Gravity: Jurnal Ilmiah Penelitian dan Pembelajaran Fisika

http://jurnal.untirta.ac.id/index.php/Gravity

ISSN: 244-515x; e-ISSN: 2528-1976

Vol. 9, No. 2, Aug 2023, Page 96 - 104

Opportunities and challenges of implementing computational thinking through unplugged activities in physics learning

Ahmad Fauzi*, Shofi Hikmatuz Zahroh

[1]*Department of Physics Education, Universitas Sebelas Maret, Indonesia*

**E-mail: fauziuns@staff.uns.ac.id*

(Received: 28 October 2022; Accepted: 20 August 2023; Published: 31 August 2023)

ABSTRACT

Computational thinking is one of the universal competencies that students must master in facing the challenges of the 21st century**.** This study describes the opportunities and challenges of applying computational thinking through unplugged activities in physics learning, especially in senior high school. This research was involved with survey research and a cross-sectional survey design type. The respondents of this study were physics teachers in the city of Semarang and Surakarta. The number of respondents in this study was 43 people. Data were taken by using questionnaires and interview techniques. This study's result indicates opportunities for applying computational thinking through unplugged activities in physics learning. Most respondents welcomed the application of computational thinking through unplugged activities in physics learning. However, according to some teachers, several aspects might become obstacles to implementing computational thinking through unplugged activities, namely the difficulty of making algorithms and simulation.

Keywords: Challenges, computational thinking, opportunity, unplugged activities.

DOI: 10.30870/gravity.v9i2.17456

INTRODUCTION

Digital skills are essential for students to master to adapt to the development of science and technology in the 21st century. These digital skills are often called the 4Cs, i.e., creativity, critical thinking, collaboration, and communication (Redesign, 2015). Students in the classroom, school, community, and country must apply these four skills. Digital skills are intended to produce communities and workers ready to face the challenges of the 21st century. Over time, Computational Thinking (CT) is added to digital skills. The addition of CT as a digital skill, based on the increasing interaction between humans and computers, affects decision-making and human thinking processes (Haseski, Ilic, & Tugtekin, 2018). The application of CT in science learning is needed to provide students with a more realistic view of science and various skills so that students are expected to get better jobs in the future (Weintrop, 2016).

Learning CT will prepare students to become individuals who can solve problems more efficiently because students learn to recognize computable problems and approach the problem-solving process skillfully (Czerkawski & Lyman, 2015). Students who learn CT are trained to use various CT components to teach students higher-order thinking skills. CT plays a vital role in improving students' thinking skills. One of the skills that can be enhanced with CT is collaboration skills, such as when students have to work with other students to make artifacts. The demand for skills students must have to choose appropriate techniques for making artifacts shows that CT can improve thinking skills (Dede, Mishra, & Voogt, 2013). CT does not require a programming language to develop CT skills. Thus, CT is an alternative way to develop students' thinking skills (Voogt, Fisser, Good, Mishra, & Yadav, 2015). CT is an important skill needed by potential inventors, innovators, and shapers of culture and public discourse (Czerkawski & Lyman, 2015). CT can be used to increase concepts' use by visualization and animation to explain abstract concepts even in early grades. Through CT, students are directly involved in understanding modeling expressed in animation or simulation with the appropriate level of abstraction. Students use abstraction to help analyze complex data (Putri, Akmam, Mufit, Sari, & Hidayat, 2022). Abstraction becomes an essential part of enhancing human creativity. Human creativity can be augmented with CT through the use of automation and logarithmic thinking so that it can change the paradigm of students as users/consumer technology to create new forms of expression, build tools, and increase creativity (Mishra, Yadav, Henriksen, & Kereluik, 2013). Creativity is one of the skills needed to find new solutions to a problem, both scientific and real-life situations (Agustinaningsih, 2020).

In the early emergence of CT, computer programming languages (plugged activities) were still the focus of learning. CT is a complementary ability to think in mathematics and engineering, which focuses on efforts to design systems in sequence to solve complex problems (Wing, 2006). The programming focus will be a barrier to students' interest in computer science (James & George, 2009). Therefore, CT is proposed as a conceptual way to solve complex problems by processing information systematically, precisely, and efficiently. The broad scope of CT also has implications for presenting CT in the classroom. Plugged activities are chosen as a general strategy for teaching CT skills in schools (Brackmann, Gonzales, & Robles, 2017). CT is intended for computer science or programming classes, natural science classes, social sciences, mathematics, languages, and even history (ISTE, 2016). This is because CT can make students understand how, when, and where computers and other technological devices can solve their problems, whether issues regarding natural, social, or language sciences. Students will also realize that computers can provide automated solutions to solve problems efficiently and effectively. Therefore, CT needs to be taught to every student so that, in the end, they will become individuals who can settle issues more precisely because they have learned how to solve problems using special skills (Lyman & Czerkawski, 2015).

