International Society of the Learning Sciences

Professional Learning to Promote Three-Dimensional Teaching Using Computational Modeling in Remote Classroom Contexts

Namsoo Shin, Linsey Brennan, Jonathan Bowers, Emanuel Eidin
namsoo@msu.edu, mcmull74@msu.edu, bowersj8@msu.edu, eidinema@msu.edu
Michigan State University
Lynn Stephens, Cynthia McIntyre, Steve Roderick, Daniel Damelin
lstephens@concord.org, cmcintyre@concord.org, sroderick@concord.org, ddamelin@concord.org
The Concord Consortium

Abstract: This study explores how to support teachers in developing and implementing effective pedagogical strategies to promote students in making sense of phenomena through computational modeling in remote contexts. Qualitative analyses of eight teachers' interviews were conducted to characterize their pedagogical strategies to achieve three-dimensional learning. Findings indicate that typical teacher strategies include the teacher and students co-constructing a model and using whole class or group discussions to support students' modeling practices.

Introduction and theoretical framework

The central notion of three-dimensional (3D) learning is that learners should understand science as a specific way of knowing and should develop capabilities to both understand and apply appropriate strategies to solve problems (National Research Council, 2012). We developed a Professional Learning (PL) program by integrating the crosscutting concept of *systems and system models* with the science and engineering practice of *developing and using models* and disciplinary core ideas selected by teachers to support teachers in the complexities of teaching remotely with open-ended modeling tools to support 3D learning. Based on project-based learning theory (Krajcik & Shin, 2022), we posit that teachers are themselves active learners and that they too should employ the same 3D learning goals as their students, especially as they learn new technologies and learning activities to bring to their classrooms. This study investigates two research questions: 1) What PL design principles could be applied to develop a PL program for supporting teachers to incorporate open-ended modeling tools in remote learning contexts? and 2) What pedagogical strategies do teachers adopt and adapt from the PL and use to promote student 3D learning in remote open-ended modeling learning contexts? Seven design principles and associated strategies from the PL program are reported in major findings and discussion.

Methods

The participants were 13 teachers from 1 elementary, 1 middle, and 11 high schools in 3 states from the eastern U.S. The content focus of the PL was on 3D learning using a web-based systems modeling tool called SageModeler (https://sagemodeler.concord.org). Thirteen PL sessions throughout the 2020-21 school year were held over Zoom. We conducted interviews with eight teachers who implemented an integrated computational modeling curriculum in their remote classroom contexts. A thematic qualitative analysis (Braun & Clarke, 2006) was employed to characterize teachers' pedagogical strategies used to promote 3D learning, as well as any adaptations of the PL design principles (DP) behind them. Two researchers discussed all codes to meet 100% agreement.

Major findings and discussion

Strategies associated with DP1, *Use collaborative activities among researchers and participants,* include a) foster collaboration between participants as colleagues with similar or shared goals; b) build community between researchers and participants and among participants; c) engage in collaborative activities among researchers and participants working in small groups (2-3 teachers by subject or grade and 1-2 researchers); d) introduce teaching and learning strategies from researchers ("top down") and encourage participants to share pedagogical tips ("bottom up"). All teachers responded that they highly valued the collaborative activities they experienced, including building system models together, discussing their plans with researchers and peers, and sharing resources with each other. Teachers went on to design collaborative lessons for their students around building models together and giving feedback to peers' models.

DP2, *Demonstrate pedagogical strategies*, and DL3, *Include active construction of tangible products,* are grouped together because the pedagogical strategies focus primarily on teaching about and with models. In

the PL, researchers were explicit about pedagogical strategies—e.g., describing the "teacher moves" they were making and the reasons for those moves—as they involved the teachers in actively constructing models. All eight teachers used pedagogical strategies they experienced in the PL program, indicating that the explicit modeling of strategies was successful in embodying ways teachers could work with their students. For example, teachers demonstrated the computational modeling process with SageModeler as an example for the whole class by first working together to construct an initial model in a whole class discussion, then having students build their own models (individually or in groups) and holding whole class or group discussions to support students in revising their models. Teachers asked questions to link their students' prior experiences (e.g., lab activities, videos) as they learned key concepts in order to support them in revising their models.

DP4, *Provide individualized support*, DP5, *Scaffold with learning technologies*, and DP6, *Sustain professional learning over time* fall under the common theme of supporting participants' learning. All teachers received individualized support through the PL program by a) working one-to-one with a researcher to meet individual needs as well as working with other participants who have similar questions or modeling challenges; b) receiving just-in-time support; and c) having ongoing support related to their needs for integrating a computational modeling tool into their teaching practices. As they had experienced in the PL, all teachers tracked their students' modeling progress, diagnosed issues or difficulties, and discussed them with the whole class, a group, or individually, depending on the situation. In order to support a wide range of students in classroom contexts, the main pedagogical strategies used across teachers were to avoid framing specific answers as "the correct answer" (e.g., indicating a specific model was "the right one") and to be flexible regarding the kind of model they accepted as "good" (e.g., scientifically appropriate for the phenomenon being studied).

DP7*, Engage 3D learning goals,* and DP8, *Use relevant phenomena,* strategies include inviting teachers to model phenomena relevant to their lives or to their teaching contexts and providing them with driving questions (DQs) to guide their exploration with SageModeler. They also used collaborative documents such as Google Documents and Jamboards to explore DQs during the PL. These activities focus on 3D learning goals to provide opportunities for participants to integrate target DCIs and CCCs with SEPs to explain phenomena. In implementing 3D teaching and learning materials using SageModeler, all teachers used phenomena relevant to students in various ways: daily experiences, lab experimental activities, or field trips to link students' prior knowledge and pique their interest in the learning goals. Teachers reported that starting with a DQ supported a continued focus on 3D learning goals and helped define the system boundaries for the models.

Conclusions and implications

Across teachers we interviewed, they commonly used three pedagogical strategies: 1) questioning students about their models, 2) holding class and group discussions, and 3) grouping students to build and revise models. A common pedagogical strategy to support 3D learning was to facilitate teacher-led or student-centered discussions using student models as referents. However, some teachers disclosed that they need both additional guidance in providing differentiated materials to their students with varied learning needs and examples of high-quality curricula integrating 3D in classrooms. Additional pedagogical strategies (e.g., by grade level and lesson topic) are needed for teachers to be able to support students' revisions through testing and debugging their models.

References

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, *3*, 77–101.

Krajcik, J., & Shin, N. (2022). "Project-Based Learning." In R. K. Sawyer (Ed.), *Cambridge handbook of the learning sciences 3rd edition*, New York: Cambridge University Press.

National Research Council. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. National Academies Press.

Acknowledgments

This material is based upon work supported by the National Science Foundation under Grant Nos. DRL-1842035, DRL-1842037, and DRL-2033922.