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Exploring Computational Thinking in Mathematics Education: Integrating ChatGPT with GeoGebra for Enhanced Learning Experiences

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Abstract

ChatGPT has become a significant topic of interest in the field of education, prompting of the potential applications of such technology. The utilization of ChatGPT may facilitate the fostering of 21st century skills, such as computational thinking (CT) and technology, which could subsequently provide a means of offering students personalized assistance. The current study presents the experience of students undertaking a GeoGebra-based mathematics+CT task with the assistance of ChatGPT. The data was collected and analyzed, including students' screen recording, students' interaction with ChatGPT, and the questionnaire. The findings indicate that a limited number of students were able to successfully construct objects on GeoGebra with the assistance of ChatGPT. Students were unable to provide a sufficiently detailed prompt to enable them to receive guidance. Nevertheless, the majority of students perceived ChatGPT as beneficial, although they felt that its responses required adaptation. This study highlights the importance of integrating and utilizing both ChatGPT and GeoGebra to enhance CT skills. Future research may examine the relationship between the expertise of using software or writing qualified prompts on ChatGPT and the effectiveness of responses.

Introduction

The growing interest in daily life and the skill of solving complex problems, which is widely regarded as one of the most important skills for the 21st century, has led to a notable increase in research into complex problem-solving strategies. This has enabled the utilization of computational thinking (CT) in a multitude of disciplines, thus establishing CT as a valuable skill (Boulden et al., 2021; Weintrop et al., 2016). CT was introduced by Seymour Papert and then adopted by Wing (2006) as a pedagogical tool for developing problem-solving skills. This provided the rationale for integrating CT into the educational curriculum. The integration of CT into mathematics education is smooth because of the similarity between the nature of CT and mathematics, which enables the application of concepts in the real world and provides opportunities for the development of problem-solving skills (Kallia et al., 2021).

As computational tools become more widespread in mathematics and science, there are promising opportunities for fostering CT in non-programming tasks and unplugged learning activities (Dagienė & Sentance, 2016). Furthermore, learners should be encouraged to use mathematical concepts and CT concepts and to engage in computational practices throughout problem-based activities (Ng & Cui, 2021). Similarly, mathematics tools intended for educational purposes can be used to foster CT within mathematics learning activities that are aligned with current curricula and educational policies (Adelabu et al., 2019). There is a lack of empirical data to investigate students' responses to CT-embedded learning activities and the integration of such activities into mathematics education (Chytas et al., 2024). There is a need for empirical studies that establish a link between the learning of mathematics and computational thinking (Hichmott et al., 2017). Nevertheless, the academic literature on the integration of CT in mathematics education provides promising evidence of positive outcomes. This trend is encouraging us to consider the integration of computational thinking into mathematics education. It can be argued that the use of GeoGebra, a mathematical tool, will foster students' understanding of computational thinking, rather than encourage the adoption of approaches based on computational tools.

GeoGebra, an interactive mathematics software, plays a pivotal role in fostering interactive learning within mathematics education (Hohenwarter et al., 2008). It is one of the most popular dynamic mathematics software programs in mathematics education. GeoGebra software can be downloaded to the device or used online. The integration of geometry, algebra, and statistics within a single platform enables students to explore mathematical concepts visually and dynamically. In addition, GeoGebra can be used to construct geometric objects using the drawing tools in the menu bars or using GeoGebra commands. The use of GeoGebra in the classroom can enhance students' understanding and improve their problem-solving skills (Karatas, 2022). Furthermore, GeoGebra's exploratory approach to mathematical problems has been well-received by students, indicating its effectiveness in engaging learners and facilitating a deeper comprehension of mathematical concepts (Salami & Spangenberg, 2024). A number of encouraging studies have indicated that GeoGebra has the potential to enhance students' computational thinking abilities within the mathematics curriculum (Yunianto, Bautista, et al., 2023; Yunianto, Prodromou, et al., 2023; Chytas et al., 2024). The integration of emerging technologies and artificial intelligence (AI) into the field of education has prompted a shift in pedagogical approaches. This phenomenon has given rise to concerns surrounding the potential benefits and challenges associated with the utilization of AI tools as a means of facilitating computational thinking instruction within the context of mathematics education.

The integration of AI tools such as the Chat Generative Pre-trained Transformer (ChatGPT) into various educational domains is becoming increasingly prevalent. This is particularly relevant given the growing public interest in ChatGPT since its introduction in 2022 by OpenAI (Sohail et al., 2023). ChatGPT has the capacity to generate, document, and evaluate software programming codes (Plata et al., 2023). In the context of emerging technologies, ChatGPT may be considered an effective tool for assisting students within the framework of Vygotsky’s Zone of Proximal Development (ZPD). The integration of ChatGPT into mathematics education presents a multitude of benefits for educators, encompassing aspects such as lesson planning, task design, and other pedagogical considerations (Wardat et al., 2023). Similarly, students stand to gain from the use of ChatGPT, with the potential for enhanced assistance and guidance (Dasari et al., 2024; Sapkota & Bondurant, 2024). With the high potential and interest of ChatGPT, it is crucial to trigger its implications, strengths, and weaknesses

(Tashtoush et al., 2023; Wardat et al., 2023).

Combining ChatGPT with dynamic mathematics software such as GeoGebra may offer several advantages. In light of this, we posed the question to ChatGPT as to whether it could generate GeoGebra commands to construct geometrical objects. To our surprise, it provided some successful commands that we noticed using both GeoGebra and ChatGPT may provide some educational benefits. Firstly, it may provide a platform for personalized learning experiences, allowing students to receive tailored support and guidance based on their individual needs and learning styles. Secondly, this integration facilitates the development of computational thinking skills. By engaging with GeoGebra and ChatGPT, students can actively apply their mathematical knowledge in real-world contexts. Furthermore, it creates an innovative platform for interactive problem-solving activities that promote computational thinking skills. This integration has the potential to innovate mathematics education by providing students with hands-on experiences that deepen their understanding of mathematical concepts and enhance their critical thinking abilities. In line with this, the objective of this study is to examine the potential of ChatGPT to assist lower secondary students in developing their mathematical understanding. The researchers aim to ascertain whether ChatGPT can provide meaningful explanations to enhance students' comprehension of constructing geometrical objects through GeoGebra commands.

This paper builds on examining ChatGPT's assistantship in lower secondary school students' performances in the context of using GeoGebra activities to integrate computational thinking on the circle concept. There is a little research on how ChatGPT assist students for learning CT and how ChatGPT can be integrated into mathematics lesson. Our study followed a design-based research approach to answer the following research question:

RQ1: What can ChatGPT do to assist lower secondary school students' experience a GeoGebra-based mathematical task aimed at promoting CT skill?

RQ2: What are the opinions of lower secondary students regarding the utility of ChatGPT in mathematics education?

In the following section, the theoretical framework of computational thinking and using ChatGPT in education will be presented.

