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Beyond Traditional Lesson Study: How Mathematics Studio Supports Generative Teacher Learning

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Abstract: In this paper, we describe the interworking of a group of middle school mathematics teachers who engaged in Mathematics Studio, an adaptation of lesson study, across three years. We use this case to illuminate specific structures, protocols, and norms of interaction within Studio that create conditions for teacher learning and incremental changes in teachers' instruction. Our analysis revealed several discourse practices, including the adoption of a research lens, a shared language of affordances and constraints, and an orientation toward student learning that supported a culture of inquiry as teachers investigated genuine questions they had about instruction. In this paper, we elaborate on these practices and share examples of pedagogically productive talk. We claim Mathematics Studio has the potential to circumvent previously identified challenges to support generative learning and the ongoing growth in teachers' instructional practice.

Keywords: professional development; discourse practices; secondary mathematics teachers; generative learning; lesson study

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1. Introduction

Despite substantial resources devoted to teacher professional development (PD), there is little evidence that investment in PD has contributed to significant changes in mathematics instruction or student learning. Many have attributed the limited effectiveness of PD to the persistent disconnect between research and practice [1,2]. Factors contributing to this disconnect include inattention to teachers' actual instructional problems, ignorance of the grain size of information teachers need in order to improve their practice, an insufficient understanding of the influence of local contexts, and a culture of professional development that perpetuates a narrow view of teacher and researcher roles [3,4]. Mathematics Studio, a local adaptation of lesson study, has the potential to bridge the research-to-practice divide by positioning teachers as researchers of their own practice. [2]. In this way, Studio supports incremental change in teachers' instruction by more closely aligning the proposed changes to teachers' current practice [5,6] and providing teachers with a common vision of the new or revised instructional practice in their own (or a colleague's) classroom [7].

This paper was motivated by our work with a group of middle school teachers who participated in Mathematics Studio across three years. As researchers, we were struck by the degree of teacher ownership and the number of times participants reported Studio was "the best professional learning experience" they had ever encountered. Thus, our broad research goal was to better understand what made Studio work, in the sense that it promoted long-term engagement and learning. In pursuit of this goal, we identified discourse practices within Mathematics Studio that supported pedagogically productive teacher discussions, opening the door for generative learning [8]. In this paper, we detail these practices and, thus, contribute to the limited knowledge base on aspects of teacher-driven professional development that foster incremental instructional change [6].

We begin by outlining our theoretical perspectives on teacher learning, with a focus on how learning is enhanced within a discourse-rich community. Next, we summarize difficulties researchers have identified regarding implementing lesson study in US contexts. Together, these sections provide a backdrop for our description of the Mathematics Studio model. We claim the adaptations within Studio may combat some of the difficulties encountered in lesson study, and contribute to collaborative teacher learning more generally.

2. Theoretical Perspectives and Literature Review

2.1. Perspectives on Teacher Learning

Our research is grounded in theoretical perspectives that highlight the importance of situating teachers' professional learning in the practice of teaching [9,10], and which also acknowledge the learning that takes place within teacher communities [11]. From a situative perspective, professional knowledge is intertwined with the activities and aspects of the setting in which it is developed and later deployed [10]. Learning is enhanced when teaching becomes an object of study, with teachers' practical experiences serving as a basis for inquiry and reflective debate about instructional practices [9,11–13]. Evidence from mathematics teacher communities specifically reveals how learning opportunities are shaped by the ways in which teachers collectively represent and explore instructional issues [14,15]. The key to knowledge development is the extent to which teacher discourse around specific instances of teaching practices is linked to abstract principles and provides teachers with resources for dealing with future problems of practice [16].

Unfortunately, idealized goals for teacher learning within professional communities are not easily realized [17]. Norms of privatization, tendencies to avoid conflict, and pressures of accountability often derail opportunities for teachers to interrogate current practices and engage in productive talk [11,14]. Conversations within teacher groups often devolve into evaluation or advice sharing that promotes a "best practice" or "correct" solution to a teaching dilemma. In contrast, Lefstein, Vedder-Weiss, and Segal [18] propose a framework for pedagogically productive talk. According to their framework, pedagogically productive talk is characterized by the following: (1) a focus on issues or concerns that arise in teachers' classrooms; (2) the use of pedagogical reasoning to interpret classroom events and justify instructional actions; (3) rich representations of practice; (4) attention to different perspectives; (5) generative orientations toward students, teaching, and problems of practice; and (6) a balance of support and critique that fosters trust and collegiality while maintaining a critical inquiry stance.

