GeoGebra pop-up notifications as formative feedback for learning computational thinking in mathematics lessons

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Computational thinking (CT) is a fundamental skill for everyone that is relevant to 21st-century skills. Initiatives have been carried out to enhance CT outside of computer science (CS) courses. In this study, we integrated CT into mathematics lessons utilizing GeoGebra. Our lessons' development was guided by the educational design research approach (EDR). When we piloted our lessons with junior high school students, we found that GeoGebra could provide pop-up notifications as formative feedback to support students' debugging skills. Pop-up notifications could act as a negotiated-style interruption or an immediate-style interruption. The first interruption is when the students get a pending message about the errors so that they become aware of them. Meanwhile, the latter informs students to revise the errors immediately. In this paper, we will discuss how these interruptions as a formative assessment could be a means of support for students while learning CT+Maths lessons.

Keywords: computational thinking, mathematics, formative feedback, assessment, GeoGebra

Introduction

The purpose of this study is to explore formative feedback that can be supported by GeoGebra while learning computational thinking in mathematics lessons. Papert (1980) introduced computational thinking (CT) through computer programming within mathematics contents. His idea was to build students' CT skills and mathematical knowledge when interacting with the LOGO turtle. A program was developed by him and his colleagues. Students could input the commands and observe what happened to them. For instance, to make a triangle, students could type in: forward 50, right 120, forward 50, right 120, forward 50, and right 120. It would produce an isosceles triangle with a length of 50 for each vertice. The program was intended to be intuitive, and students could develop CT skills as well as mathematics concepts, which were considered too formal for young learners.

Since LOGO Turtle and its similar programs were introduced, schools in the US have started to initiate programming activities. However, Resnick (2009) found that this initiative was not sustainable due to some challenges, such as students finding it difficult with the textual commands (syntaxes). Later, he and his colleagues developed what we now call block programming, 'Scratch' to smoothen how students learn programming. Nowadays, Scratch is used by users around the world. Additionally, in order to enhance CT in mathematics learning, visual programming (Scratch) and mathematics software (spreadsheets, GeoGebra, and MATLAB) have been utilized (Ye et al., 2023). However, visual programming tends to provide little space for debugging as it was not designed to

do so (Liu et al., 2017), and block programming prevents syntax errors from happening (Resnick, 2012). Therefore, our lessons utilized GeoGebra, which has a 'pop-up' feature to facilitate debugging when command errors are inputted.

Ukkonen (2023) asserted that integrating CT in mathematics education is new, and to ensure successful integration, we need to consider formative assessment. Instead of the formative feedback provided by the teachers, we consider formative feedback from the tool students use (GeoGebra) that aligns with the idea of constructionism by Papert (1980) in which students build up their knowledge through their interaction with computer programs. Therefore, we would like to present our experience when utilizing GeoGebra for formative feedback while learning CT in mathematics lessons. Therefore, we would like to find out how GeoGebra's pop-up could support students in accomplishing debugging tasks, which is a form of formative assessment.

Conceptual Framework

We commonly have two types of assessment, namely formative (assessment for learning) and summative (assessment of learning) (Tan, 2011). The first aims to support students to reach their learning goals through feedback during the learning process and enhance students' learning (Black & Wiliam, 1998). For instance, when a student had a misconception about adding a decimal number with an integer by neglecting the decimal separator, the teacher could assist students with questions and/or feedback to deal with the misconception. Meanwhile, the second is conducted at the end of the topic, lesson, term, or semester to know what students have gained from their learning. In this paper, we are interested in formative assessment, which mainly focuses on formative feedback.

Formative feedback

Cizek et al. (2019) defined formative feedback as teachers' and students' support to infer strengths, weaknesses, and opportunities for improvements in learning. They stated that with formative assessment, students could deepen their understanding, improve their achievement, take responsibility for their learning, and self-regulate their learning. However, Burkhardt and Schoenfeld (2019) argued that it is unlikely that teachers could provide formative assessments for each student during a class teaching period because of time limitations.