Related Literature

Computational Thinking

Computational thinking is 'a fundamental skill as reading, writing, and arithmetic for everyone, and it is a problem-solving skill like a computer scientist thinks when solving problems' (Wing, 2006, p. 33). CT has gained significant interest from researchers around the world (Bocconi et al., 2016, 2022), so some countries have included CT in their curricula. Furthermore, CT is taught in various ways across countries. Although there is no doubt that CT is significant, there is no consensus on how to integrate it into the curriculum. Some countries include it as a specific subject, while others integrate it into other disciplines. Yet others included CT as a component (Bocconi et al., 2016). It is therefore not surprising that computational thinking has found its place in mathematics education. The integration of CT into mathematics lessons has been shown to have positive effects,

including the enhancement of students' algorithmic thinking, generalization, data practices, and fostering autonomy (Chytas et al., 2024; van Borkulo et al., 2021, 2023). The utilization of programming languages and technological tools enables students to solve real-world problems, analyze, and interpret data, and create algorithms. This approach not only facilitates a deeper understanding of mathematical concepts, but also prepares students for the demands of current and future 21st century skills.

The research on integrating CT into mathematics education has increased significantly in the past five years (Subramaniam et al., 2022). Weintrop et al. (2016) provided a computational thinking in mathematics practices taxonomy where data practices (collecting data, creating data, manipulating data, analyzing data, and visualizing data) are prominent in this taxonomy. Additionally, Shute et al. (2017) provided a connection between mathematics and CT that they share the same cognitive skills, such as problem solving, and proposed six CT facets (decomposition, abstraction, algorithms, debugging, iteration, and generalization).

Furthermore, Ang (2020) showed how CT could be a habit of mind for students working on mathematical modeling. Ye et al. (2023) conducted a systematic literature review on the integration of CT into mathematics education and summarized that the integration benefits both sides as CT skills and mathematics skills could co-develop together. Chan et al. (2021) compared Singaporean students with computational thinking treatment in the experimental group, revealing no significant difference in the students' mathematical performance with the students in the control group due to the short intervention. Other studies also revealed that students could learn mathematics concepts and CT concepts such as programming and debugging (Yunianto, Bautista, et al., 2023; Yunianto, Prodromou, et al., 2023).

Wang et al. (2022) and Ye et al. (2023) have helped our study consider what tools to be used in integrating CT in mathematics education. Based on their studies, we decided to utilize GeoGebra to enhance students' CT skills while learning mathematics. In our previous studies, we utilized GeoGebra in dynamic mathematics tasks aimed at fostering CT skills, which have supported students' mathematics concepts and CT skills (Yunianto, Bautista, et al., 2023; Yunianto, Prodromou, et al., 2023).

ChatGPT in Mathematics Education

Ever since its establishment, ChatGPT has been challenged by people who post mathematical puzzles online for it to solve. ChatGPT poses limitations in solving mathematical problems and might produce inaccurate results (Rane, 2023). However, Li et al. (2023) proved that ChatGPT could efficiently solve the Taiwanese mathematics examination covering various topics at the high school level with an accuracy rate of 90% (proficient).

The integration of ChatGPT into mathematics education has opened up new possibilities for teaching and learning, both for educators and students. With its natural language processing capabilities, ChatGPT can provide personalized and interactive learning experiences for students (Wardat et al., 2023). Hence, ChatGPT's capabilities can facilitate interactive and engaging learning experiences, catering to different learning styles and paces. This artificial intelligence (AI) model has the potential to assist students in understanding mathematical concepts,

solving problems, exploring real-world applications of mathematics, and providing instant feedback (Guo et al., 2023). Using ChatGPT in mathematics education presents several challenges for teachers, including reliability issues, cheating, teacher-student interaction, uncontrolled educational environments, and assessment challenges (Sánchez-Ruiz et al., 2023), although it also offers a variety of opportunities for educators to enhance the learning experience for students. However, both educators and students must develop the requisite competencies to effectively incorporate ChatGPT and navigate the advancements in AI technology within the realm of mathematics education (Klimova et al., 2024). While there is considerable diversity of opinion among educators regarding the integration of ChatGPT in educational settings, some express concerns about potential positive and negative aspects. There are also those who advocate for its use as a valuable teaching and learning support tool to enhance efficiency and effectiveness in mathematics education (Mai et al., 2024).

Furthermore, the remarkable capabilities demonstrated by ChatGPT, such as passing rigorous examinations and providing immediate responses to inquiries, underscore its potential to enhance students' understanding of mathematical concepts and related topics, ultimately contributing to their educational success (Mai et al., 2024; Urhan et al., 2024). This highlights the significance of embracing AI technologies such as ChatGPT as a progressive opportunity for educational advancement, rather than a source of apprehension. These tools are expected to play a prominent role in shaping the future of education. As educators continue to explore the integration of ChatGPT into mathematics education, it is essential to consider how ChatGPT can assist students in learning. It is important to ensure that the use of AI in education does not replace human interaction. It is of the utmost importance to achieve a balance between the advantages offered by AI and the necessity of human involvement in the learning process.

The ChatGPT in Generating Computer's Program

The benefits of generative AI in engineering domains have been observed through its capacity to generate, document, and evaluate software programming codes (Plata et al., 2023). According to Cotton et al. (2023), ChatGPT has been employed in computer science classes to facilitate the generation of computer programs. Shabunina et al. (2023) suggested that ChatGPT has the potential to aid students in acquiring proficiency in difficult tasks such as programming. In terms of generating computer programs, ChatGPT has been proven to generate GeoGebra commands (Yunianto, Lavicza et al., 2024). Nevertheless, the utilization of ChatGPT could encourage students to memorize the AI-generated programs or codes as a means of exam preparation, notwithstanding their limited proficiency in programming at their current state (Zdravkova et al., 2023).

Method

This research forms part of the first researcher's dissertation. The researcher developed a list of mathematical tasks based on an educational design-based approach. These tasks, called Math+CT, were aimed at fostering CT skills in GeoGebra among 13–14-year-old lower secondary school students. In this study, students are allowed to use ChatGPT to examine how it assists them during one of the developed Math+CT tasks. This section presents the educational context and related information about the methodology of the study.

Study Context

This study was guided by the educational design research (EDR) by McKenney & Reeves (2018) with the objective of understanding the integration of CT in mathematics lessons. The research team, consisting of a mathematics educator, GeoGebra experts, and mathematics teachers, conducted a comprehensive analysis of the relevant literature and learning domains, and subsequently designed a list of Math+CT tasks on GeoGebra. These tasks were then implemented in the classroom, with the researchers working closely with the participating mathematics teachers throughout the process. The teachers who took part in the project also participated in the analysis and design of the tasks. The researcher and mathematics teachers engaged in a discussion regarding the implementation of the aforementioned tasks within the mathematics classroom. In order to enhance the efficacy of the tasks, the analysis and redesign should be carried out in accordance with the data obtained from the implementation process. Consequently, the Math+CT tasks have been implemented and developed through an iterative process.