2.2. The Promise and Challenge of Lesson Study

Research both internationally and in the US has demonstrated how lesson study contributes to growth in teacher knowledge and beliefs [19–21]. Importantly, lesson study has also been shown to promote the generative, evidence-based dialogue about teaching and learning characterized above [22]. By its very nature, lesson study makes teaching practice public and provides a clear structure for teachers to focus on student learning while investigating teaching [22–24]. Through joint lesson planning and observation, teachers have opportunities to explore the effectiveness of new teaching materials and instructional practices in a supportive setting [21,25,26].

Despite this promise, researchers have enumerated several challenges associated with implementing lesson study in the US. These challenges include structural barriers and differing norms around professional learning, as well as an incomplete understanding of lesson study purposes and processes [27–29]. For example, Yoshida [29] describes how lesson study, as adapted within US contexts, is often misunderstood as a means of developing best practices or producing exemplary lessons, rather than as a process to help teachers become life-long learners. The result is often a superficial adoption of lesson study structures without sufficient attention to observing students and collecting data on student learning during the lesson [29,30]. An inability to adopt student and researcher lenses during planning may also result in a lesson that does not make student thinking visible, or an insufficient data collection plan [27,28,30]. Relatedly, teacher learning may be compromised in the post-lesson discussion due to poor data quality or to a culture of evaluation or politeness. Such challenges have led many to claim that lesson study in the US will not reach its full potential until teachers learn how to craft researchable questions about their practice and design lessons that can elicit concrete evidence to shed light on those questions.

We claim that, as a shorter, more teacher-driven form of lesson study, Mathematics Studio has the potential to circumvent many of these challenges and foster collaborative learning that can lead to incremental, but sustainable, changes to instruction. In the following section, we provide a brief description of Mathematics Studio, including some of the ways it differs from traditional lesson study.

2.3. Mathematics Studio Model

The basic activities and structures that comprise a Mathematics Studio are outlined in Table 1 below. This one-day cycle includes the following: (1) establishing a research question aligned with an overarching vision or goal for instruction the week prior; (2) beginning the day with a review of Studio protocols; (3) engaging teachers in the mathematics of the lesson; (4) reviewing and modifying a lesson from the teachers' current curriculum; (5) collecting data while observing the lesson implemented in the Studio teacher's classroom; (6) debriefing the observation; and (7) reflecting on the research question in light of the day's activities and articulating individual commitments. The table illustrates alignment, as well as points of contrast, to the four-step cycle of lesson study outlined by Lewis and colleagues [28]. The most notable adaptation is the fact that, unlike traditional lesson study, the full Mathematics Studio cycle is often completed in a single day. By keeping the grain size small and situating the work in teachers' current curriculum and context, Mathematics Studio opens classrooms as spaces for teacher learning without getting caught up in larger-scale pacing and planning conversations that sometimes undermine teacher learning within professional communities [14].

Table 1. Mathematics Studio components.

Studio Activity	Activity Description	Purpose	How Studio Differs from Traditional Lesson Study
Determine research question	Prior to Studio, the Studio teacher (often in consultation with grade-level PLC) chooses question to explore based on a current problem of practice.	Ground the Studio in something teachers want to learn/improve about their practice.	The school team identifies a general goal/vision for the year, but each Studio stands alone. There is no in-depth study of the topic prior to the Studio.
Review Studio norms	Facilitator begins every Studio with a review of the purpose and norms for Studio.	Establish that Studio is a safe place to investigate genuine questions about instruction.	Participants may vary slightly from one Studio to the next depending on the session focus and teacher availability.
Do the math	Participants solve task for themselves, anticipate student approaches, and identify concepts or procedures needed to access the task.	Specify learning goal to determine success measures; lay foundation for lesson planning (e.g., what resources or scaffolds are needed).	Group does not research student thinking about the specific math topic prior to Studio.
Plan the lesson	Modify lesson to incorporate new instructional strategies or, otherwise, address the research question.	Make instructional decisions visible.	Group starts with the lesson provided in school's adopted curriculum.

Table 1. *Cont.*

Studio Activity	Activity Description	Purpose	How Studio Differs from Traditional Lesson Study
Observe the lesson	Studio teacher teaches while others observe and collect detailed data on what students do and say during the lesson.	Gather data to inform research question—build habit and skill of careful observation of students; enhance quality and impact of conversations by grounding them in shared observation.	Depending on the research question, more than one lesson may be observed. Specific data collection processes and tools are often created in-the-moment.
Debrief the lesson observation	Participants first share student data collected during the lesson before discussing aspects of instruction that impacted student learning and engagement.	Hone teachers' focus on student thinking and support explicit connections between instructional decisions and student learning.	While some adjustments to the lesson may be suggested, the focus is on how instruction impacted students, not on revising the lesson plan.
Reflect	Discuss data in relation to the Studio research question before final individual reflection: what did you learn today and what will you do as a result?	Make new learnings available to the group and support teachers in making small changes to their future instruction.	There is no expectation for teachers to implement the focus lesson or report to broader community.