As a way to execute there are several forms of approaching computational thinking in science classes that several researchers proposed. CT in the classroom can be implemented using tinkering (playing), creating, debugging (checking), persevering, and collaborating

(Yılmaz, Yılmaz, & Durak, 2018). In science classes, CT should be introduced as a taxonomy of data practice, simulation, modeling, problem-solving, and systems thinking approach (Weintrop, 2016). Meanwhile, ISTE uses nine CT practices: problem-solving or decomposition, data collection, data analysis, data representation, simulation, abstraction, algorithms, automation, and parallelization. Although there are differences in practicing CT among experts, the practice of CT involves four primary procedures, specifically decomposition, pattern recognition, abstraction, and algorithm design (ISTE, 2014).

Based on the number of courses that students must take, many countries have not established CT as a compulsory subject. One method to teach CT in countries without a CT curriculum is to embed them in ICT or computer programming subjects (Bocconi, Chioccariello, Dettori, & Ferrari, 2016). As a universal competency students must master, using computers in CT will be a big problem. This is because not all students have computers or are skilled in programming languages. Therefore, many researchers began to develop CT without using computer/digital devices (unplugged activities). These unplugged activities can be the basis for students to learn computer science (Caeli & Yadav, 2020). In addition, unplugged activities can be an excellent approach to introducing students to CT (Looi, How, Longkai, Seow, & Liu, 2018).

There are various activities that teachers can use in teaching CT through unplugged activities. A board game can teach CT concepts to children aged 6-10 (Apostolellis, Stewart, Frisina, & Kafura, 2014). The teacher uses a board game to train students to orient tangible and magnetized manipulatives to complete or create paths. The board game corresponds to structural programming, including sequential, conditional, and repetitive structure, as well as the modeling concept of calling a procedure in programming languages (Kuo & Hsu, 2020). The study of using a board game showed that student learning achievement had increased. Meanwhile, Waterman et al. (2020) developed a CT integration model for the learning of elementary school children through physical movements that train students to do abstraction, data modeling, simulation, and algorithms. The research showed that students could demonstrate CT skills, increasing their mathematics achievement (Waterman, Goldsmith, & Pasquale, 2020).

Based on the description above, it can be concluded that CT research with unplugged activities still focuses on elementary school students. Research on CT with unplugged activities focuses on introducing students to CT with games and body movements. This causes not all CT skills to be introduced to students. Therefore, examining opportunities to teach CT with unplugged activities is essential, especially for students with higher abstraction abilities, such as at senior high school.

RESEARCH METHODS

This research uses a quantitative research design, namely survey research. The type of survey is a cross-sectional design that aims to collect the opinions of senior high school physics teachers in Surakarta and Semarang about opportunities to teach CT with unplugged activities. The research was conducted from February to May 2021. The subjects of this research are 43 high school physics teachers in Surakarta and Semarang. The choice of research subjects was based on the consideration that Surakarta and Semarang city are the main cities in Central Java with adequate learning facilities and infrastructure, thus expected to support computational thinking through unplugged activities.

Data collecting techniques used in this study were questionnaires and interviews. The questionnaire contains questions about what teachers have done in learning, which is expected to support the implementation of computational thinking through unplugged activities. Interviews were conducted to analyze the conditions of teachers and facilities that will support the implementation of computational thinking through unplugged activities.

This research questionnaire was adopted from the operational definition of computational thinking by ISTE (2014). The questionnaire consists of 28 questions. To validate the questionnaire, the questionnaires were given to 63 respondents. The data were analyzed quantitatively using the Rasch model technique. The data was analyzed using Microsoft Excel and Winstep 3.73 software. The instrument's reliability is known by looking at the summary statistics data. The validity of each item was tested based on three criteria, namely point-measure correlation (Pt-Measure Corr), outfit mean-square (MNSQ), and outfit z-standardized (ZSTD). An item is declared valid if it meets at least two of the three criteria, namely 1) 0,5 < MNSQ < 1,5, 2) -1,9 < ZSTD < 1,9, and 3) 0,4 < Pt-measure Corr < 0,85 (Sumintono & Widhiarso, 2014). Based on the results of the data analysis, it can be concluded that the instrument's reliability is 0,93 with a Cronbach alpha value of 0,81. The reliability value of 0,93 indicates the instrument's reliability is very good. The MNSQ Outfit value is between 0,56 – 1,54. The ZSTD value is in the range -3,0 – 2,7, and the Pt-Measure Corr value is 0,15-0,66. Based on these criteria, the questionnaire items numbered 6, 8, 13,19, 20, and 22 are in the invalid category and are not used. Meanwhile, the other items were declared valid. The data analysis steps in this study follow the six syntaxes suggested by Creswell (2014): organizing and preparing, reading and exploring data, coding the data, describing, presenting the findings, and interpreting the results (Creswell, 2014).