The initial cycle was a pilot study (Yunianto, Prodromou, et al., 2023) while the preceding cycle was implemented in a real classroom to assess the impact of the tasks on the development of CT skills (a manuscript submitted to a journal). This was followed by a further two cycles, during which the tasks were analyzed in terms of their effect on language (on progress) and culture (Yunianto, Cahyono, et al., 2024). In the previous cycles, students worked on the Math+CT tasks without the assistance of ChatGPT. As ChatGPT has recently emerged, we have innovated to utilize it to ascertain its potential to support students' CT skills while working on Math+CT tasks. In this paper, the effects of using ChatGPT for fostering students' CT skills during the use of Math+CT tasks on GeoGebra will be examined as the fifth cycle. The implementation was conducted in a physical classroom with lower secondary school students.

The first researcher attended the class virtually to guide the students or the teacher if necessary. The teacher was supported by the first researcher before and during the implementation of the Math+CT task. The teacher's role was to provide guidance to students. Students were introduced to the Math+CT tasks and asked to solve the tasks. Math+CT tasks are designed on GeoGebra. In this study, the Math+CT tasks are used online. The teacher and most of the students were already familiar with the ChatGPT. The teacher had some experience with how to use ChatGPT in the classroom.

The tasks we developed and used in this study address CT and mathematics content using GeoGebra. The learning context of the task is the exploration of the area of a circle, approached through the area of an inscribed regular polygon. The task asks students to construct a hexagon inscribed in a circle with center (0,0) and a radius of four by using only GeoGebra commands in the algebra view of GeoGebra. It requires students to input the constructions in a step-by-step manner in order to do so successfully. The task presented to the students was as follows: "Can you construct an inscribed hexagon on a circle whose center is (0,0) and radius is 4 by using only GeoGebra commands with the help of the ChatGPT?". This task requires the mathematical knowledge of constructing a circle, the properties of a circle, and the interior angle of a regular hexagon. It also requires the CT skills of programming and debugging. The expected GeoGebra commands and their explanations are given in

Table 1.

Table 1. Steps of Commands to Construct an Inscribed Hexagon

Step	Command	Description
1	A=(0,0)	Constructing a point of A as the center of the circle.
2	c=Circle(A,4)	Drawing a circle ‘c’ whose center is (0,0) and radius is 4.
3	B=Point(c)	Constructing a point of B on the circle.
4	a=360deg/8	Creating an internal angle for a hexagon (45°).
5	Angle(B,A,a)	Constructing a point of B’ by rotating the point of B with an angle of rotation is a.
6	Polygon(B,B’,8)	Creating a hexagon inscribed on the circle ‘c’.

Inputting commands following Table 1 correctly and respectively, students constructed an inscribed hexagon on the circle according to the given conditions on GeoGebra (see Figure 1).

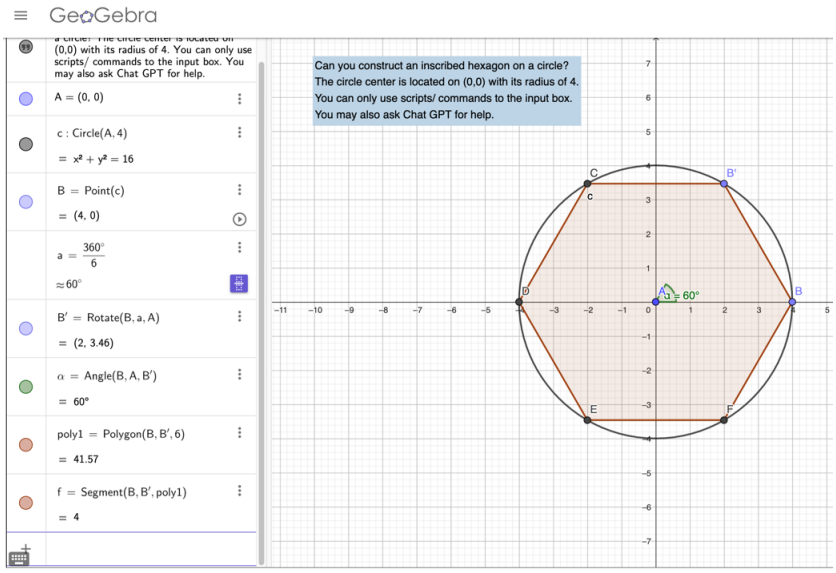

Figure 1. A Hexagon Construction by Inputting GeoGebra Commands

Participants

This study participants were seventh and eighth-grade lower secondary school students in Indonesia (n = 16) who were 13- 14 years old when the study was conducted. All students had experience using GeoGebra and participated as volunteer. The first researcher collaborated with the mathematics teacher who has been involved in the previous cycles to implement the utilization of the Math+CT lessons. The mathematics teachers informed the researchers that she has introduced ChatGPT to students prior this research but not to generate computer programs.

Data Collection and Analysis

The data collection process collected video screen recording, students’ written discussion with ChatGPT while

working on the task, and questionnaire. The first author conducted an online meeting with the students and the teacher. Some students used laptops and other used mobile phones. The teacher supported to assist students in responding to the researcher's questions or instructions. The first author initially presented the task to the students and asked them to read the problem and solve it on GeoGebra by using ChatGPT. The students started discussing with ChatGPT how to construct the given task on GeoGebra. "Students Generated Questions" (SGQ) strategy was utilized to reveal a students' performance and observe assistance of ChatGPT according to students' performance. SGQ consist of the collection of idea of students to remember, identify, and synthesize the key elements of a concept (Cheng et al., 2023). In this line, students communicated with ChatGPT by writing their own prompts. After constructing the given task, students shared their experiences with an online questionnaire.

The questionnaire comprises six multiple-choice questions and one open-ended question. The objective is to assess the students' ability to use both ChatGPT and GeoGebra, to evaluate the final result of the given task, to train ChatGPT, to assess the helpfulness of ChatGPT, and to share their own opinions about their experience of using ChatGPT while programming on GeoGebra. This paper focused on students' experiences with ChatGPT. The students were informed that there was no time limit, and they were given the freedom to write any prompt on ChatGPT. The students solved the problem in approximately 40 minutes. The first author provided necessary guidance for students if needed.

For the link to ChatGPT, the researchers could not access all links provided by students due to errors while opening the links and students did not have a ChatGPT account resulting in losing the conversation with ChatGPT. It seems that some students either deleted the links, failed to save their work on ChatGPT, or encountered other technical issues, since some of them were working on mobile phones. Therefore, there were only nine ChatGPT links that could be accessed. There were 16 responses from the questionnaire containing some information such as students' responses related to their experiences of using ChatGPT to solve the Math+CT task. The data from the screen video recording would be used to triangulate data from students' final commands.

It can be seen when students demonstrated how their final commands work during presentation on the zoom meeting. Meanwhile, the ChatGPT links were quantatively analyzed by counting the number of iterations students made with ChatGPT, the number of successful commands, and the difference amongst the commands and to our commands. In addition to that, we analyzed whether students argued and or train ChatGPT. We used thematic analysis (Braun & Clarke, 2006, p. 87) by following their six steps (familiarizing yourself with your data, generating initial codes, searching for themes, reviewing themes, defining and naming themes, and producing the report for students' experiences while working with ChatGPT derived from the questionnaire.

