International Society of the Learning Sciences

Organizational Co-design: Triggering Science Teacher Sensemaking to Support Recognition of Varied Forms of STEM Learning

Sara C. Heredia, University of North Carolina at Greensboro, scheredi@uncg.edu
Ti'Era D. Worsley, North Carolina at Greensboro, tdworsle@uncg.edu
Carrie D. Allen, University of North Texas, carrie.allen@unt.edu
Jakayla Clyburn, Rockingham County Schools, jclyburn@rock.k12.nc.us

Abstract: Co-design has become an important resource in supporting instructional reform in science education. Various studies of teacher learning in co-design have focused on the outcomes of this work, including teacher content learning and use of co-designed resources in their practice. In this study, we focus on how the co-design process created opportunities for teachers to develop their interpretive power of students' STEM learning to identify varied forms of participation and learning in STEM activities through the co-design of an afterschool STEM program. We found that observations of students engaged in out-of-school STEM activity supported teachers to view STEM learning in varied ways and that the organization of students' activity mattered for what they paid attention to in relation to student learning.

Introduction

Science teacher co-design has emerged as an important tool in support of science instructional reform (Penuel, Roschelle, & Shechtman, 2007). In this work, science teachers engage with researchers to design instructional resources that align to science reform and take into consideration the localized expertise of science teachers. Research on science teacher co-design has demonstrated a variety of learning outcomes of the co-design process, including teachers' greater use of resources they have designed alongside researchers (Furtak & Heredia, 2014), supporting teachers' engagement in reflection of their instructional practice (Matuk, 2016), and a focus on teacher learning of content knowledge for teaching (Kelter et al., 2021). In this paper, we seek to understand how the co-design process supported science teachers to identify multiple forms of student learning in STEM activity. To do so, we explore the initial phases of the co-design process as science teachers work to design an afterschool STEM program for their schools as part of a larger STEM ecosystem (National Research Council, 2015). In what follows, we introduce the design problem related to teacher recognition of various forms of student learning in STEM environments and a conceptual framework used to organize the co-design process.

Design Problem

In this project, science teachers were supported to co-design a STEM afterschool program organized as part of a STEM ecosystem designed to support students to develop varied STEM identities and interests. However, fostering variety in students' STEM identities is not necessarily a key feature of formal classroom instruction (Tan et al., 2013). Rather, science teachers tend to focus on standardized curricula, geared toward local and state-level accountability measures, including high stakes testing contexts (Settlage & Meadows, 2002). Such curricula generally offer a narrow conception of learning in science that emphasize evaluating student learning of discrete facts and vocabulary (Otero & Nathan, 2008), rather than the myriad ways students can demonstrate growth and learning in science, such as increasingly sophisticated forms of participation in science practices over time (Rogoff, 2003). Therefore, science teachers need opportunities to build their interpretive power to learn to recognize the varied ways that students make sense of science content and phenomena to support multiple pathways to develop interest and identities in STEM (Roseberry et al., 2016).

Conceptual Framework

Guiding our work is the recognition that when teachers engage in learning of new practices, they do so as actors in complex organizations, enmeshed in their day-to-day work practices (Spillane & Hopkins, 2013). Therefore, we leverage constructs from organizational sensemaking (Weick, 1995) to guide our approach to co-design. Organizational sensemaking is the process by which individuals interpret changes to their work environment and make decisions about how and what to change in their work practices (Weick, 1995). Teachers' sensemaking can be supported through intentional opportunities for them to see what's new or different about a

 © ISLS

reform instruction, and then have access to resources that support their design and implementation that make the integration of new practices feasible, given their local expectations (Allen & Heredia, 2021).

In this study, we anticipated that science teachers' interpretive power in student activity aligns with accountability systems and that they would privilege students' correct use of science vocabulary in science activity, which would cause some ambiguity when observing student learning in out-of-school settings that work to develop a variety of ways students can engage with science. Therefore, we intentionally designed their learning activities to surface this ambiguity through observations of students engaged in out-of-school science activity. Then we provided opportunities for teachers to make sense of students' learning and to recognize the ways in which science learning can be organized to support varied pathways in STEM.

Methods

We used a design-based approach (Barab & Squire, 2004) to develop and study our work with teachers in co-design. Here, we focus on early phases of this co-design process and explore how anticipated sources of ambiguity about student learning surfaced and how designed activities in the professional development triggered science teachers' sensemaking about student STEM learning beyond conceptual understanding.

Participants and professional development context

Participants included six middle school teachers from three schools who worked in teams (two teachers were each from the same school). The teachers ranged in teaching experience from 4 - 27 years in the classroom. They were all certified science teachers and have degrees either in science or elementary education.