As formative assessment could be in the form of feedback, Hattie and Timperley (2007) explained how the power of feedback could benefit learning. Feedback is information that leads students to confirm, add to, overwrite, tune, or restructure it in memory (Winnie & Butler, 1994 as cited in Hattie & Timperley, 2007). Hattie and Timperley (2007) described three directions and four levels of feedback. For the directions, they classified them into (1) feedback about where a student is (FeedBack), (2) where a student is going (FeedUp) and (3) where a student will go next (FeedForward). The following model (Figure 1) by (Hattie & Timperley, 2007, p. 87) is used to help us consider the feedback provided by GeoGebra pop-up.
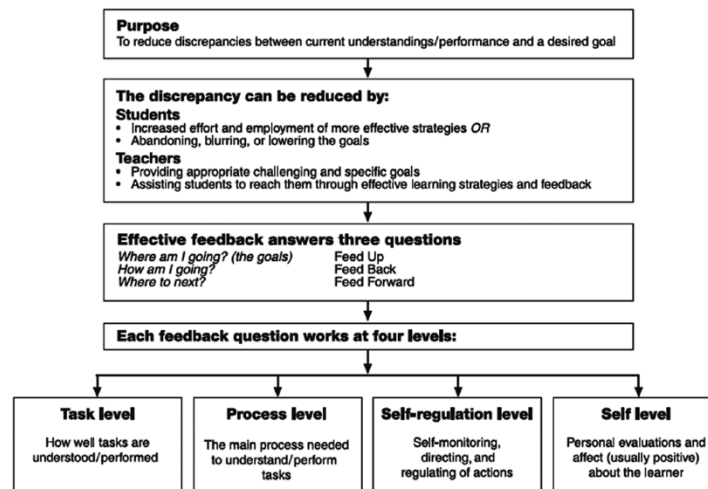
Figure 1: A model of feedback to enhance learning (Hattie & Timperley, 2007, p. 87)

Ukkonen (2023) used this model for analyzing a case study with a teacher and two students when learning computational thinking in a mathematics lesson. In this paper, we will utilise this model to specify to which parts the GeoGebra pop-ups belong to the model, discuss, and analyse how the GeoGebra pop-ups have helped students in our study.

Technology and Formative Assessment

Digital technology can gather and process data on a large scale and speed, making it a powerful resource to support teachers in formative assessment (Looney, 2010). Dalby and Swan (2019) argued that digital technology could support and empower students in formative processes by providing feedback. Additionally, the feedback could act as a replacement for or an addition to teacher-led processes (Dalby & Swan, 2019). From their study, we could learn that technology could help process students' responses quickly and provide feedback quickly so that students can modify their responses.
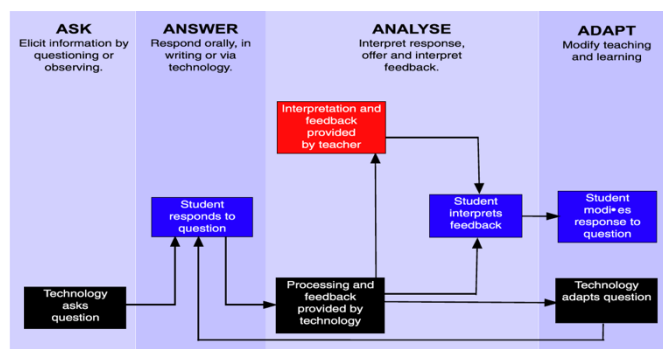

Figure 2: A model of feedback to enhance learning (Dalby & Swan, 2019, p. 841).

The AuthoMath project (https://www.authomath.org/) utilizing STACK and GeoGebra is relevant to our study. Using STACK and GeoGebra for formative assessment has helped students to be more successful with accomplishing the tasks (Sanz-Ruiz et al., 2023). With this digital technology, students would receive feedback if they made mistakes by pressing a check button. The difference from our study is that GeoGebra will automatically notify students when incorrect commands are inputted without pressing the check button. Our previous study, Yunianto et al. (2023) utilized this

GeoGebra feature (pop-up notifications), and it benefited students. GeoGebra's pop-up is related to two styles of interruptions, namely, the immediate style of interruption and the negotiated style of interruption. Robertson et al. (2004) investigated these interruptions when students were debugging and found that negotiated-style interruption is better than immediate-style interruption when supporting debugging activities.

Method

This study explored the potential of the GeoGebra pop-up as formative feedback when learning computational thinking (CT) in mathematics lessons. It investigated how GeoGebra pop-up could act as formative feedback to benefit students when accomplishing Math+CT tasks. The analysis of our data about how this feature has helped us in our study is qualitative descriptive research as it provides a comprehensive summary of data describing the primary properties of the participants' actions, words, and experiences during data collection and then interpreting it (Ayton, 2023).