Results

This section presents the study's findings with insight into what ChatGPT can do to assist students while solving a dynamic mathematics task fostering CT skills in lower secondary school mathematics lesson with GeoGebra and students' experiences. The next sub-sections aim to have a closer look at the study to provide a more comprehensive idea of the findings.

Generated GeoGebra Commands

The number of the iterations students made to their final GeoGebra commands was counted and was tired out the final commands from students' ChatGPT links. Each code generation on the ChatGPT was counted as one iteration. Students' grade level, the number of the iterations, and the questionnaire result for whether the final results of steps were successful or not, arguing and training ChatGPT was given in Table 2 according to students.

Table 2. A Summary of Students' Communication with ChatGPT

Student	Grade	# of iterations	Successful	Argue with ChatGPT	Training ChatGPT
S1	7	11	No	Yes	No
S2	8	2	Yes	Yes	No
S3	8	8	Yes	Yes	Yes
S4	7	5	No	No	No
S5	8	1	No	No	No
S6	8	1	No	No	No
S7	7	1	No	No	No
S8	7	1	No	No	No
S9	8	1	No	No	No

As can be seen in Table 2, most of the students were not successful. This means that the students cannot construct an inscribed hexagon on a circle with the help of ChatGPT. Only two students (S2 and S3) were successful. Observing the number of iterations of the successful students, we can say that there might be no relation between the number of iterations and the final result. Otherwise, if we compare the training ChatGPT, there is an obvious difference between these two students. It is interesting that the only one student who trained the ChatGPT had a successful result in this study.

When examining S1's screen recording and communication with ChatGPT, we noticed that although she produced various commands with the help of ChatGPT and attempted 11 times, the generated commands did not work in GeoGebra to construct the requested objects because some commands were not executable in GeoGebra and S1 encountered an error. The unknown command phrase came up from GeoGebra's pop-up notification when users enter incorrect commands (see Figure 2). It seems that the phrase from GeoGebra's pop-up notification could help S1 to argue with ChatGPT to refine the commands as in "unknown command: cos gives another command".

After arguing with ChatGPT about the unknown command notification on GeoGebra, ChatGPT generated new commands (see Figure 3). GeoGebra would execute a command in a single line. Therefore, the fourth line over "for" in the command given by ChatGPT would not fit on GeoGebra. S1 did not try again and stopped the task in this step because he did not have any working commands.

S1 constructed variables from the r, n, angle and vertices given in Figure 3 by copying and pasting them into GeoGebra's input bar. When he tried to do the same for the for command, it did not work and gave an error. When

this happened, this student was not able to tell GeoGebra to only give single line commands. It seems that the student did not yet understand what commands GeoGebra could execute.

Figure 2. GeoGebra Pop-Up Notification Showed an Unknown Command

```
r = 4
n = 6
angle = 360/n
vertices = {}
For[i = 1, i <= n, i++,
  x = r * Cos[i * angle * Pi/180]
  y = r * Sin[i * angle * Pi/180]
  vertices[i] = {x, y}
]

H1 = Polygon[Sequence[Table[vertices[i], {i, 1, n}]]]
```

Figure 3. S1 Final Commands Generated by ChatGPT

In this study, S2 was one of the students who constructed an inscribed hexagon on a circle with given conditions using GeoGebra commands generated from ChatGPT consisting of eight commands with two iterations. In S2's first attempt, S2 asked ChatGPT to construct a regular hexagon inside a circle with center at (0,0) and radius 4 using codes for GeoGebra. ChatGPT provided some commands and S2 followed the generated commands. S2 noticed that one command did not work and used it to communicate with ChatGPT to provide another command. S2 asked ChatGPT as "code Point[Circle[(0,0), 4], k/6] doesn't work, please give another command". ChatGPT generated new commands according to his request (see Figure 4).

1. **Create a Circle** : `Circle[(0,0), 4]`
2. **Create Points on a Circle** : To create a regular hexagon, we need to place 6 points on the circle with an angle distance of 60 degrees between each point (because 360 degrees / 6 sides = 60 degrees). We can use commands `Rotate[Point, Angle, Center]` to get these points. First, create a starting point on the circle:
   - `A = Point[Circle[(0,0), 4]]` This will place point A on the circle.

   Then, use the rotation command to create the next points:
   - `B = Rotate[A, 60°, (0,0)]`
   - `C = Rotate[B, 60°, (0,0)]`
   - `D = Rotate[C, 60°, (0,0)]`
   - `E = Rotate[D, 60°, (0,0)]`
   - `F = Rotate[E, 60°, (0,0)]`
3. **Connect the Dots to Make a Hexagon** :
   - `Polygon[A, B, C, D, E, F]`

Figure 4. S2 Final Commands That Could Create the Inscribed Hexagon

With the help of ChatGPT, S2 successfully constructed the given object on GeoGebra (Figure 5) by typing in the last commands shown in Figure 4 one by one.

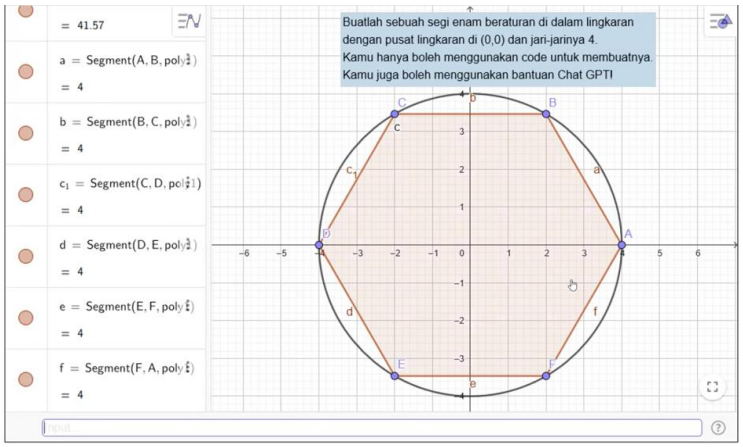

Figure 5. S2 Successful Construction Captured from the Zoom Meeting

S3 was another student who constructed the required object in GeoGebra. She went through eight iterations. Interestingly, she started with the prompt "Please construct a circle with center (0,0) and radius 4", similar to S2. Then she wrote the same prompt but added "in GeoGebra" at the end of the sentence after realizing that the given commands belonged to Python. Crucially, S3 wrote the prompt step by step, meaning that she trained ChatGPT to construct the required object in a sequence. Another surprising finding is that although S3 communicated with ChatGPT in Bahasa Indonesia during the iteration process, S3 asked ChatGPT to change the command to English: 'Please replace Lingkaran with Circle'. ‘Lingkaran’ is the Indonesian word for circle. ChatGPT later provided S3 with the command in English. Another training that S3 gave to ChatGPT was to use lower case instead of upper case for the sine and cosine commands: 'Cos and Sin use lower case'. This evidence showed us that a lower secondary student could interact with and train ChatGPT. Similar to S2, S3 was able to receive final commands that successfully constructed the inscribed hexagon. Figure 6 shows S3's final commands, which consist of eight commands (colored texts).