3. Methods

3.1. The Mathematics Studio Group

The core Mathematics Studio group consisted of four middle school teachers (Nick, Sam, Kelly, and Randy), a university researcher, and an instructional coach (Haley) who served as a facilitator. Given their academic status, the researcher (first author) was sometimes positioned as an expert, but, for the most part, avoided any formal role as knowledgeable other [31]. Instead, they served as a participant-observer, offering ideas from their own experiences as a former teacher and current mathematics teacher educator as appropriate. The university researcher had prior experience with Mathematics Studio alongside Haley, the instructional coach [32] and thus also played a small role in establishing the purpose of Studio and modeling productive norms. This core group attended every Studio session. Other professionals (i.e., middle school colleagues, elementary or high school teachers from the same district, pre-service teachers, paraeducators, and school administrators) attended select Mathematics Studios based on their availability and the Studio topic.

The group conducted thirteen Mathematics Studios across three academic years. Each Studio was designed around a research question chosen by the Studio teacher, or developed by a grade level team, prior to the Studio session and followed the general process outlined in Table 1. After a brief introduction (or review) of Studio norms and purposes, teachers worked on the mathematics task and anticipated how students might go about solving it. The group then offered suggestions or modifications to the lesson plan based on the goals of the lesson and determined what student data should be gathered to address the Studio research question. Depending on the research question, the group observed and collected data from a single lesson, or across multiple classes. During the debrief, teachers were first asked to share what they observed students say and do during the lesson, and what that implied about student learning. Second, teachers were asked to consider how components of the lesson contributed to the mathematics students accomplished and how this informs the Studio research question. Each Studio session ended with a final reflection wherein individuals each shared what they learned and what they planned to do differently based on their learning.

3.2. Data Collection and Analysis

Primary data consisted of video recordings and artifacts (e.g., Studio agendas, lesson planning documents, and student work) from a representative sample of 6 of the 13 total Studio sessions. The six Studio sessions spanned the entirety of the project, were situated in various classrooms with different teachers serving as the Studio teacher, and illustrated the range of research questions the group explored. The format of the Studios varied, with some sessions incorporating multiple classroom observations and others focusing on only one classroom observation. It was important to include a variety of research foci and Studio formats as these differences not only impacted the amount of time teachers spent planning and debriefing, but also influenced the dialogic interactions throughout the Studio. Table 2 provides background details on the structure and focus of these Studio sessions.

Table 2. Mathematics Studio descriptions.

Studio # Teacher	Date	Research Focus	Studio Structure
1—Nick	Winter Year 1	How much scaffolding is needed? What are the affordances and constraints to presenting tasks so that they are more open-ended?	Observation of two Grade 8 classes. Same underlying task, but the lesson launch and amount of scaffolding provided differed.
2—Sam	Spring Year 1	Improving student discourse. What is it about fractions, or about division, that is difficult for students?	Observation of two Grade 7 classes. Adjustments to the second lesson were made on the fly based on evidence of student learning during the first observation.
3—Kelly	Spring Year 1	MENU as a differentiation strategy. Does giving students a choice in tasks improve engagement and/or learning?	Observation of one Grade 8 class. Students were given a choice of three tasks with differing complexities related to the base angle theorem.
4—Randy	Fall Year 2	What are the affordances and constraints of students working in groups of four vs. pairs?	Observation of two Grade 6 classes. Students worked on same task in each lesson but were grouped differently.
5—Sam	Fall Year 3	Differentiation—where is it inherent in task design and where are there opportunities to add it in?	Observation of one Grade 7 class.
6—multiple teachers	Spring Year 3	How do students at different grade levels think about a similar task?	Observation of four classes including: Grade 1, 2, 5, and 7. All lessons used the same video launch with students exploring similar (but grade-appropriate) questions.

Given our research goal and theoretical perspective on teacher learning as occurring and being evidenced through interaction in context, we focused our analysis on the video data from each Studio, utilizing the agendas and Studio artifacts as supplementary data. The two authors viewed the video recordings independently, with the second author creating detailed event summaries of each Mathematics Studio session that the first author then reviewed. Like other forms of field notes, these summaries included organizational information (e.g., who participated, the guiding research question, and grade level of the observed classroom lesson or lessons), as well as objective accounts of central topics discussed during each Studio activity [33]. The researchers then met to discuss initial themes and develop codes (i.e., research lens, not-evaluative, common vision, affordance/constraints, student focus, and ownership) to guide subsequent analysis.

