

Didactical engineering of students' emotional pathways in sequenced problem-solving

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What problem is addressed?

The crucial role of emotions in mathematical problem solving has long been recognized (e.g., McLeod & Adams, 1989; Op't Eynde et al., 2006; Zan et al., 2006), and there has been growing criticism of instructional approaches that treat students as a “non-emotional audience” (Alsina, 2002, p. 6). Numerous studies (e.g., Goldin, 2000; Gómez-Chacón, 2017; Op't Eynde et al., 2006) have shown that students' emotions can fluctuate substantially during mathematical problem solving: a student may begin a lesson feeling interested, yet an instructional approach may quickly lead to frustration or confusion. Conversely, another instructional approach can transform initial feelings of frustration into joy and confidence. Goldin (2000) conceptualizes these emotional fluctuations as an “emotional pathway”—a sequence of emotional states that students experience while engaging with a mathematical learning activity.

However, little is known about how to design problem-solving lessons in which students' emotional pathways can be predicted and intentionally shaped. Only a few studies have illustrated this possibility. For example, Marmur and Koichu (2016) demonstrated, in a university context, that a

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lesson that eventually evoked in students a “wow-experience” had begun with the intentional induction of frustration and even anger. Furthermore, Koichu et al. (2017) showed how expectations generated by solving one problem influenced the intensity of surprise experienced when middle-school students engaged with a subsequent problem; this study was conducted in a laboratory setting.

Building on these findings, the present study seeks to address the challenge of implementing at scale, and in new instructional contexts, the design principles for problem-solving lessons that enable anticipating and intentionally shaping students’ emotional pathways.

How is it addressed?

This research is grounded in four theoretical frameworks: Goldin’s (2000) affective pathways, which facilitate analyzing and mapping students’ dynamic emotional responses. Variation Theory (Marton & Booth, 1997), employed to design four problem-solving sequences that highlight critical mathematical features through differences in form, not content. Huron’s (2006) Contrastive Valence Theory, which leverages emotional transitions from struggle to enjoyment, and Didactical Engineering (Artigue, 2009), providing the methodological basis for the systematic design and analysis of problem sequencing and delivery across multiple student groups receiving tasks in varied orders. Each framework addresses distinct dimensions of the emotional and cognitive learning processes.

What is implemented?

The study implemented theoretical insights from previous research on emotions in problem solving, with a special focus on didactical strategies for engineering of students’ emotional pathways (e.g., confusion → surprise → enjoyment → accomplishment).

The intended participants are approximately 240 ninth-grade students from 12 classes across schools in Israel, organized into four instructional clusters to vary the order of problem sequencing. Four mathematical problems will be used: two in geometry (noticing and proving in the context of planar shapes) and two in algebra (equation solving). Within each domain, problems will be presented consecutively to create an intentional sequence: the first problem is expected to evoke surprise, confusion, and frustration, while the second problem is designed to evoke enjoyment, satisfaction, and a sense of accomplishment.

The intended teachers have participated in professional learning communities centered on teaching mathematical problem solving during the last two years. Students’ in-situ emotions will be measured using a

questionnaire (Trifonov et al., 2026), in which they self-report on emotional states and rate their intensity three to five times during the process of solving each problem. To capture the dynamics of students' emotions, the study applies Multilevel Vector Autoregression (mlVAR) modeling (Epskamp et al., 2019). Data collection is planned for the 2025–2026 academic year.

What is the potential importance and significance?

Putting descriptive conceptual apparatus on students' emotions in design-research perspective; testing and implementing didactical ideas from past studies in new contexts, developing not only theoretical but pedagogical tools (tools for working with teachers, like design principles of problem sequencing and questionnaire for measuring emotional pathways during problem solving); systematic characterization of implementability of problem-solving sequences designed for different didactical purposes (e.g., from easy to difficult – for causing the feeling of success; from difficult to easy – for causing the feeling of surprise, etc.).

References

- Alsina, C. (2002). Why the professor must be a stimulating teacher: Towards a new paradigm of teaching mathematics at university level. In D. Holton (Ed.), *The teaching and learning of mathematics at university level* (Vol. 7, pp. 3–12). Springer.
- Artigue, M. (2009). Didactical design in mathematics education. In C. Winsløw (Ed.), *Nordic research in mathematics education* (pp. 7–16). Sense Publishers.
- Epskamp, S., Deserno, M. K., & Bringmann, L. F. (2019). *mlVAR: Multi-level vector autoregression* (Version 0.4.4) [R package]. <https://cran.r-project.org/package=mlVAR>
- Goldin, G. A. (2000). Affective pathways and representation in mathematical problem solving. *Mathematical Thinking and Learning*, 2(3), 209–219. https://doi.org/10.1207/S15327833MTL0203_3
- Gómez-Chacón, I. M. (2017). Appraising emotion in mathematical knowledge. In U. Xolocotzin Eligio (Ed.), *Understanding emotions in mathematical thinking and learning* (pp. 43–73). Academic Press. <https://doi.org/10.1016/B978-0-12-802218-4.00002-9>
- Huron, D. (2006). *Sweet anticipation: Music and the psychology of expectation*. MIT Press.
- Koichu, B., Katz, E., & Berman, A. (2017). Stimulating student aesthetic response to mathematical problems by means of manipulating the extent of surprise. *The Journal of Mathematical Behavior*, 46, 42–57. <https://doi.org/10.1016/j.jmathb.2016.11.005>

- Marmur, O., & Koichu, B. (2016). Surprise and the aesthetic experience of university students: A design experiment. *Journal of Humanistic Mathematics*, 6(1), 127–151. <https://doi.org/10.5642/jhummath.201601.09>
- Marton, F., & Booth, S. (1997). *Learning and awareness*. Lawrence Erlbaum Associates.
- McLeod, D. B., & Adams, V. M. (Eds.). (1989). *Affect and mathematical problem solving: A new perspective*. Springer.
- Op't Eynde, P., De Corte, E., & Verschaffel, L. (2006). “Accepting emotional complexity”: A socio-constructivist perspective on the role of emotions in the mathematics classroom. *Educational Studies in Mathematics*, 63(2), 193–207. <https://doi.org/10.1007/s10649-006-9034-4>
- Trifonov, M., Cooper, J., & Koichu, B. (2026). Shedding light on curiosity windows in a middle-school mathematics classroom. In H. Krzywacki, M. Häikiöniemi, E. Haataja, M. S. Hannula, & P. Hästö (Eds.), *Proceedings of the 49th Conference of the International Group for the Psychology of Mathematics Education: Research reports* (pp. 1467–1474). PME.
- Zan, R., Brown, L., & Hannula, M. S. (2006). Affect in mathematics education: An introduction. *Educational Studies in Mathematics*, 63(2), 113–121. <https://doi.org/10.1007/s10649-006-9028-2>