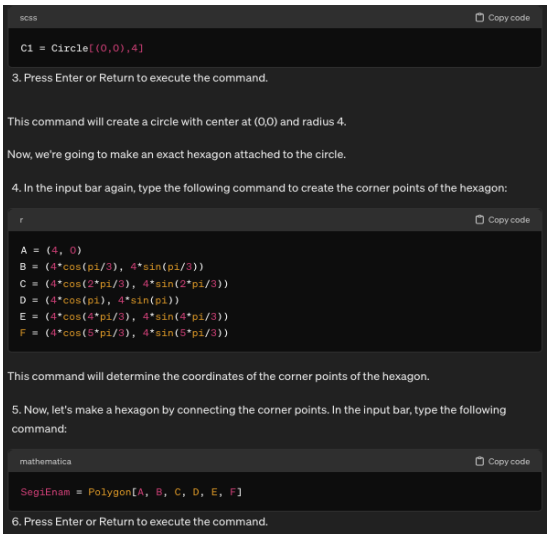

Figure 6. S3 Final Commands

The rest of the students (S4, S5, S6, S7, S8 and S9) could not generate correct final commands due to the lack of a proper prompt. S4, S5 and S6 wrote a prompt like “construct a regular hexagon inside the circle with the center at (0,0) and radius 4”. After several attempts to copy and paste the given commands to GeoGebra, they could not construct the required object in GeoGebra. As they did not guide ChatGPT to produce a list of commands for GeoGebra, ChatGPT gave the students some commands for Python, Scratch or HTML format. S4 asked ChatGPT to give another command seven times. However, not all of them were for GeoGebra. S5 and S6 tried only once and gave up. S8 and S9 also tried once, but included "with/in GeoGebra" in their prompt. However, ChatGPT did not produce a correct command that worked on GeoGebra (see Figure 7 for an example - colored texts) and the students were unable to complete the task. Entering these commands into the GeoGebra input field would not successfully construct the inscribed hexagon. This taught us that ChatGPT could generate codes from various computer programs that we did not want to use.

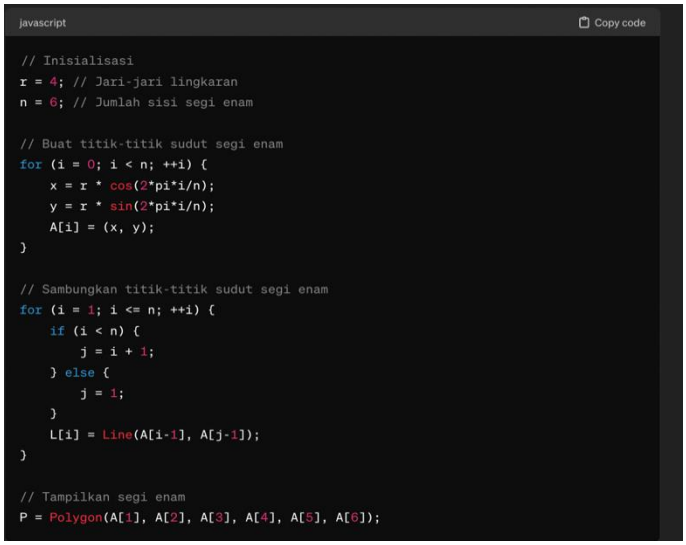

Figure 7. ChatGPT Generated JavaScript Codes for S8

Students’ Experiences with ChatGPT

Students’ experiences in constructing an inscribed hexagon on a circle with given conditions in GeoGebra using ChatGPT are presented in Table 3. The students' experiences were categorized under the themes “useful” or “impractical”.

Table 3. Themes derived from Students' Experiences

Themes	Codes	f	Students’ Comments
Useful	Helpful	4	“ChatGPT is very helpful” (S3) “Very impressive and very helpful in working on GeoGebra” (S7) “MADE MY LIFE EASIER, very useful and adding experiences” (S15)
	Improvable	3	“First, I asked ChatGPT to help me write down the GeoGebra code, it turned out it couldn't, then I tried asking ChatGPT to correct it again, after trying it a second time, I was finally able to create the hexagon and

Themes	Codes	f	Students' Comments
			circle." (S9)
			"When asking questions on ChatGPT it's quite easy but not all answers are the same/correct so we have to adapt the questions given to ChatGPT." (S11)
			"ChatGPT has a lot of faults, to the point where I have to correct it myself" (S6)
Impractical	Technical issue	2	"I used ChatGPT to create something on GeoGebra, but when I used ChatGPT, it kept lagging" (S4)
			"When I ordered the ChatGPT to create a circle it produced the correct code, but when I tried to create a hexagon, it didn't work/error" (S14)
	Confusing	2	"Still a little confused" (S8)
			"Cannot be used" (S5)

The findings of the study indicated that the majority of students expressed a positive opinion of the assistance provided by ChatGPT. The majority of students found the tool to be useful. Although ChatGPT initially produces incorrect commands, students indicated that it can be adapted by requesting corrections or by leveraging their own knowledge. Four students found ChatGPT to be of impractical, citing incorrect or confusing commands as the reason for this.

Discussion and Conclusion

A number of studies (e.g., Chytas et al., 2024; Yunianto, Bautista, et al., 2023; Yunianto, Prodromou, et al., 2023) have explored the potential benefits of utilizing GeoGebra in mathematics classrooms, particularly in terms of fostering students' computational thinking skills. The present study examined the potential of ChatGPT to assist in the performance of a mathematical task involving computational thinking in GeoGebra. The findings from the students' screen recordings, their interactions with ChatGPT, and their responses to the questionnaire indicate the potential and future significance of using ChatGPT in mathematics education to assist students' learning experiences, programming, supporting problem-solving and learning mathematics. As technology continues to evolve, the potential for advanced AI models and interactive software in education is considerable. Our study highlighted the necessity for educators and researchers to continue exploring innovative methods of integrating technology into the classroom, including the potential of utilizing both ChatGPT and GeoGebra in mathematics education. ChatGPT has the potential to enhance the development of 21st-century skills in students, including problem-solving and communication (Luo et al., 2023; Sánchez-Ruiz et al., 2023). ChatGPT was found to have the potential to help students develop their computational thinking skills. However, it would be desirable for it to be adapted for use with or integrated into GeoGebra.