Context

We developed GeoGebra-based Math+CT lessons on the topic of the area of a circle (Yunianto et al., 2023) guided by an educational design research (EDR) approach (McKenney & Reeves, 2018). More details of the development of GeoGebra-based Math+CT lessons can be found in our previous study. In the lessons, students learned how to construct an inscribed regular polygon on a circle with GeoGebra commands. Students also had to debug a program to create a circle and an inscribed polygon. The participants of this study were seventeen junior high school students (aged 12-15) from five different schools in Indonesia.

Data collection and analysis

We collected data by recording students' screens while they were engaging in the tasks. Students were well informed by their teachers about this research and consented to participate in this study. Not all videos recorded full lessons due to the limited storage capacity of the devices and technical issues. Some videos captured the voices of students and a teacher. For this paper, we could not provide the analysis of all videos but rather a few videos that depict the potential of formative feedback. We transcribed students' discussions with themselves, their peers, and the teachers and then provided the interpretation of the transcripts. The analysis was one of progressive focussing (Robson, 1993). At the first stage, the recordings were simply transcribed, and screenshots were incorporated as necessary to make sense of the transcription. Subsequently, the first author turned the transcript into a plain account and an interpretative account was written and the validity of those interpretation was discussed with other authors.

Findings

The following paragraphs present the work of a student who worked on constructing a regular polygon with a slider. The polygon vertices could change as the slider was moved (from 3 to 10). Therefore, this construction would produce an equilateral triangle, a square, a pentagon, a hexagon, a heptagon, an octagon, a nonagon, and a decagon respectively to the slider. This student inputted an incorrect command for the slider 'n-Slider(3,10,1)' and GeoGebra notified her with a pop-up. It said,

"Create slider(s) for n". She then edited the command to be n=Slider(3,10,1) and continued to input the next command. Finally, she accomplished this task by creating a regular polygon with a slider.
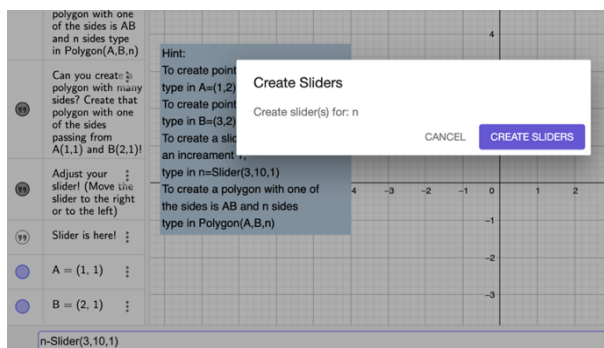

Figure 3: A pop-up notification for an incorrect slider command

While doing this task, this student talked to herself immediately after the pop-up notification appeared. The self-talk of this student is as follows:

Student A: Why is it incorrect? (the student was thinking for a while)
Student A: (self reply) Oh this one, the equal sign.

From the transcript, we can see that this student reflected on her command after seeing the pop-up notification and thought for awhile what was wrong. Her self-reflection led her to the correct answer.

On another task, she also benefitted from the notification. She was working on a task and inputted all correct commands but missing a (the angle). The pop-up (Figure 4) notified the error (*Please check your input, undefined variable B*'). The student misinterpreted the notification first and she edited the polygon, thinking it was the source of error. Afterwards, she discussed with her peer, and they reflected to the previous experiences of similar tasks. Based on their prior knowledge and peer discussion, she realized that she missed the a. Hence, she inserted a (a=360deg/n). In the end, she had 3 runs and 0 clear and accomplished the task.
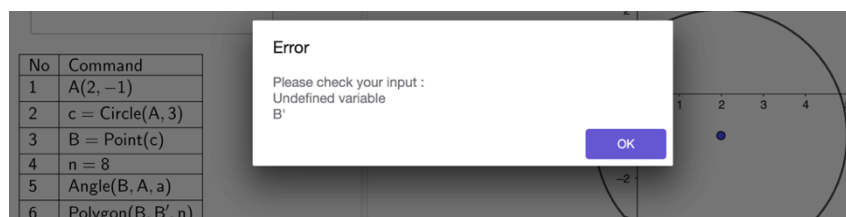
Figure 4: A pop-up notifying an error

The following excerpts present another case when a student discussed with his teacher when he encountered the pop-ups. He inputted commands for point A and point B correctly. He typed in n=Slinder(3,10,1), with the additional letter n. A pop-up appeared notifying the "Unknown command: Slinder" (Figure 5). He edited it and pressed enter, then he deleted it.

