

User testing in the design of modeling activities: Lessons from a study with pre-service teachers

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What problem is addressed?

The incorporation of mathematical modeling into initial teacher training faces a twofold challenge: pre-service teachers must not only learn how to promote mathematics learning through modeling, but they must also experience modeling themselves to reflect on their conceptions (Vargas-Alejo et al., 2024). It is often mistakenly assumed that, when individuals such as teachers possess advanced formal mathematical knowledge, their open-ended problem-solving processes will be immediately sophisticated and efficient, and will not go through cycles of modification, extension, and refinement (Lesh & Yoon, 2004). However, according to the Models and Modeling Perspective (MMP), there is a gap between possessing mathematical knowledge and knowing when and how to use it in complex situations (Lesh & Doerr, 2003). The specific problem addressed in this conceptual replication study (Jankvist et al., 2021) is the influence of validation constraints (user testing) on model refinement. The research ques-

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tions are: How does the absence of user testing affect the development of modeling cycles in pre-service teachers? Is expert mathematical knowledge sufficient to refine a model, or is experience with reality required to drive self-evaluation of the final model and refinement?

How is it addressed (theory/methods)?

This study was grounded in the MMP (Lesh & Doerr, 2003). Under this framework, learning is conceived as the development of local models or conceptual systems that evolve through iterative cycles when an individual faces a problem and interacts with others to solve it. In these iterative cycles, interpretations, “descriptions, explanations, and predictions are gradually refined, revised, or rejected—based on feedback from trial testing” (Lesh & Doerr, 2003, p. 18). The models are dynamic constructions that reveal how individuals organize and express their thinking when engaging with real-world problems, known as model-eliciting activities (MEAs).

To address the research questions, the conceptual replication research design was selected (Jankvist et al., 2021). Specifically, an adaptation of “The Quilt Problem” MEA, developed by Lesh and Carmona (2003), was implemented. The study population consisted of eight pre-service mathematics teachers at the university level, organized into small collaborative groups. The MEA asked participants to develop a reusable procedure for transforming a small photograph of a quilt into a full-scale pattern for a double bed, providing a template for this purpose. For this report, we focused on an in-depth analysis of a three-member team. The data collected included letters, audio recordings of the presentations, and observations of the teachers. The data analysis focused on identifying: a) the nature of the models constructed (conceptual systems), and b) the role of user testing in refining the team’s models. Whereas the original study by Lesh and Carmona (2003) included a user testing phase in which participants (children) physically constructed quilt templates, the replication study reported here omitted that phase, restricting participants’ work to generating the written procedure (model).

What is implemented/replicated?

The implementation of The Quilt Problem MEA with pre-service teachers allowed us to identify that they approached the MEA by quickly activating their geometric knowledge of measurement and scale. They identified the need to establish a ratio between the quilt photograph and the actual dimensions of the requested quilt.

Interpretation 1: The team defined their “unit of measurement” based on the size of the large squares in the quilt pattern. They established a direct linear relationship (rule of three) to scale the dimensions of the full

quilt. As reported by Lesh and Carmona (2003): once the pre-service teachers “found a scaling-up factor, they decided to apply it to the parts and the whole of the given shape” (p. 88).

Interpretation 2: The team defined a new “unit of measurement” based on the size of the small figures contained within the large visible squares of the quilt. They used a linear relationship to scale the dimensions, attempting to adjust the previously obtained scale. As in the original study, the pre-service teachers were mapping from one unit to another within two similar pictures; they focused on part-part relationships and comparing parts to parts. Finally, they drafted the requested letter to the client explaining the procedure through multiplication by a certain scale factor. Once the theoretical proposal was formulated, the team considered the problem “solved,” similarly to the original study. Since they did not have to cut pieces of paper or attempt to physically assemble the quilt (as in the original study), they did not encounter difficulties with measurement inconsistencies or edge misalignment, and they did not have the opportunity to create a more refined model.

The analysis reveals that the pre-service teachers’ model stabilized at the theoretical level. Although their mathematical language was more technical than that of the children in the original study, and their measurements were more precise, their solution remained at a descriptive/theoretical level. It could be said that they acted under a principle of cognitive economy: since they were not asked to conduct a user test, the theoretical model, logically consistent on paper, was considered sufficient.

What is the potential importance and significance?

This replication study allowed for the comparison of the ways of thinking of secondary students and pre-service teachers to identify the skills that should be emphasized in the training of mathematics teachers. It also offers suggestions for improving the implementation of MEA in teacher training.

It highlights the importance of not overlooking elements such as user testing, which can influence the refinement of mathematical models. The refinement of a model does not depend exclusively on the intellectual capacity of the individual, but rather on the quality of the feedback provided by the environment (Lesh et al., 2000). By eliminating user testing instruction, the need to modify, extend, and continue refining the model was eliminated.

This suggests that, to train teachers in modeling, a central element, in addition to promoting collaborative classroom environments for solving MEAs (Montero-Moguel et al., 2023), is to promote real-world experience to trigger the constant review of models and drive their refinement. This

study shows that “real-world experience” is not a didactic accessory, but an epistemological engine that drives the evolution of conceptual systems, as described by Lesh and Carmona (2003).

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