Exploring Teachers' Design and Enactment of Rigorous Lessons through a Collaborative Design Experience

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Abstract

Reform efforts targeting science instruction emphasize that students should develop scientific proficiency that empowers them to collaboratively negotiate science ideas as they develop meaningful understandings about science phenomena through science practices. The lessons teachers design and enact play a critical role in engaging students in rigorous science learning. Collaborative design, in which teachers work together to design, enact, and reflect on their teaching, holds potential to support teachers' learning, but scarce research examines the pathways by which collaborative design can influence teachers' instructional practices. Examining the teaching and reflective thinking of two science teachers who engaged in collaborative design activities over two years, we found that their enactment practices became more supportive of students' rigorous learning over time, and that they perceived collaborative efforts with teacher educators and partner teachers to plan lessons and analyze videos of instruction as supportive of their learning to enact rigorous instruction.

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Subject/Problem

Reform efforts targeting science instruction emphasize that students should develop scientific proficiency that empowers them to collaboratively negotiate science ideas as they develop meaningful understandings about science phenomena through science practices (Furtak & Penuel, 2019; NRC, 2012; NGSS Lead States, 2013; Tekkumru-Kisa, Stein & Schunn, 2015). Lessons designed for rigor exert high cognitive demand on students' thinking, asking them to answer guiding questions and make sense of puzzling science phenomena as they develop deeper understanding of science content and practices (Odden & Russ, 2019; Tekkumru-Kisa, Stein & Schunn, 2015; Windschitl & Barton, 2016). Teachers' design and enactment of such lessons plays a critical role in supporting students to engage in rigorous science learning (Kang et al., 2016; Tekkumru-Kisa, Stein & Schunn, 2015; Tekkumru-Kisa, Stein, & Coker, 2018). Considering the pervasiveness of classrooms in which students do not engage in rigorous science lessons (Banilower et al., 2018; NASEM, 2015), there is a critical need to understand how teachers can be supported to design and enact instruction that affords students opportunities for rigorous science learning.

Designing instruction in which teachers facilitate rigorous science learning is complex work, as is enacting those lessons while maintaining their rigor on students' learning. Even when teachers approach instruction equipped with rigorously designed curricular materials, teachers face challenges to their enactment of these materials. These challenges to their intended implementation often cause them to constrain the rigor of the lesson (Kang et al., 2016; McNeill et al., 2018; Sandoval et al., 2018; Tekkumru-Kisa, Stein, & Coker, 2018). During the task launch in which the teacher frames the intellectual work that students will engage in, and during the task implementation in which students work on the task, a teacher may struggle to maintain the potential rigor of the lesson as particular teacher moves inadvertently lessen the cognitive demand (Kang et al., 2016; Stein et al., 2007; Tekkumru-Kisa, Stein, & Coker, 2018). Thus, helping teachers to shift their practice towards supporting rigorous learning in lesson design and enactment remains a challenge for teacher educators and educational researchers.

Achieving the goal of engaging students in rigorous science learning will depend on focusing efforts in supporting teachers as the targets and agents of change (Cohen & Ball, 1990; Gess-Newsome et al., 2003). Research on teacher-design teams, lesson studies, and other teacher education innovations that focus teachers' sensemaking through instructional design have shown the potential of *collaborative design* to influence teachers' learning (Coburn, 2001; Munson & Dyer, 2020). Collaborative design experiences are effective when they situate teachers' learning within their own classroom teaching and student learning contexts, allow for agency in teachers' uptake and adaptation of practices, provide opportunities for reflection on teachers' instruction of co-designed lessons, and leverage other teachers', educational researchers', and disciplinary experts' thinking as resources for instructional design (Finklestein, 2013; Gomez, 2015; Voogt et al., 2011). While research on collaborative design of instruction has demonstrated its potential to shift teachers' practices, the paths by which collaborative design influences teachers' learning to enact rigorous instruction remain unexplored.