Student B: Why is it incorrect?
Teacher: That is there to make a slider.
Student B: I saw it from the hint!
Teacher: Yes, you can see it from the hint
Student B: I made it sir!
Teacher: Are you sure? Where is the slider?

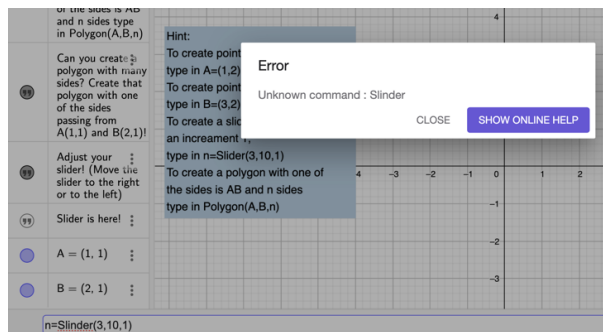Student B: Look at this first!(pointing to the slider on screen)

Figure 5: A pop-up notification as an immediate-style interruption

The above excerpts show how the GeoGebra pop-up notification provided immediate feedback to the student, so he looked at the hint to receive guidance about how to create a slider.

In another case, we witnessed a negotiated style of interruption where an incorrect point B command B=(2:2) was inputted but did not provide a pop-up because it could be run as a slider. This notification was delayed until it was used for the polygon's command. It would notify it as incorrect when it is used for the polygon command as B was not a point (*illegal argument Number B*) (Figure 6). It helped students to locate the error so that they could go directly and fix the command that caused the error. Besides it directed students to the error, it suggested them how to use correct commands and variables when programming geometrical objects. For instance, in this case they only needed to use points to create a polygon.
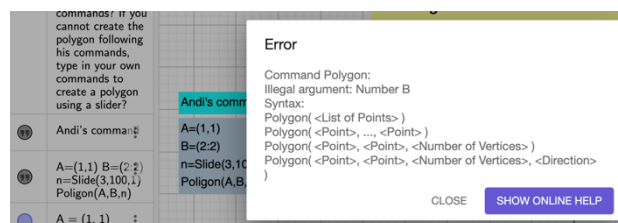

Figure 6: A pop-up notification as a negotiated-style interruption

We counted the number of pop-up cases on our 17 videos. In total, there are 35 cases where 27 of them led students to successfully accomplish the tasks because both styles of interruption informed them about the errors and how they could fix them. Nevertheless, we did not investigate if the students struggle with the pop-ups that were written in English language.

Discussion

Students benefited from the GeoGebra pop-up notifications that helped them to complete the tasks successfully. This result is in line with the study by Sanz-Ruiz et al. (2023). We observed that in some cases after our students received a pop-up, they made fewer errors when they engaged later with the remaining tasks. This might be called effective error detection skills as per Hattie and Timperley (2007). Students experienced errors and would notice similar pop-ups if they made the same mistakes. They could avoid the same mistakes in later tasks. In this paper, we studied the impact of GeoGebra pop-up notifications on students' actions at the task level of the model of Figure 1. In future studies,

we aspire to examine in detail the impact of feedback on students' actions and interactions at the process level, self-regulation level, and self-level.

We showed that the formative feedback from the GeoGebra pop-ups provided students with immediate feedback and notification about their errors so they could reflect on their actions, revise, and make relevant corrections. This type of feedback belongs to the Feed Back direction at first level, feedback of the task (FT) and second level, feedback of the process (FP) by Hattie and Timperley (2007). The provided information about pop-ups and the task is similar to the study by Simmons and Cope (1993) in which LOGO feedback was attributed to FT leading students to more correct answers. At the FP level of the model (Figure 1), the GeoGebra pop-up notification (Figure 6) could act as a cueing mechanism (Hattie & Timperley, 2007),which helps students improve their strategies of programming and coding. It could be in the form of immediate-style of interruption and negotiated-style of interruption to support students reflect on their mistakes. Our data shows that students spent more time to identify their errors when they used the negotiated style of interruption. On the contrary, the immediate-style interruption informed them directly about their errors. However, our data do not support that immediate style of interruption is better than negotiated style of interruption as suggested by the literature (Robertson et al., 2004). Our data show that both styles of interruptions are beneficial to students.

