence (Munir et al., 2024).

Based on the system implemented, MECONESIS, Silly Game, and moveSMART implement plugged and unplugged systems; they use applications in computers (such as decomposition, abstraction, pattern recognition, and algorithms) and then put into movement practice.

There is one that implements a plugged system; Students are introduced to CT through AppInventor to design games. Apart from that, the application of an unplugged system was also found; students are given five missions to complete by moving, and while moving, students follow the code (code is given with a flowchart). CT opportunities are very open to promotion in PE learning, especially with an unplugged system (the number is still limited).

CONCLUSION

More research is still needed on CT practices in PE. However, from the existing data, we can find some critical information about the practice of CT in PE that has been implemented. CT practice in PE is carried out by considering the appropriateness of the topic. It is not only done in PE; it can be practiced integratively with other subjects. However, CT steps must still be considered so they are still implemented. Even though we think of computing as related to computer science, CT can be developed with a system without a computer (unplugged).

The application of CT in PE is not only for general students but can also be inclusive (students with special needs). It can be applied not only at secondary and higher education levels but also at the preschool level. CT practice in PE supports the achievement of 21st-century competencies. This research shows the achievement of critical thinking, problem-solving, communication, and creativity through CT practice in PE learning. The system implemented is plugged, unplugged, or a combination of both. CT is implemented through game design, play, and physical movement activities. Great opportunities still exist to develop games that can promote CT through PE learning (especially unplugged).

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