We suggest that one way to help teachers design and enact rigorous lessons is through teacher learning experiences situated in the collaborative design and analysis of rigorous lessons. Research on teachers' learning through design highlights the importance of collaborative work on changing teachers' beliefs, affect, and knowledge (Voogt, 2015), but scarce research investigates the influence of collaborative design to shift teachers' practices. The goal of this proposal is to develop understanding about the role of collaborative design in supporting teachers to shift their practices towards designing and enacting instruction that supports students' rigorous science learning.

Research Questions

This study explores the instructional practices of two science teachers, Jerry and Kate, as they engaged together in collaborative design around lessons that they iteratively co-designed, implemented, co-analyzed, and redesigned over two years. We also seek to understand what aspects of collaborative design activities they perceive as influential for their learning. Concerning Kate and Jerry's collaborative design work on two lessons, we ask:

1. What was the potential of teachers' co-designed lessons to engage students in rigorous thinking, and to what extent was the demand on students' thinking maintained as these lessons were launched and enacted?
2. How did teachers perceive the role of collaborative design in shaping their instructional practices to promote students' engagement in rigorous opportunities for learning?

Design/Procedures

This study occurred within the context of an NSF-funded project that focused on teachers' learning to facilitate productive science talk in classrooms through professional development that featured collaborative design. Focal to this study are teachers' experiences in lesson design and enactment through four cycles of collaborative lesson design that began in a summer professional development institute and continued the following school year (Southerland et al., 2017). In each of the four lesson design, teach, and analysis cycles, teachers engaged in collaborative lesson design with other teachers (design), independently taught their lessons (teach), and met with other teachers to collaboratively analyze clips of their own or others' teaching of the designed lessons (analyze).

Kate (21 years teaching) and Jerry (3 years teaching) were two middle-school biology teachers from different schools who collaborated together in collaborative lesson design cycles for four lessons. Kate and Jerry's collaborative work extended beyond this initial year, as they chose to continue refining particular lessons together. Because of this close and multi-year collaborative effort, we focused our study on their teaching and collaborative work.

Data Collection and Analysis

To answer the first research question about the potential and enacted opportunities for rigor, we examined the products of teachers' collaborative work over two years. We focused on the last two lessons from teachers' year 1 collaborative design cycles—one about cell division (Cancer Lesson), and another about sexual selection (Guppies Lesson)—which they continued to collaborate on in the following school year. These lessons were taught at the end of each year, allowing teachers opportunities to develop classroom norms and understandings of their students.

To analyze the opportunities for rigor in the tasks as designed and enacted, we employed the IQA-Science Rigor Rubric (Tekkumru-Kisa *et al.*, 2021). By using the rubrics, opportunities for rigor can be assessed by attending to the level and kind of thinking in which students could potentially engage as they work on a given task. The rubrics also require attention to the framing of the lesson as the task is set up for the students, and the level and kind of student thinking as the teacher and students engage in the task. Three of the authors independently scored each lesson using the rigor rubrics (interrater reliability across wider project dataset = 80%) and discussed disagreements to reach consensus. Coders utilized the numeric scores from the IQA-Science Rigor rubrics, but these are simplified in the presented finding to how the phases of the lessons were framed and enacted as *figuring out*, *learning about*, or *rote/procedural* throughout the phases of the tasks (Table 1).

Table 1: Generalized Meaning of Scores across Rigor Rubrics

Code Range	Generalized Descriptions
4-5	"Figuring Out": More Rigorous. Demand on students' thinking is high, with meaningful engagement in science content and practices.
3	"Learning About": Less Rigorous. Demand on students' thinking is high, but opportunities for meaningful engagement in science content and practices are fewer OR students only meaningfully engage in one at the expense of the other.
0-2	"Rote/Procedural": Not Rigorous. Demand on students' thinking is low, with few opportunities for meaningful engagement in science content or practices.

