Exploring Collaborative Design to Support Teachers' Learning to Facilitate Rigorous Science Learning

Ryan Coker[1], Ozlem Akcil-Okan[1], Danielle Rhemer[1], Sierra Morandi[1], Jennifer Schellinger[1], Miray Tekkumru-Kisa[2], Sherry A. Southerland[1]

[1]*School of Teacher Education*
[2]*School of Teacher Education & Learning Systems Institute*
Florida State University

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 identified 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.

Corresponding author: Ryan Coker (rcc08e@my.fsu.edu)

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Objectives

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). However, designing instruction in which teachers facilitate rigorous science learning is complex work; 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). 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 instruction that affords students opportunities for rigorous science learning.

We suggest that one way to help teachers design and enact rigorous lessons is through teacher learning experiences situated in the design, enactment, 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.

Theoretical Framework

Lesson design plays a critical role in supporting students to engage in rigorous science learning while they use disciplinary content and practices to make sense of phenomena (Kang et al., 2016; Tekkumru-Kisa, Stein & Schunn, 2015; Tekkumru-Kisa, Stein, & Coker, 2018). 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). Designing a cognitively demanding task can be challenging work for teachers, as is maintaining that demand throughout the phases of a lesson. 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). One challenge for teacher educators is to help teachers shift their practice towards supporting rigorous learning in lesson design and enactment.

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 (Coenders et al.,2010; Simmie, 2007). 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.

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 perceived as influential for their learning. Concerning Kate and Jerry's collaborative design work on two lessons, we ask:

1. What was the potential of the co-designed lessons to engage students in rigorous scientific thinking, and to what extent did teachers' enactment of those lessons support students' engagement in rigorous science learning?
2. As teachers reflected on their collaborative design work (including lesson planning and analysis), what aspects of collaboration did they discuss in relation to their developing teaching practice?

Methods

This study occurred within the context of an NSF-funded project about supporting teachers learning to support discourse-rich science learning through collaborative design. During the first year of this project, Kate and Jerry, two middle-school biology teachers from different

schools, engaged in cycles of collaborative design for four lessons. Each cycle, facilitated by project team members, included a *design session* focused on collaboratively designing a rigorous lesson, a *teach session* in which teachers independently implemented co-designed lessons, and an *analyze session*, in which teachers collaboratively analyzed video clips of their codesigned lesson instruction selected by the research team. Kate and Jerry's collaborative work extended beyond this initial year, as they chose to continue refining particular lessons together. Because of their close, continuing collaboration after the initial project, and their invitations for us to continue to learn from their collaborative efforts, we examined Kate and Jerry's data in this study. See Table 1 for additional information on study participants

Table 1. Information about the study participants

Pseudonym	Experience	Year	Focal Classroom Demographics
Jerry	3 years of teaching	1	9 African American, 10 Asian, 1 Hispanic, 5 White
		2	8 African American, 3 Asian, 5 White
Kate	21 years of teaching	1	3 African American, 4 Asian, 1 Hispanic, 17 White
		2	2 African American, 4 Asian, 4 Hispanic, 8 White

Data Collection and Analysis

To answer the first research question, we examined the co-designed lesson plans and student-facing materials of two lessons—one about cell division (Cancer Lesson), and another about sexual selection (Guppies Lesson). These curricular materials and classroom videos of the enacted lessons were analyzed through the Instructional Quality Measure Rubrics (Tekkumru-Kisa *et al.*, 2021) which was developed to analyze science instruction in terms of students'

intellectual work by four rigor rubrics. These rubrics, informed by work understanding how particular interactions among students, teacher, and task function to shape the level of rigor on students thinking in different phases of a lesson (e.g., Kang et al., 2016; Tekkumru-Kisa, Stein, & Coker, 2018), provide insight about the rigor on students' thinking throughout the designed potential (RP), launch (RL), implementation (RI), and whole class discussion phases of a lesson (RD). (See Table 2 for meaning of scores on Rigor Rubrics.). 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.