The teachers chaperoned students from their school to the university for an out-of-school STEM program called Saturday Stormwater Investigations (SSI). The SSI program engaged students in STEM activities that were designed to support them to understand local problems related to stormwater and how to use best management practices to solve these problems. While students participated in the SSI program, the teachers engaged in professional development learning in parallel with their students. The primary focus of the professional development was to support science teachers to design and implement an afterschool program that extended students' engagement in the campus-based SSI program. In the professional development, the teachers learned about the design of the SSI as a pedagogical model for their afterschool STEM clubs. Professional development activities included applying the pedagogical framework to the designed activities for the SSI, observing students as they engaged in the activities (facilitated by university staff and faculty) and then reflecting on their observations.

Data sources

Each of the six teachers participated in a total of 45 hours of professional development over the course of three years. We collected video and audio recordings of the professional development meetings with teachers. Here, we focus on data from the first year of the professional development when teachers participated in a total of 20 hours of professional development. Additionally, we interviewed teachers prior to the start of the project and again after their first year in the program. The initial interview asked teachers to describe their educational background, their teaching practices, and experience with afterschool programs. The second interview happened over the summer to support teacher reflection of their learning, as well as to provide feedback to the research team about student programming.

Data analysis

We sampled conversations from the professional development meetings that asked teachers to debrief and reflect on their observations of students' activities during the SSIs (Table 1). We transcribed these conversations and coded teacher utterances according to the nature of student activity they noticed and discussed with the group. Codes included teacher discussion of student conceptual understanding of science (right/wrong, conceptual sensemaking, scientific language), student's social and emotional learning, students' cultural resources (asset-based and deficit-based), and student identity work. We coded each transcript independently and discussed how we applied codes, refining, and adjudicating differences in our discussions. We wrote short research memos about the nature of the teacher post-observation conversations. We similarly coded and wrote memos for teacher interview responses to questions about student learning in the SSIs. Finally, we organized these memos into a time-ordered matrix (Miles & Huberman, ?) to look for changes over time.

Table 1
SSI activities observed and discussed by the teachers

Date	SSI activity observed
Meeting 1	Students walked to a wetlands on campus and they looked for aspects of stormwater management. At the wetlands, they were given a variety of science tools to explore the living and non-living aspects of the wetland environment.
Meeting 2A	Students traveled with their teachers on buses to the university for the SSI program.
Meeting 2B	Students self-selected into different activities: science activity - monitoring biotic and abiotic indicators of water health at the wetlands, engineering activity - exploring permeable pavement, and technology - exploring various tech tools for advocacy.

Findings

The data revealed shifts in the ways in which teachers recognized and noticed different aspects of students' science learning in the out-of-school setting as compared to their descriptions of student science learning in their classrooms. In initial interviews, teachers highlighted the importance of school growth data to inform if and how their students were learning science. While they initially focused on the use of science vocabulary in student activity during the SSIs, they also noticed other aspects of students' learning, including student affect during the activity, their collaboration and interaction with students from other schools, and student science identity work.

Not surprisingly, all six teachers focused on students' conceptual understanding of science as a measure of growth at the on-set of the study. In their pre-interviews, they discussed a variety of methods and tools to assess student learning in science, including quizzes, technology, end of year state assessments and benchmarks, and students' explanations of science content. For example, one teacher described how he makes teaching decisions based on students' scores on assessments: "I then also analyze my data ... really the best place to get it is that test, and I can look at the tests I give them or the quizzes I give them, because I use Schoolnet, and I get instant data." Each of the teachers focused on data related to content understanding, with some attention to students' behavior and general engagement.

During the first year of professional development, the teachers had multiple opportunities to share their observations of student activity in the SSI. The focus of those conversations related to students' engagement with the activity and with each other and their science content learning. The teachers made connections to their observations of students in their classroom or at the school and their modes of participation in the SSI activities. For example, after observing students engaged in a creek and wetland exploration on the first day of the SSI, one teacher noted, "And not knowing how they were going to interact and be so happy about...the different interactions you saw between your own students that you didn't expect and then how they also interacted with others. It was really good, really good reinforcement." The teachers also recognized the lack of access that their students have to this kind of science activity and were excited they had an opportunity to explore a creek in a disciplinary way.

While they did recognize other forms of learning, they also paid attention to the ways in which students were developing science conceptual understanding. For example, in a debriefing conversation after teachers observed students in breakout activities in computing, science, or engineering, the teachers focused more on students' conceptual understanding as they engaged in the activities and expressed frustration at the lack of science vocabulary. One teacher noted that the students described the concept of permeability and talked about it, but never named it. "They didn't directly make the connection immediately, so when the kids- she was asking them about what did you see, about the different materials they were using. They were giving all of the words that are permeability, but no one said it until later." Here he was focused on their conceptual understanding that was being developed during the activity and expressed frustration that the students did not use scientific vocabulary in their explanations.

