Foregrounding Mathematics in STEM through Covariational Reasoning Supported by Digital Technology

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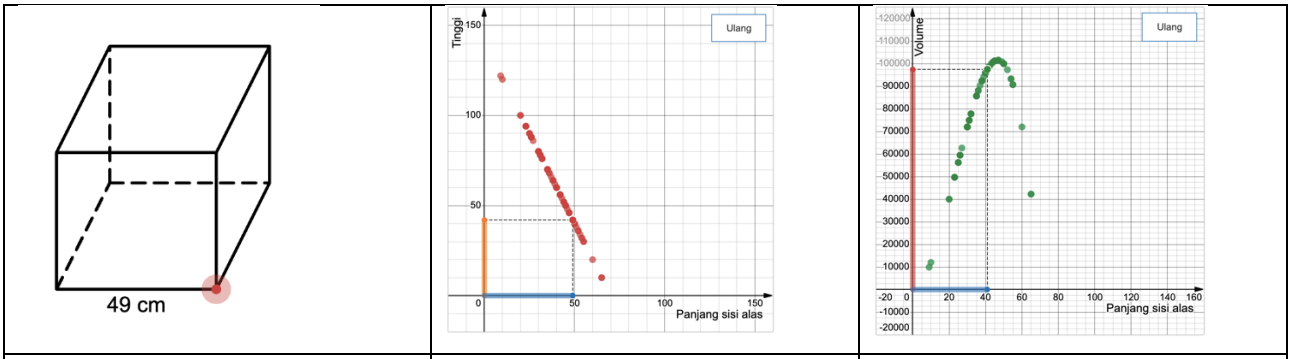
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Introduction

Integrated STEM involves problem sets in real-life contexts to be solved through an engineering design process that necessitates the application of mathematics or science knowledge (Moore et al., 2020). Yet, typical STEM activity often reduces mathematics to measurement, calculation, or data representation in the service of science or engineering (Roehrig et al., 2021). To foreground mathematics in integrated STEM, this study proposes covariational reasoning, which is the cognitive process involved when simultaneously tracking two varying quantities (Carlson et al., 2002). In particular, this study proposes to embed covariational reasoning as a way for students to justify their engineering design solution, so that mathematics is no longer a tool but an essential part of decision-making. Additionally, the use of digital tools featuring interactive graph representation has also been widely suggested (e.g. Kristanto et al., 2025). The research question this study attempts to answer is *how does students' covariational reasoning emerge during the design activity, and to what extent does it inform their design decisions?*

Methodology

The lesson was implemented at an urban junior high school in Central Java, taught by the mathematics teacher who was also part of the LS team, and with 26 students participating, working in pairs.



(a) (b) (c)

Figure 1: Students exploring the relationship between the length of base and height (b) as well as the length of base and volume (c) of a box (a).

The task was designed to be part of a mathematics lesson on the topic of functions with the science topic of waste management as context, and constructed on the graphing calculator platform Desmos. The students designed a trash can for waste management in their school in the shape of a cuboid, with a given length of wire as the frame. The students manipulated the Desmos interface by dragging the

red dot (Figure 1a) to explore the relationship between the length of the base and the height of the box (Figure 1b), and then the length of the base and the volume (Figure 1c). Before the graph manipulation activity, the students are asked to sketch their trash can, and then to revise their sketch after the activity to improve their design. The data collected were the students' written responses in Desmos platform.

Findings and Discussion

During the activity, the students manipulated the Desmos interface to see the relationship between two variables in a way that is not possible to do with static graphs and tables. The students' written responses reveal that while all groups of students had no difficulty interpreting the relationship between the length of the base and the height, the same cannot be said for the relationship between the length of the base and the volume. All groups responded that "*If the length of the base is shorter, then the height is longer*" or vice versa. However, only four groups described how the length of the base and the volume change together, using the word "peak" in their response to describe the maximum point (e.g. "*If the base side is longer, the volume of the cuboid increases, but at a certain peak point, the volume can also decrease*."). Other groups' reasoning used gross coordination of values, usually by sticking to the left side or the right side of the maximum point. Later in the class discussion, this was addressed by the teacher to allow all students to arrive at the same conclusion. However, even though the activity allowed them to engage with information that is relevant in designing the trash can, the students did not consider the information (the dimension of the trash can) when asked to improve their sketch of an ideal trash can.

Conclusion

This study describes the task design intended to foreground mathematics in STEM activity through covariational reasoning supported with digital technology. Four of 13 students' responses suggests that they were able to engage with covariational reasoning related to information relevant to the engineering design challenge solutions, but did not transfer the reasoning to their design decision. Sufficient scaffolding by the teacher and appropriate selection of problem contexts are important to support the students' reasoning.

References

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