RESULTS AND DISCUSSION

Questionnaires were given to determine the teacher's response to CT based on the teacher's experience in teaching in class. The number of respondents who responded to the questionnaire was 43 people. The results of the analysis are briefly presented in Table 1. Based on Table 1, it can be seen that most teachers believe that students will be able to learn with the CT approach, especially in data collection and abstraction skills. Respondents also thought students could describe problems, represent data through tables/graphs, and analyze data to find patterns. Most respondents doubted students could learn with a CT approach, especially simulation and algorithm skills.

The interview results show that all respondents have heard of computational thinking. However, only 46.5% of respondents claimed to be interested in reading online articles about CT. Respondents who had read several CT articles admitted to having difficulty understanding CT. However, all respondents expressed interest in applying CT in physics learning. Most respondents also stated that the simulations were only limited to using products downloaded from the internet. Respondents indicated that they had no experience teaching students to create computer simulations. Concerning questions about algorithms and automation, respondents stated that students most likely have difficulty compiling algorithms to solve a problem. Respondents also claimed that students are most likely to experience automation challenges because they cannot yet verify the truth of their simulation results.

Table 1. Summary of questionnaire analysis results

Computational Thinking Skills	Response
Decomposition in solving a complex problem	67.5% of respondents believed that students will be able to decompose problems.
Collecting data through observation and measurement	90.7% of respondents believed that students would be able to collect data through observation and measurement
Representation of data through tables /graphs	69.8% of respondents believed that students would be able to represent experimental data through tables/graphs.
Data analysis to find patterns (pattern recognition)	65.1% of respondents believed that students would be able to analyze data to find patterns.
Simulation in learning using either equations or computer simulations	44.2% of respondents believed that students would be able to carry out simulations.
Abstraction (decision-making/concluding)	90.7% of respondents believe that students will be able to make decisions/conclusions based on data or phenomena
Making flow diagrams/procedures (algorithm)	53.5% of respondents believed that students would be able to make a flowchart/sequence of steps in solving a problem.

In the interview, respondents also positively perceived applying CT without computers in the learning process (unplugged activities). Respondents stated that learning has been carried out with the syntax of scientific approach such as observing, asking, gathering information, associating, and communicating. Most respondents believed it would be excellent if scientific method learning integrated with CT. According to the respondents, data collection and abstraction skills can be applied to learning. Nevertheless, it is still challenging for the other skills because education has focused on physics concepts, in contrast to CT, which focuses more on using physics concepts to solve problems. Respondents declared that CT learning using computers would be challenging because most teachers claimed not to have mastered computer programming languages. Students also do not master computer programming languages because there are no particular subjects that teach them.

On the other hand, the respondents said they are very interested in teaching CT without computers or digital devices. The limited understanding of teachers about CT is possible because the government has not provided much socialization and training on CT learning. However, this also happens in several other countries, such as Malaysia. Most primary school teachers in Malaysia are not aware of teaching with CT (Mensan, Osman, & Majid, 2020). In Turkey, CT is not yet included in the curriculum that must be prepared for students. Research in Turkey shows that teachers who have attended CT training regard CT as problem-solving with a contribution to helping students produce something accompanied by various skills such as algorithms. The skills that teachers need to master in teaching CT are technology and understanding pedagogy to prepare CT activities (Yılmaz, Yılmaz, & Durak, 2018).

The positive response from the respondent about integrating unplugged activities in the learning process carried out with a scientific approach indicates an opportunity to be applied in physics class. According to ISTE (2016), CT learning can be done in several steps: formulating a problem definition, collecting data or identifying relevant data sets, breaking the problem into components, understanding how automation works, and using algorithmic thinking. Based on these learning steps, there is potential for computational thinking to be applied in science learning. Students are still asked to observe, formulate problems, explore, analyze data, and make generalizations. The difference with science learning is that the steps are extended by directing students to create a settlement work procedure (algorithm), which is then applied to the appropriate technology to be adequately resolved. CT learning with unplugged activities is expected to provide students with an experience in learning the basics of CT while increasing their understanding of physics concepts. This learning approach also emphasized some attitudes that students must own. These attitudes include self-confidence, persistence, tolerance, facing open problems, communication, and cooperation to achieve common goals. Although CT tends to focus on data, thinking, and technology, this approach still tries to maintain the attitudes humans need to become human beings who benefit their environment (Barr & Stephenson, 2011).