Table Note: We utilized the specific, detailed codes from the proposed IQA-Science rigor rubrics (Tekkumru-Kisa et al., 2021) to assign codes to each phase of a lesson [i.e., Task Potential Rigor, Launch, Implementation, and Concluding Whole-Class Discussion] based on whether and how students were supported to engage in rigorous science learning. Rigor ratings are on a six-point scale, with zero being the lowest rigor and five being the highest (i.e., scores can be 0, 1, 2, 3, 4, or 5). If there is no whole-class concluding discussion, scored as "N/A". This table is provided to give some context about what these scores mean in a generalized way.

To address the second research question which focused on exploring how teachers perceived the role of collaborative design in shaping their instructional practices to promote students' engagement in rigorous opportunities for learning. We examined teachers' comments about collaborative design and their developing practice in lesson specific interviews which occurred after they taught each lesson both years, and general interviews conducted over multiple years. Using emergent thematic analysis (Miles & Huberman, 1994), we will present preliminary findings of the themes that began to emerge from Kate and Jerrys' interviews about collaboration.

Findings and Analysis

Addressing the first research question, we found that for both Kate and Jerry, the task potential to engage students in rigorous opportunities for science learning did not increase from year one to year two, but also that Kate and Jerry could better maintain the rigor of their lessons as they enacted them from year one to two (presented in Table 2). The potential rigor scores of the Cancer and Guppy lessons in year 1 indicate that while both lessons could engage students in complex thinking processes about disciplinary content and practices, scaffolds in the lesson designs reduced the cognitive demand on students' thinking and constrained their engagement in content and practices. This reduction was more severe in the Cancer lesson, which emphasized learning about content over engaging in science practices, compared to the Guppies lesson, which emphasized engagement in content and practices as students figured out a phenomenon. Our analysis of Kate and Jerry's enactments indicated that they were better able to maintain the potential rigor of each lesson in the second year of lesson enactment

To illustrate these trends, we present detailed interpretations of one of the lessons, the "Guppies" lesson, that Kate and Jerry collaborated on over two years. Beginning with the Guppies task as designed, the task co-designed as a part of the PD was designed with the potential rigor at the level of "*figuring out*". There were no changes in the potential rigor of the lessons from year 1 to 2, despite Jerry and Kate's continued work in collaborative re-design of the lessons, indicating that these modifications did not result in increased potential for rigorous learning for either lesson. The task afforded students the opportunity to wrestle with an authentic phenomenon and figure out an explanation to a guiding question about what was causing the trends in the coloration in guppy populations.

Across both years of enacting this task, Kate successfully maintained this rigor on her students' thinking (we did see improvement in Kate's enactment practice to maintain rigor year-over-year in the Cancer lesson). For Jerry, we see in year one that although the lesson was designed at the level of "*figuring out*", and though both teachers launched the lesson using the same fiddler crab sexual selection video, after watching and discussing the video Jerry framed students' work during the launch as "*learning about*" the trends in guppies. His enactment focused more on ensuring that students completed argumentation posters that included versions of the correct content, indicating that he was helping students in "*learning about*" the content and practice of science, rather than facilitating their efforts to make sense of this puzzling phenomenon related to guppies. During the whole group wrap up discussion students provided brief one-word answers or fill in blanks. Jerry was seen as the intellectual authority, providing the correct answer and deciding on the correctness of students' ideas. Thus, the rigor was lowered in the discussion to "*rote/procedural*".

Table 2. Jerry & Kate's Enacted Rigor of Two Lessons over Two Years (Y1/Y2)

	Potential	Launch	Implementation	Discussion
Kate Cancer Y1	3: Learning About	2: Rote/Procedural	3: Learning About	N/A
Kate Cancer Y2	3: Learning About	4: Figuring Out	4: Figuring Out	3: Learning About
Kate Guppies Y1	4: Figuring Out	5: Figuring Out	5: Figuring Out	5: Figuring Out
Kate Guppies Y2	4: Figuring Out	4: Figuring Out	4: Figuring Out *	*Not Recorded* *
Jerry Cancer Y1	3: Learning About	3: Learning About	2: Rote/Procedural	1: Rote/Procedural
Jerry Cancer Y2	3: Learning About	3: Learning About	3: Learning About	N/A
Jerry Guppies Y1	4: Figuring Out	3: Learning About	3: Learning About	1: Rote/Procedural
Jerry Guppies Y2	4: Figuring Out	4: Figuring Out	3: Learning About	4: Figuring Out