In response to RQ1,"What can ChatGPT do to assist lower secondary school students' experience a GeoGebra-based mathematical task aimed at promoting CT skill?", the results of students' interactions with ChatGPT offer a comprehensive insight into the capabilities of the ChatGPT. ChatGPT provides a platform for users (e.g.,

teachers and students) to pose questions related to any problem and communicate in order to find solutions. This is performed by providing assistance, enhancing learning experiences, and facilitating personalised feedback (Kooli, 2023; Kuhail et al., 2022). ChatGPT has the potential to enhance users' capabilities and abilities in mathematical contexts (Wardat et al., 2023). Nevertheless, the results indicated that there is still a limited understanding of GeoGebra on the part of ChatGPT. It was observed that there were instances where the coding provided by ChatGPT was not entirely accurate, and in some cases, the command was not functional within the GeoGebra. It would be beneficial for users to have a basic understanding of GeoGebra in order to be able to identify these issues or adapt the prompt provided to match the capabilities of GeoGebra. This result lends support to the argument that developing critical evaluation skills is beneficial for assessing the accuracy and relevance of information provided by ChatGPT (Albadarin et al., 2024). In the course of our study, only two of the nine students were able to construct an inscribed hexagon on a circle whose center was located at (0,0) and radius was 4 on GeoGebra with the assistance of ChatGPT. Although only a small number of students were able to successfully construct the desired geometric objects with the assistance of ChatGPT, this demonstrates that ChatGPT has the potential to support students in generating accurate GeoGebra commands. The majority of students were unable to construct the desired shape due to the lack of guidance provided by ChatGPT. Although ChatGPT can be considered a virtual intelligent assistant, the majority of students believed that it does not always provide accurate responses (Albadarin et al., 2024).

More than half of the student respondents (S4, S5, S6, S7, S8 and S9) attempted the task on one instance and then gave up on it. In their review of the literature, Albadarin et al. (2024) argued that students consider ChatGPT to be a tool that requires a certain level of background knowledge. Our findings concur with those previously study. Some students were unable to complete the Math+CT task and consequently failed to achieve the desired outcome. It may be assumed that the students lacked the requisite knowledge to engage in effective communication with ChatGPT. The responses generated by ChatGPT are contingent upon the guidance, words, and direction provided in the prompts (Rospigliosi, 2023). It is therefore imperative to consider the ways in which ChatGPT can be utilized as an educational instrument. A significant challenge associated with ChatGPT is the assurance of accuracy and quality in the responses it provides (Meyer et al., 2023). ChatGPT has the potential to provide incorrect information. Recent research has demonstrated the capacity of combining large language models (LLMs) with prompting techniques to automatically solve mathematical problems, thereby illustrating the evolving landscape of AI in education (Liang et al., 2023). In order to elicit more accurate responses from ChatGPT, it would be beneficial to consider implementing training for both educators and students in order to facilitate the creation of qualified prompts (Lo, 2023).

In response to RQ2, “What are the opinions of lower secondary students regarding the utility of ChatGPT in mathematics education?”, the results from the student questionnaire provided profound insights and raised significant concerns. With regard to the insights, the students considered ChatGPT to be a helpful tool, despite the inclusion of some mistakes or errors. These benefits have the potential to transform and revolutionize education, offering a range of pedagogical advancements (Kooli, 2023; Valtonen et al., 2022). The results of this study demonstrated that the adoption and development of innovative learning and teaching strategies enabled by ChatGPT have the potential to contribute to significant educational reforms. Conversely, it became evident that

students lacking the requisite skills to utilize ChatGPT may experience adverse effects. Some students have stated a negative opinion of the use of ChatGPT, asserting that it causes technical issues and confusion. Seven students indicated that ChatGPT should be capable of adaptation. Although it is capable of generating commands, it may initially produce results including errors. It is recommended that students either correct the errors themselves or request that ChatGPT make the necessary improvements. Prior research in this field has highlighted the importance of evaluating the manner in which ChatGPT responds to user input in mathematical reasoning (Sánchez-Ruiz et al., 2023; Wardat et al., 2023). The majority of students are acutely aware of the limitations of ChatGPT in the context of our study. Conversely, four students identified ChatGPT as impractical due to the presence of errors in the responses. This highlights the necessity for guidance on the utilization of ChatGPT, as well as enhancements to the latter. The failure to utilize the benefits of ChatGPT has the potential to perpetuate inequality in education, which in turn may contribute to the perpetuation of inequality of opportunity. It is therefore imperative that action be taken with regard to the utilization of ChatGPT.

Recommendations

This study is of great significance in terms of paving the way for further investigation and the creation of tools that can harness the potential of artificial intelligence to enhance the learning experiences of students in mathematics and beyond. In addition to the positive student opinions observed in this study, future research should aim to gain a deeper understanding of the specific ways in which the integration of ChatGPT and GeoGebra could be optimized for different educational settings and student profiles. The integration of ChatGPT with GeoGebra signifies a substantial advancement in the domain of mathematics education (Botana & Recio, 2024). It has the potential to transform the learning experiences of students by adapting learning experiences to suit their individual learning styles and personal needs. Moreover, it provides the requisite support to facilitate their benefit from the training. Furthermore, an understanding of the potential challenges and limitations of this integration would contribute to the refinement and improvement of the overall approach. Future studies should investigate the long-term impact of integrating ChatGPT and GeoGebra on learning outcomes, such as the conceptual understanding of mathematical concepts and the development of computational thinking skills. To provide valuable insights for the introduction of chatbots into the classroom (Wardat et al., 2023), future studies should examine students' experiences with ChatGPT in greater depth, taking into account students' backgrounds (language, and culture), abilities to use software, and knowledge of mathematical concepts. During the course of our investigation, S3 instructed ChatGPT to compose text in English rather than in her native language. This raises the question of the impact of language. It would be beneficial for future researchers to compare the results obtained in different languages in order to ascertain the effectiveness of each.

Notwithstanding the challenges encountered by users in utilizing ChatGPT, it is imperative not to allow these difficulties to impede the promotion of ChatGPT in the teaching and learning of mathematics. The incorporation of AI-based language processing models, such as chatbots, into interactive mathematics software represents a novel approach to learning that may prove both engaging and effective. There is evidence to suggest that GeoGebra has the potential to foster students' CT skills in mathematics education (Chytas et al., 2024; van Borkulo et al., 2021, 2023; Yunianto, Bautista, et al., 2023; Yunianto, Prodromou, et al., 2023). Students were

able to cultivate computational thinking abilities while simultaneously attaining a more profound comprehension of mathematical concepts. In this study, we witnessed that the integration of ChatGPT with GeoGebra has demonstrated the possibility to assist students with CT skills while learning mathematics. Furthermore, using correct syntax (commands) in a software can be a factor in fostering CT (Wing, 2010), as students must identify and correct errors in the responses generated by ChatGPT and adapt them into GeoGebra. Trying the generated commands by ChatGPT, students realized some commands did not work and requested ChatGPT to fix or give another command and this contribute to debugging skill proposed by Shute et al. (2017). Additionally, inputting the generated commands from ChatGPT to the GeoGebra input box has contributed to support students' ability to program as proposed by Shute et al. (2017). However, our study has not yet investigated deeply how students learned mathematical concepts that embedded on generated commands from ChatGPT. We have not yet explored the students' prior knowledge of GeoGebra and other programming software to act and reflect on the ChatGPT generated commands that may be in the form of phyton or JavaScript codes. Therefore, our next stage will be to investigate the effect of expertise on using GeoGebra and the ChatGPT.