Table 2: Generalized Meaning of Scores across Rigor Rubrics

Code Range	Generalized Descriptions
4-5	Rigorous: Demand on students' thinking is high, with meaningful engagement in science content and practices.
3	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 practice at the expense of the other.
0-2	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 Instructional Quality Assessment (IQA) (Tekkumru-Kisa *et al.*, 2021) to assign codes to each phase of a lesson [i.e., Task Potential Rigor (RP), Launch (RL), Implementation (RI), and Concluding Whole-Class Discussion (RD)] based on whether and how students were supported to engage in rigorous science learning. This table is provided to give some context about what these scores mean in a generalized way.

At the end of each of their first three years of their involvement in the project, Kate and Jerry participated in interviews about their engagement in and learning from collaborative design activities. To address the second research question, the first four authors engaged in thematic analysis (Miles & Huberman, 1994) of the interviews to analyze teachers' talk about the

influence of collaborative design on their practice. Emergent themes about teachers' perceptions about the role of collaborative design on their teaching practice are reported below.

Results

Our analysis of the two research questions demonstrated that Kate and Jerry's Cancer and Guppy lesson enactments increased in rigor between years one and two (Figure 1), and that they identified collaborative design as influential in their changing teaching practices. Addressing the first research question, 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. There were not 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.

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 (Figure 1). In year 1, Jerry's rigor scores during the enactments of both lessons declined below the task potential across the phases of tasks (i.e., launch, enactment, whole-class discussion), indicating that students had limited opportunities to engage in rigorous science learning. In year 2, only the implementation phase of Jerry's Guppy lesson featured a decline in rigor below the potential of the task. While Kate was adept in maintaining the level of rigor on students' thinking in the

year1 Guppy lesson, she struggled to maintain the rigor of the Cancer Lesson in year 1. In year 2, Kate maintained rigor across the enactment of both tasks. There was an improvement in teachers' practices during enactment of the co-designed lessons from year 1 to year 2, despite little detectable changes in the potential of these lessons from year 1 to 2. Given this, we suspected that outside of the curricular materials, Jerry and Kate may have begun to re-examine their teaching practices differently in year 2 than in year 1 to support the maintenance of rigor as they enacted each task.