Table Note: See Table 1 for rubric definitions for the scores and generalized descriptors. N/A means the teacher did not facilitate a whole-class discussion.
** Kate Guppies Y2 enactment features a whole-class concluding discussion, but it was not recorded for analysis. This lesson extended one day beyond what the research team could record, and the teacher indicated that she would hold a whole class discussion on this unrecorded day. Thus, it is possible that the score for rigor in implementation is a four as we coded in recorded videos, or it may be higher or lower than that based on what might have occurred during the final day in which Kate held the whole-class discussion.*

Addressing the second research question, we explored how Kate and Jerry perceived the role of collaboration in shaping their instructional practices. During the interviews across the years, both Jerry and Kate highlighted that their collaboration with each other, and also with other teachers and PD team members supported their practices. They perceived that collaboration supported their design and redesign of complex lessons and collaboration also supported their implementation of co-designed lessons. Our findings regarding teachers' perceptions of the role of collaboration in supporting their practice suggested us to turn back to our findings regarding rigor in teachers' instruction, contributing nuance to our interpretations.

Kate shared how "collaboration with Jerry allows the lesson to become stronger" and added nuance about how her collaboration with Jerry had "more to do about the students and fine-tuning the lesson". She also added that collaboration with the research team helped her to enact better practices for facilitating productive science talk, one of the goals of the summer PD she and Jerry participated in. Turning back to our findings regarding rigor in Kate's instruction, we saw that she designed and implemented the Guppies lesson at the level of "figuring out" across both the years. The numeric rubric scores denote some movement between levels 4 and 5 within these scores—evidence, perhaps, of the fine-tuning and tailoring to students' she felt appropriate for the task and for her students.

In addition to Kate, Jerry also discussed the supportive role of collaboration. Jerry stated that collaboration with Kate and other teachers who attended the collaborative design cycles helped him to hear about new perspectives and teaching strategies that he could not even think about by himself. Jerry also highlighted that collaborative lesson analysis informed his practice. For instance, in Year 2, after he taught the guppies lesson, he participated in a lesson specific interview to talk about his teaching. Jerry described that in Year 2, he facilitated a student-driven class discussion by asking his students to focus on both what they did and what other groups did. He discussed how that differed from his leading of that discussion in Year 1, reflecting on how he used that discussion to deliver the correct answer for the students at the end of the lesson. Jerry's insights are corroborated by our analyses of these discussions with the Year 1 discussion rating of "*rote/procedural*", and his Year 2 discussion rating of "*figuring out*" for this lesson. Reflecting on this difference and his change of practice, Jerry explained that he had wanted "to have a more in depth discussion, having [the students] carry the discussion instead of me". He mentioned the influence of watching his and Kate's teaching videos in the same analyze session in the collaborative design cycle for this lesson, noting that he "didn't necessarily do a poor job, but Kate's discussion was just much more in depth, if that makes sense. 'Cause she had students carrying it versus the teacher doing it."

Contribution to the Teaching and Learning of Science

In this research study, we showed how teachers engaged in collaborative design improved their instructional practices to better maintain opportunities for rigorous science learning year over year, and how they perceived collaborative design experiences as beneficial. This study contributes to literature about teachers' learning to enact rigorous instruction by engaging teachers in collaborative design of rigorous instruction and learning from their experiences in the collaborative design and enactment of instruction. Collaborative design might be a productive tool to foster teachers' learning to design and enact rigorous opportunities for science learning, however, more research is needed to explore further the mechanisms by which collaborative design influences teachers' practice. As science teacher educators look for ways to support teachers to promote all students' rigorous thinking and sensemaking, the findings of this study support the use of collaborative design activities as a site of teacher learning. For researchers, our findings about two teachers' learning invite larger inquiries about how teachers learn and develop practice when supported to collaboratively design, enact, and analyze instruction.

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