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References

Albadarin, Y., Saqr, M., Pope, N., Tukiainen, M., (2024). A systematic literature review of empirical research on ChatGPT in education. *Discover Education 3,* 60. https://doi.org/10.1007/s44217-024-00138-2

Adelabu, F., Makgato, M., & Ramaligela, M. (2019). Enhancing learners' geometric thinking using dynamic geometry computer software. *Journal of Technical Education and Training, 11*(1), 44–53.

Ang, K. C. (2020). Computational thinking as habits of mind for mathematical modelling. *Proceedings of the Asian Technology Conference in Mathematics.*

Bocconi, S., Chioccariello, A., Dettori, G., Ferrari, A., & Engelhardt, K. (2016). Developing computational thinking in compulsory education - *Implications for policy and practice* (P. Kampylis & Y. Punie, Eds.). Publications Office of the European Union. https://doi.org/10.2791/792158

Bocconi, S., Chioccariello, Augusto Kampylis, P., Dagienė, V., Wastiau, P., Engelhardt, K., Earp, J., Horvath, M., Jasutė, E., Malagoli, C., Masiulionytė-Dagienė, V., & Stupurienė, G. (2022). *Reviewing Computational Thinking in Compulsory Education* (A. I. dos Santos, R. Cachia, N. Giannoutsou, & Y. Punie, Eds.). Publications Office of the European Union. https://doi.org/10.2760/126955

Botana, F., & Recio, T. (2024). Geometric loci and ChatGPT: Caveat emptor! *Computation, 12*(2), 30. https://doi.org/10.3390/computation12020030

Boulden, D. C., Rachmatullah, A., Oliver, K. M., & Wiebe, E. (2021). Measuring in-service teacher self-efficacy for teaching computational thinking: Development and validation of the T-STEM CT. *Education and Information Technologies, 26*(4), 4663–4689. https://doi.org/10.1007/s10639-021-10487-2

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology, 3*(2).

https://doi.org/10.1191/1478088706qp063oa

Chan, S. W., Looi, C. K., Ho, W. K., Huang, W., Seow, P., & Wu, L. (2021). Learning number patterns through computational thinking activities: A Rasch model analysis. *Heliyon, 7*(9). https://doi.org/10.1016/j.heliyon.2021.e07922

Cheng, Y.-P., Lai, C.-F., Chen, Y.-T., Wang, W.-S., Huang, Y.-M., & Wu, T.-T. (2023). Enhancing student's computational thinking skills with student-generated questions strategy in a game-based learning platform. *Computers & Education, 200*, 104794. https://doi.org/10.1016/j.compedu.2023.104794

Chytas, C., van Borkulo, S. P., Drijvers, P., Barendsen, E., & Tolboom, J. L. J. (2024). Computational thinking in secondary mathematics education with GeoGebra: Insights from an intervention in calculus lessons. *Digital Experiences in Mathematics Education.10*(2), 228–259 https://doi.org/10.1007/s40751-024-00141- 0

Cotton, D. R. E., Cotton, P. A., & Shipway, J. R. (2023). Chatting and cheating: Ensuring academic integrity in the era of ChatGPT. *Innovations in Education and Teaching International.* https://doi.org/10.1080/14703297.2023.2190148

Dagienė, V., & Sentance, S. (2016). It's computational thinking! Bebras tasks in the curriculum. In A. Brodnik & F. Tort (Eds.), *Informatics in schools – Improvements on informatics knowledge and perception: 9th international conference on informatics in schools – Situation, evolution and perspectives* (pp. 28–39). Springer.

Dasari, D., Hendriyanto, A., Sahara, S., Suryadi, D., Muhaimin, L. H., Chao, T., & Fitriana, L. (2024). ChatGPT in didactical tetrahedron, does it make an exception? A case study in mathematics teaching and learning. *Frontiers in Education, 8*. https://doi.org/10.3389/feduc.2023.1295413

Guo, B., Zhang, X., Wang, Z., Jiang, M., Nie, J., Ding, Y., Yue, J., & Wu, Y. (2023). *How close is ChatGPT to human experts?* Comparison Corpus, Evaluation, and Detection.

Hickmott, D., Prieto-Rodriguez, E. & Holmes, K. (2018). A scoping review of studies on computational thinking in k–12 mathematics classrooms. *Digital Experiences in Mathematics Education, 4*(1), 48–69. https://doi.org/10.1007/s40751-017-0038-8

Hohenwarter, M., Hohenwarter, J., Kreis, Y., & Lavicza, Z. (2008). *Teaching and calculus with free dynamic mathematics software GeoGebra*. 11th International Congress on Mathematical Education.

Kallia, M., van Borkulo, S., 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

Karatas, V. (2022). *The impacts of using GeoGebra on students' perceptions and achievement in learning geometric transformations* (Publicatioon No. 1148) [Doctoral dissertation, The University of Texas Rio Grande Valley]. ScholarWorks

Klimova, B., Pikhart, M., & Al-Obaydi, L. H. (2024). Exploring the potential of ChatGPT for foreign language education at the university level. *Frontiers in Psychology, 15.* https://doi.org/10.3389/fpsyg.2024.1269319

Kooli, C. (2023). Chatbots in education and research: a critical examination of ethical implications and solutions. *Sustainability, 15*(7), 5614. https://doi.org/10.3390/su15075614.

Kuhail MA, Alturki N, Alramlawi S, Alhejori K. (2022). Interacting with educational chatbots: a systematic

review. *Education and Information Technologies, 28*(1), 973–1018. https://doi.org/10.1007/s10639-022-11177-3

Li, P. H., Lee, H. Y., Cheng, Y. P., Starčič, A. I., & Huang, Y. M. (2023). Solving the self-regulated learning problem: Exploring the performance of ChatGPT in mathematics. *Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics*), 14099 LNCS. https://doi.org/10.1007/978-3-031-40113-8_8

Liang, Y., Zou, D., Xie, H., & Wang, F. L. (2023). Exploring the potential of using ChatGPT in physics education. *Smart Learning Environments, 10*(1), 52. https://doi.org/10.1186/s40561-023-00273-7

Lo, L. S. (2023). The CLEAR path: A framework for enhancing information literacy through prompt engineering. *The Journal of Academic Librarianship, 49*(4), 102720. https://doi.org/10.1016/j.acalib.2023.102720

Luo W, He H, Liu J, Berson IR, Berson MJ, Zhou Y, Li H. (2023). Aladdin's genie or Pandora's box for early childhood education? Experts chat on the roles, challenges, and developments of ChatGPT. *Early Education and Development 34*(1), 96-113. https://doi.org/10.1080/10409289.2023.2214181

Mai, D. T. T., Da, C. Van, & Hanh, N. Van. (2024). The use of ChatGPT in teaching and learning: a systematic review through SWOT analysis approach. *Frontiers in Education, 9.* https://doi.org/10.3389/feduc.2024.1328769

McKenney, S., & Reeves, T. C. (2018). Conducting educational design research. In *Conducting Educational Design Research*. https://doi.org/10.4324/9781315105642

Meyer, J.G., Urbanowicz, R.J., Martin, P.C.N. et al. (2023). ChatGPT and large language models in academia: opportunities and challenges. *BioData Mining 16*(1), 1-20. https://doi.org/10.1186/s13040-023-00339-9