Our GeoGebra-based Math+CT lessons seem to follow the model in Figure 2 by Dalby and Swan (2019). We provided students with GeoGebra tasks. If students input incorrect commands, a pop-up will notify them. Students could proceed with their actions or discuss the pop-up with their peers and teacher. Next, students could delete or edit their incorrect commands and proceed with the next task.

References

Ayton, D. (2023). Qualitative Descriptive Research. In D. Ayton, T. Tsindos, & D. Berkovic (Eds.), *Qualitative Research – a practical guide for health and social care researchers and practitioners* . Monash University.

Black, P., & Wiliam, D. (1998). Assessment and classroom learning. *International Journal of Phytoremediation*, *21*(1). https://doi.org/10.1080/0969595980050102

Burkhardt, H., & Schoenfeld, A. (2019). Formative Assessment in Mathematics. In H. L. Andrade, R. E. Bennett, & G. J. Cizek (Eds.), *Handbook of Formative Assessment in the Disciplines* (pp. 35–67). Taylor and Francis. https://doi.org/10.4324/9781315166933-3

Cizek, G. J., Andrade, H. L., & Bennett, R. E. (2019). Formative Assessment: History, Definition, and Progress. In *Handbook of Formative Assessment in the Disciplines* (pp. 3-19). Routledge.

Dalby, D., & Swan, M. (2019). Using digital technology to enhance formative assessment in mathematics classrooms. *British Journal of Educational Technology*, *50*(2). https://doi.org/10.1111/bjet.12606

Hattie, J., & Timperley, H. (2007). The power of feedback. In *Review of Educational Research* (Vol. 77, Issue 1). https://doi.org/10.3102/003465430298487

Liu, Z., Zhi, R., Hicks, A., & Barnes, T. (2017). Understanding problem solving behavior of 6–8 graders in a debugging game. *Computer Science Education*, *27*(1). https://doi.org/10.1080/08993408.2017.1308651

Looney, J. (2010). Making it Happen: Formative Assessment and Educational Technologies. *Promethean Thinking Deeper Research Papers*.

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

Papert, S. (1980). *Mindstorms: Children, Computers, and Powerful Ideas* (1st ed.). Basic Books.

Resnick, M. (2012). Reviving Papert's Dream. *Educational Technology*, *52*(4).

Resnick, M., Maloney, J., Monroy-Hernández, A., Rusk, N., Eastmond, E., Brennan, K., Millner, A., Rosenbaum, E., Silver, J., Silverman, B., & Kafai, Y. (2009). Scratch: Programming for all. *Communications of the ACM*, *52*(11). https://doi.org/10.1145/1592761.1592779

Robertson, T. J., Prabhakararao, S., Burnett, M., Cook, C., Ruthruff, J. R., Beckwith, L., & Phalgune, A. (2004). Impact of interruption style on end-user debugging. *Conference on Human Factors in Computing Systems - Proceedings*. https://doi.org/10.1145/985692.985729

Robson, C. (1993). *Real World Research: A Resource for Social Scientists and Practitioner-Researchers* (1st ed.). Blackwell.

Sanz-Ruiz, M., Diego-Mantecón, Manuel, J., & Ortiz-Laso, Z. (2023). Formative feedback on linear equations. *CADGME 2023: Digital Tools in Mathematics Education*.

Simmons, M., & Cope, P. (1993). Angle and rotation: Effects of different types of feedback on the quality of response. *Educational Studies in Mathematics*, *24*(2). https://doi.org/10.1007/BF01273690

Tan, K. (2011). Assessment for Learning Reform in Singapore – Quality, Sustainable or Threshold? In *Assessment Reform in Education*. https://doi.org/10.1007/978-94-007-0729-0_6

Ukkonen, A. (2023). Formative assessment of computational thinking in mathematics – a case study. *Proceedings of the Thirtieth Congress of the European Society for Research in Mathematics Education*, 1–8.

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., 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