Figure 1. Jerry & Kate's Enacted Rigor of Two Lessons over Two Years

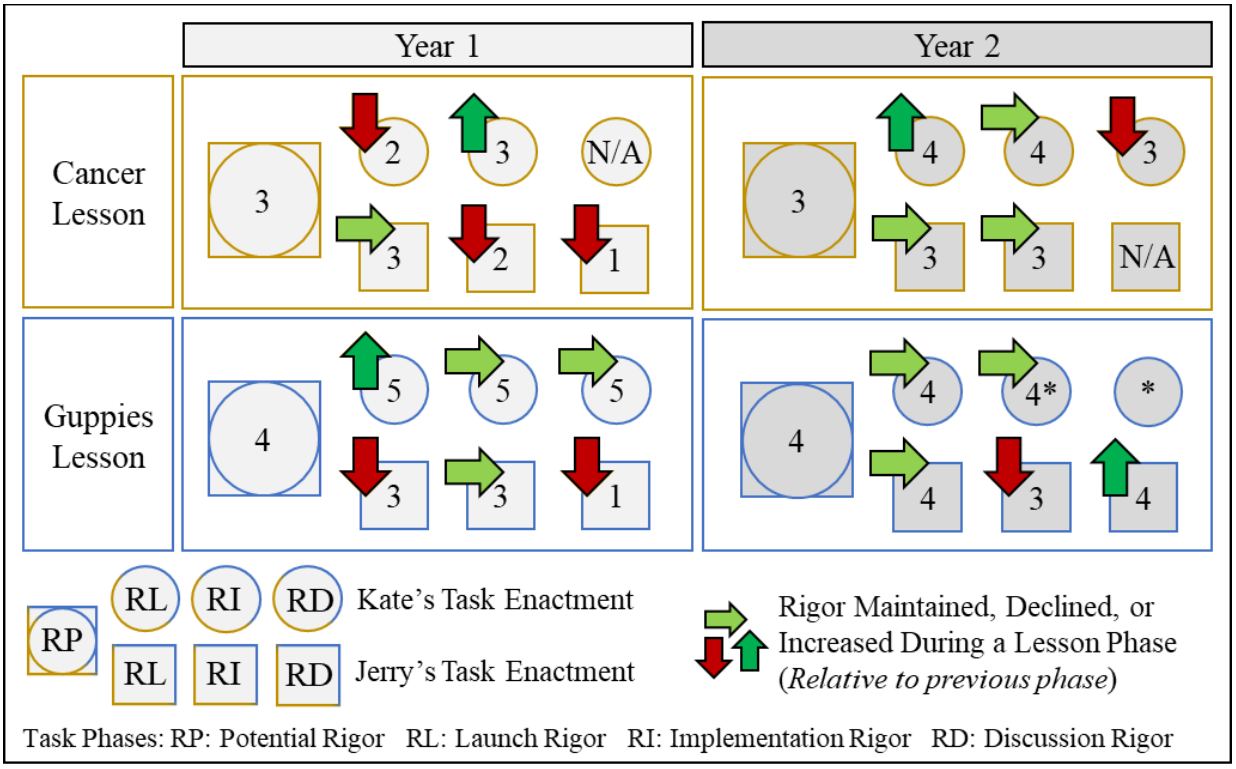

Figure Note: Rigor ratings are on a six-point scale, with zero being the lowest rigor and five being the highest (i.e., scores can be 0, 1, 2, 3, 4, or 5). If there is no whole-class concluding discussion, score given is "N/A". *Whole-Class Concluding Discussion not recorded for analysis. This lesson 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 a whole-class discussion.

Addressing the second research question, interview analysis illuminated how collaborative design influenced teachers' learning to enact rigorous instruction. One major theme was the influence of their collaborative partners (including each other and the research team facilitator) within *co-design* to influence design practices. They emphasized that their collaborators provided support to "revamp" the lessons in their year 1 co-*design* sessions and continued year 2 collaborative efforts. Jerry discussed how Kate's thinking influenced his lesson design, saying, "I wouldn't have ever been able to design that without the input of someone else and it went relatively well". Kate noted that "the collaboration with Jerry has more to do about the students and fine-tuning the lesson", and that the research team facilitators supported her to "very strongly" develop her capacity to facilitate a rigorous launch. Kate and Jerry also indicated that collaboration with the research team facilitators' assistance to make sense of and use disciplinary content to design their lessons, as when Kate described designing the cancer lesson in year 1, "I had content questions, that was always nice to get perspective and feedback with that".

Another theme Kate and Jerry discussed was about the influence of the collaborative *analyze* sessions. Jerry shared that "the most help was from the small group meetings we would have where we collaboratively plan and also break down some of the lessons like watch ourselves on film. Because we were just being students, we were having productive talk about [facilitating students' engagement in] productive talk". Kate describes how in the *analyze* sessions after teaching, "we would come back together and analyze the lessons and analyze our teaching and our thinking and what we observed in our own classes. And we would just continually try to fine tune [the lessons]" and that "collaboration with Jerry allows the lesson to become stronger and the scaffolding to be probably as good as it could possibly be." While

difficult to disentangle, we suspect that their collaborative work in the year 1 *analyze* sessions was consequential for their year 2 *co-design* sessions as they thought about how to enact the co-designed lessons in ways that could support and scaffold students' engagement in rigorous discourse during the task enactment.

Significance

We found improvement in the enactment practices of two teachers who engaged in collaborative design, and our analysis of teacher interviews revealed how teachers perceived collaborative design to influence their 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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