Ng, O.-L., & Cui, Z. (2021). Examining primary students' mathematical problem-solving in a programming context: towards computationally enhanced mathematics education. *ZDM- Mathematics Education, 53*(4), 847–860. https://doi.org/10.1007/s11858-020-01200-7

Plata, S., De Guzman, M. A., & Quesada, A. (2023). Emerging research and policy themes on academic integrity in the age of ChatGPT and generative AI. *Asian Journal of University Education, 19*(4), 743–758. https://doi.org/10.24191/ajue.v19i4.24697

Rane, N. (2023). Enhancing mathematical capabilities through ChatGPT and similar generative Artificial Intelligence: Roles and challenges in solving mathematical problems. *SSRN Electronic Journal*, 1–9. https://doi.org/10.2139/ssrn.4603237

Rospigliosi, P. (2023). Artificial intelligence in teaching and learning: what questions should we ask of ChatGPT? *Interactive Learning Environments, 31*(1), 1–3. https://doi.org/10.1080/10494820.2023.2180191

Salami, O. O., & Spangenberg, E. D. (2024). Integration of GeoGebra software into mathematics instruction. *Studies in Learning and Teaching, 5*(1), 118-126. https://doi.org/10.46627/silet

Sánchez-Ruiz, L. M., Moll-López, S., Nuñez-Pérez, A., Moraño-Fernández, J. A., & Vega-Fleitas, E. (2023). ChatGPT challenges blended learning methodologies in engineering education: A case study in mathematics. *Applied Sciences (Switzerland), 13*(10). https://doi.org/10.3390/app13106039

Sapkota, B., & Bondurant, L. (2024). Assessing concepts, procedures, and cognitive demand of ChatGPT-generated mathematical tasks. *International Journal of Technology in Education, 7*(2), 218–238. https://doi.org/10.46328/ijte.677

Shabunina, V., Sarancha, V., Maslak, V., Shevchenko, O., & Tur, O. (2023). *Educational potential of chatgpt:*

teaching tool for students' competencies development. 2023 IEEE 5th International Conference on Modern Electrical and Energy System (MEES), 1–6. https://doi.org/10.1109/MEES61502.2023.10402380

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

Sohail, S. S., Farhat, F., Himeur, Y., Nadeem, M., Madsen, D. Ø., Singh, Y., Atalla, S., & Mansoor, W. (2023). Decoding ChatGPT: A taxonomy of existing research, current challenges, and possible future directions. *Journal of King Saud University - Computer and Information Sciences, 35*(8), 101675. https://doi.org/10.1016/j.jksuci.2023.101675

Subramaniam, S., Maat, S. M., & Mahmud, M. S. (2022). Computational thinking in mathematics education: A systematic review. *Cypriot Journal of Educational Sciences, 17*(6), 2029–2044. https://doi.org/10.18844/cjes.v17i6.7494

Tashtoush, M. A., Wardat, Y. A., & Elsayed, A. M. (2023). Mathematics distance learning and learning loss during covid-19 pandemic: Teachers' perspectives. *Journal of Higher Education Theory and Practice, 23*(5). https://doi.org/10.33423/jhetp.v23i5.5933

Urhan, S., Gençaslan, O., & Dost, Ş. (2024). An argumentation experience regarding concepts of calculus with ChatGPT. *Interactive Learning Environments,* 1–26. https://doi.org/10.1080/10494820.2024.2308093

Valtonen T, López-Pernas S, Saqr M, Vartiainen H, Sointu E, Tedre M. (2022). The nature and building blocks of educational technology research. *Computers in Human Behavior, 128,* 107123. https://doi.org/10.1016/j.chb.2021.107123

van Borkulo, S. P., Chytas, C., Drijvers, P., Barendsen, E., & Tolboom, J. (2021). Computational thinking in the mathematics classroom: Fostering algorithmic thinking and generalization skills using dynamic mathematics software. In *ACM International Conference Proceeding Series*. https://doi.org/10.1145/3481312.3481319

van Borkulo, S. P., Chytas, C., Drijvers, P., Barendsen, E., & Tolboom, J. (2023). Spreadsheets in secondary school statistics education: Using authentic data for computational thinking. *Digital Experiences in Mathematics Education. 9*(3), 420–443. https://doi.org/10.1007/s40751-023-00126-5

Wang, C., Shen, J., & Chao, J. (2022). Integrating computational thinking in STEM education: A Literature Review. *International Journal of Science and Mathematics Education, 20*(8), 1949–1972. https://doi.org/10.1007/s10763-021-10227-5

Wardat, Y., Tashtoush, M. A., AlAli, R., & Jarrah, A. M. (2023). ChatGPT: A revolutionary tool for teaching and learning mathematics. *Eurasia Journal of Mathematics, Science and Technology Education, 19(*7). https://doi.org/10.29333/ejmste/13272

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 and Technology, 25*(1). https://doi.org/10.1007/s10956-015-9581-5

Wing, J. M. (2006). Computational thinking. In *Communications of the ACM.* https://doi.org/10.1145/1118178.1118215

Wing, J. M. (2010). *Computational Thinking: What and Why?* https://www.cs.cmu.edu/link/research-notebook-computational-thinking-what-and-why

Ye, H., Liang, B., Ng, O.-L., & Chai, C. S. (2023). Integration of computational thinking in K-12 mathematics education: a systematic review on CT-based mathematics instruction and student learning. *International Journal of STEM Education*, *10*(3), 1–26. https://doi.org/10.1186/s40594-023-00396-w

Yunianto, W., Bautista, G., Indra Prahmana, R. C., & Lavicza, Z. (2023). GeoGebra applet to learn programming and debugging in mathematics lessons. 2023 *International Symposium on Computers in Education (SIIE)*, 1–5. https://doi.org/10.1109/SIIE59826.2023.10423707

Yunianto, W., Cahyono, A. N., Prodromou, T., El-Bedewy, S., & Lavicza, Z. (2024). CT integration in STEAM learning: Fostering students' creativity by making Batik stamp pattern. Science Activities, 1–27. https://doi.org/10.1080/00368121.2024.2378860

Yunianto, W., Prodromou, T., & Lavicza, Z. (2023). Debugging on GeoGebra-based mathematics+computational thinking lessons. *28th Asian Technology Conference in Mathematics*, 322–331. http://atcm.mathandtech.org/EP2023/abstracts.html#22065

Yunianto, W., Lavicza, Z., Kastner-Hauler, O., & Houghton, T. (2024). Investigating the use of ChatGPT to solve a GeoGebra based mathematics+computational thinking task in a geometry topic. *Journal on Mathematics Education*, *3*(15), 1027–1052. https://doi.org/10.22342/jme.v15i3.pp1027-1052

Zdravkova, K., Dalipi, F., & Ahlgren, F. (2023). Integration of Large Language Models into Higher Education: A Perspective from Learners. 2023 *International Symposium on Computers in Education (SIIE)*, 1–6. https://doi.org/10.1109/SIIE59826.2023.10423681

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