During their interviews following the SSIs, teachers mentioned that in the SSI program, students learned science, but also how to communicate and interact with different people and about the college campus. One teacher talked about how youth gained sensitivity and an awareness of the environment around them and they learned to use science to solve problems. When asked about what they noticed during student activity in the SSI program they talked about students' interactions with one another, the conversations they were having and the questions they were asking, and the connections they were making between the content and the real world. The shift evident in their interviews suggests that the teachers' experiences observing students in the SSI supported them to move beyond simply did my students get the science content to recognizing other forms of learning, such as developing identities to care for the environment and their interactions with other students.

 © ISLS

Discussion

This study presents an initial analysis into the ways in which observations of student activity in out-of-school science settings can support in-service teachers to build their interpretive power to see varied forms of student learning in STEM activity. We found that teachers identified students' content learning in the SSIs, but they also paid attention to how students interacted and collaborated with other students, how the activity supported (or not) students' STEM identity development, and student affect as they engaged in SSI activities. Similar to research on pre-service teacher learning in informal settings (Jurow et al., 2012), we found that observations of students in the informal setting are productive sites for learning for in-service teachers as well. Next steps would be to collect data on science teachers' classroom practices after participating in the professional development to see if and how they are applying these varied views of student science learning in their classrooms. This study provides evidence that science teachers have the capacity to see other forms of learning. However, our understanding of the role of context suggests that it's possible that teachers may not apply different lenses for recognizing student science learning in their classrooms given the organizational focus on content learning.

References

Allen, C. D., & Heredia, S. C. (2021). Reframing Organizational Contexts from Barriers to Levers for Teacher Learning in Science Education Reform. *Journal of Science Teacher Education*, *32*(2), 148-166.

Barab, S., & Squire, K. (2004). Design-based research: Putting a stake in the ground. *The journal of the learning sciences*, *13*(1), 1-14.

Furtak, E. M., & Heredia, S. C. (2014). Exploring the influence of learning progressions in two teacher communities. *Journal of Research in Science Teaching*, *51*(8), 982-1020.

Jurow, A. S., Tracy, R., Hotchkiss, J. S., & Kirshner, B. (2012). Designing for the future: How the learning sciences can inform the trajectories of preservice teachers. *Journal of Teacher Education*, *63*(2), 147-160.

Kelter, J., Peel, A., Bain, C., Anton, G., Dabholkar, S., Horn, M. S., & Wilensky, U. (2021). Constructionist co-design: A dual approach to curriculum and professional development. *British Journal of Educational Technology*, *52*(3), 1043-1059.

Matuk, C., Gerard, L., Lim-Breitbart, J., & Linn, M. (2016). Gathering requirements for teacher tools: Strategies for empowering teachers through co-design. *Journal of Science Teacher Education*, *27*(1), 79-110.

Miles, M. B., & Huberman, A. M. (1994). *Qualitative data analysis: An expanded sourcebook*. Sage.

National Research Council. (2015). *Identifying and Supporting Productive STEM Programs in Out-of-School Settings*. Washington, DC: The National Academies Press. https://doi.org/10.17226/21740.

Otero, V. K., & Nathan, M. J. (2008). Preservice elementary teachers' views of their students' prior knowledge of science. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, *45*(4), 497-523.

Penuel, W. R., Roschelle, J., & Shechtman, N. (2007). Designing formative assessment software with teachers: An analysis of the co-design process. *Research and practice in technology enhanced learning*, *2*(01), 51-74.

Rogoff, B. (2003). *The cultural nature of human development*. Oxford university press.

Rosebery, A. S., Warren, B., & Tucker-Raymond, E. (2016). Developing interpretive power in science teaching. *Journal of Research in Science Teaching*, *53*(10), 1571-1600.

Settlage, J., & Meadows, L. (2002). Standards-based reform and its unintended consequences: Implications for science education within America's urban schools. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, *39*(2), 114-127.

Spillane, J. P., & Hopkins, M. (2013). Organizing for instruction in education systems and school organizations: How the subject matters. *Journal of Curriculum Studies*, *45*(6), 721-747.

Tan, E., Calabrese Barton, A., Kang, H., & O'Neill, T. (2013). Desiring a career in STEM-related fields: How middle school girls articulate and negotiate identities-in-practice in science. *Journal of Research in Science Teaching*, *50*(10), 1143-1179.

Weick, K. E. (1995). *Sensemaking in organizations* (Vol. 3). Sage.

Acknowledgments

This material is based upon work supported by the National Science Foundation under grant no. 1657194. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.