The positive response of respondents to CT will be a good chance for implementing unplugged activities in schools. Many studies show that unplugged activities positively affect CT understanding and skills. Unplugged activities before plugged activities in elementary schools positively impact students' self-confidence in understanding CT concepts (Hermans & Aivaloglou, 2017). Unplugged activity learning based on games and puzzles contributes positively to students' understanding of programming, behaviors, and attitudes (Sun, Ouyang, Li, & Zhu, 2021). Unplugged activities are a promising teaching strategy for improving students' CT skills (Chen, Yang, Metwally, Lavonens, & Wang, 2023). Unplugged activities have an essential role in instilling CT skills. Learning with unplugged activities without a programming language or a little programming language can develop CT skills. One of the unplugged activities that can improve CT skills is using board games and paper activities (Hsu & Liang, 2021).

Teachers can face challenges or difficulties implementing unplugged CT in class because teachers' understanding of CT is minimal. This challenge is very likely to arise due to the low familiarity of students with the CT approach. The computational thinking approach extends the scientific approach (Sengupta, Kinnebrew, Basu, Biswas, & Clark, 2013). This relationship is seen in the ISTE and Weintrop taxonomies, which still include inquiry practices in their taxonomies, such as data collection, data analysis, and data representation. Therefore, if students experience difficulties learning with a scientific approach, then students will also share the same difficulties in understanding a computational thinking approach. Based on research on the effectiveness of unplugged activities, it can be stated that CT has an excellent opportunity to be taught to senior high school students using unplugged activities with an activity-oriented scientific approach combined with paper activities.

CONCLUSION

Based on the description above, it can be concluded that unplugged computational thinking activities can be applied in senior high school, especially in physics learning. The challenge faced in applying unplugged computational thinking activities to senior high school physics classes is the low application of simulation and algorithm skills. Learning physics with a scientific approach needs to be emphasized in various activities to improve students' skills in making algorithms and simulations. This can be done by implementing project-based physics learning models like problem-based learning. Regarding these opportunities and challenges, it is necessary to carry out further research to integrate CT with unplugged activities in physics learning, especially in senior high school.

REFERENCES

Agustinaningsih, W. (2020). Creativity profile of prospective physics teachers with learning management based on learning styles. *Jurnal Pendidikan Fisika*, 8 (1), 112-125.

Apostolellis, P., Stewart, M., Frisina, C., & Kafura, D. (2014). RaBit EscApe: A board game for computational thinking. *ACM International Conference Proceeding Series* (page. 349-352). Aarhus: IDC.

Barr, V., & Stephenson, C. (2011). Bringing computational thinking to k-12: what is involved and what is the role of the computer science education community? *ACM Inroads*, 48-54.

Bocconi, S., Chioccariello, A., Dettori, G., & Ferrari, A. (2016). *Developing computational thinking in compulsory education–implications for policy and practice.* Luxembourg: Publications Office of the European Union.

Brackmann, C., Gonzales, R., & Robles, G. (2017). Brackmann, C.P. (Development of computational thinking skills through unplugged activities in primary Proceedings of 12th Workshop in Primary and Secondary Computing Education Nijmegen, November 8–10. *Proceedings of 12th Workshop in Primary and Secondary Computing Education.* Netherlands: Nijmegen.

Caeli, E. N., & Yadav, A. (2020). Unplugged approaches to computational thinking: a historical perspective . *TechTrends*, 64(1), 29–36.

Chen, P., Yang, D., Metwally, A., Lavonens, J., & Wang, X. (2023). Fostering computational thinking through unplugged activities: a systematic literature review and meta-analysis . *International Journal of STEM Education*, 10 (47), 3-25.

Creswell, J. W. (2014). *Research design (4th ed.)* . Thousand Oaks, CA: SAGE.

Czerkawski, B. C., & Lyman, E. (2015). Exploring issues about computational thinking in higher education. *TechTrends*, 59 (2), 57-65.

Dede, C., Mishra, P., & Voogt, J. (2013). Working group 6: advancing computational thinking in 21st century learning. *International summit of ICT in education.* Semantic scholar.

Haseski, H. I., Ilic, U., & Tugtekin, U. (2018). Defining new 21st century skill-computational thinking: concepts and trend. *International Education*, 11(4), 29-42.

Hermans, F., & Aivaloglou, E. (2017). To scratch or not to scratch?: a controlled experiment comparing plugged first and unplugged first programming lessons. *The 12th workshop on primary and secondary computing education* , (hal. 49-56).

Hsu, T. C., & Liang, Y. S. (2021). Simultaneously improving computational thinking and foreign language learning: Interdisciplinary media with plugged and unplugged approaches. *Journal of Educational Computing Research*, 59(6), 1184–1207.

ISTE. (2016, July 1). *ISTE Standards for students. international society for technology in education*. Diambil kembali dari Edsurge: https://www.iste.org/standards/for-students

ISTE. (2014). Computational thinking leadership toolkit first edition. International Society for Technology in Education. Retrieved from https://cdn.iste.org/www-root/ct-documents/ct-leadershipt-toolkit.pdf?sfvrsn=4, on 5 February 2022. (t.thn.).

James, J., & George, H. (2009). Thinking about computational thinking. *ACM SIGCSE Bulletin*, 41 (1), 260–264.

Kuo, W., & Hsu, T. (2020). Learning computational thinking without a computer: how computational participation happens an computational thinking board game. *Asia Pacific Education Researcher*, 29(1), 67-83.

Looi, C., How, M., Longkai, W., Seow, P., & Liu, L. (2018). Analysis of linkages between an unplugged activity and the development of computational thinking. *Computer Science Education*, 28 (3), 255-279.

Lyman, W., & Czerkawski, B. (2015). Exploring issues about computational thinking in higher education. *TechTrends*, 59, 57-65.

Mensan, T., Osman, K., & Majid, N. (2020). Development and validation of unplugged activity of computational thinking in science module to integrate computational thinking in primary science education. *Science Education International* , 31(2), 142-149.

Mishra, P., Yadav, A., Henriksen, D., & Kereluik, K. (2013). Rethinking technology and creativity in the 21st:of art and algoritms. *TechTrends*, 57(3), 10-14.

Putri, R., Akmam, Mufit, F., Sari, S., & Hidayat, R. (2022). Analysis of student's creative thinking ability in the computation physics course. *Gravity: Jurnal Ilmiah Penelitian dan Pembelajaran Fisika*, 8 (2), 78-86.

Redesign, C. f. (2015). *Skills for the 21st century: what should students learn?* . Boston: Center for Curriculum Redesign.

Sengupta, P., Kinnebrew, J., Basu, S., Biswas, G., & Clark, D. (2013). Integrating computational thinking with k-12 science education using agent-based computation: a theoretical framework. *Education and Information Technologies*, 351–380.

Sumintono, B., & Widhiarso, W. (2014). *Aplikasi model rasch untuk penelitian ilmu-ilmu sosial. Trim Komunikata.* Cimahi: Trim Komunikata.

Sun, D., Ouyang, F., Li, Y., & Zhu, C. (2021). Comparing learners' knowledge, behaviors, and attitudes between two instructional modes of computer programming in secondary education. *International Journal of STEM Education*, 8 (54).

Voogt, J., Fisser, P., Good, J., Mishra, P., & Yadav, A. (2015). Computational thinking in compulsory education: towards an agenda for research and practice. *Educ Inf Technol*, 20, 715-728.

Waterman, K., Goldsmith, L. .., & Pasquale, M. (2020). Integrating computational thinking into elementary science curriculum: an examination of activities that support students' computational thinking in the service of disciplinary learning. *Journal of Science Education and Technology*, 53-64.

Waterman, K., Goldsmith, L., & Pasquale, M. (2020). Integrating computational thinking into elementary science curriculum: an examination of activities that support students' computational thinking in the service of disciplinary learning. *Journal of Science Education and Technology*, 29 (1), 53-64.

Weintrop, D. (2016). Defining computational thinking for mathematics and science classroom. *Journal of Science Education and Technology*, 25 (1). 127–147

Wing, J. (2006). Computational thinking. *Communications of the ACM*, 49(3), 33-35.

Yılmaz, F. .., Yılmaz, R., & Durak, H. (2018). *A Review on the opinions of teachers about the development of computational thinking skills in K-12.* Hershey PA, USA: IGI Global.

Yılmaz, F., Yılmaz, R., & Durak, H. (2018). Teaching computational thinking in primary education. Dalam S. Ozcinar, G. Wong, & H. Ozturk, *A review on the opinions of teachers about the development of computational thinking skills in K-12* (hal. 157-181). Hershey PA, USA: IGI Global.