With these initial themes in mind, we engaged in several rounds of individually re-watching Studio video, conferring, and memoing [33]. We purposefully zoomed in on dialogic exchanges in which teachers challenged ideas, engaged in evidence-based discussions, or made pedagogical rationales explicit. Based on the literature, we considered these to be particularly noteworthy as they open opportunities for teachers to debate and consider ideas from a new perspective [14,32]. These dialogic exchanges were transcribed and color-coded to illuminate commonalities within and across the six Studio sessions. Through this process, we identified Studio features and norms that contributed to potential knowledge- or perspective-building opportunities. This focused analysis also led us to hone our initial themes into three characteristics of teachers' discourse we think are key to generative professional learning and to motivating incremental instructional change.

4. Results

4.1. Mathematics Studio Discourse Practices

The goal of our study was to determine what made Mathematics Studio "work". Our analysis revealed how structures and norms established within Mathematics Studio supported three key discourse practices critical to the success of Studio, namely, (1) the adoption of a researcher lens, (2) a language of affordances and constraints, and (3) a foregrounding of students. In the sections that follow, we discuss each of these in turn. Throughout those descriptions, we offer extended excerpts from teacher discussions to illustrate pedagogically productive talk [16], adding to our argument that Studio provided opportunities for generative learning in support of incremental instructional change.

4.1.1. Adopting a Research Lens

As in lesson study more generally, the development of a researcher lens is a critical aspect of Mathematics Studio. Each Mathematics Studio is framed by a research question driven by a local problem of practice. With this research question in mind, the group designs a lesson that will help them answer the question or further their thinking around common pedagogical dilemmas. Together, teachers decide what to look and listen for as evidence of student learning and determine what role each will play in the data collection process. The group often utilizes specific tools, such as discourse observation protocols, for clarity and consistency in data collection.

The discussion from Studio 3 illustrates how teachers took on this researcher role to consider the type of data needed to inform their research question. As captured in Kelly's statement below, Studio 3 was driven by a desire to improve student engagement, and, hence, student learning, through differentiation. Kelly, Grade 8, was the Studio teacher:

Kelly: How do you get students to engage in the lesson enough to do the hard work that's necessary to really learn the content? Because that's the thing, the biggest reason I think that students don't learn content is that they're not actively engaged in the content. So that's been kind of an ongoing exploration Nick [the other Grade 8 teacher] and I have been working on for some time now. What can we do to get more engagement? And then Nick brought up the idea of differentiation—that differentiation is a really effective way to help students meet the proper level of rigor for them individually because if you differentiate, the task will more likely be at a level they can actually engage in.

Based on these ideas, the group went on to collectively create, or revise, three tasks to offer the students. Each task covered similar content, but, in the teachers' opinion, were of differing rigor.

Just prior to the classroom lesson, Haley, the instructional coach, prompted the group to consider what data they would be collecting during the observation. Lisa, Randy, and Sam teach Grades 5, 6, and 7, and Kristin (first author) is a participant-researcher.

Haley: What is it that we are going to be looking for? What data will help us know?
Nick: Appropriate rigor—
Haley: What would that look/sound like?
Randy: If they are using proper vocabulary for the task at hand.
Lisa: Should we be listening to questions Kelly asks? Because the level of her questions will tell us about the level of their—
Kristin: (nods in agreement) And the questions students ask.

Nick: They (students) are making progress but still have to discuss. I mean if they are questioning themselves as they're going but they aren't just stuck. That would be appropriate rigor.

Kelly: And questioning each other. That's what I am really hoping. If they are engaged and really talking about content, they should be asking each other questions like "how do you know that" or "are you sure about that" or they might be arguing with each other saying things like "no you can't put that down because that would mean blank and we need to do blank". Those are the kind of statements I would hope for because that would mean they are actually engaging in argumentation.

Randy: And that would be another check for appropriate vocabulary that was used and the understanding of the vocabulary.

Kelly: Yea, and precision.

Sam: Would it be reasonable to measure engagement every five minutes? Have one of us go through the room every five minutes and count the number of students who are actively engaged at the moment? We don't have anything to compare it to—a day when we're not doing menu, but that has been one of the hypotheses.

Kelly: Does someone feel comfortable doing that?

Sam: I will.

Kelly: It will be interesting because that seems kind of ambiguous a little bit. How do you count whether they are engaged or not? I mean it will be interesting to see what observations you make.

Multiple teachers responded to Haley's prompt and offered potential indicators of "appropriate rigor", such as students using precise vocabulary or questioning each other. Sam then suggested a more systematic way of monitoring engagement, although he acknowledged that they lack comparable data from a non-menu lesson. Kelly agrees the information could be "interesting", but also responds with some tentativeness and wondering about what might count as engagement.

This healthy skepticism, further evidence of teachers taking on a research lens, often emerged during post-observation discussions when teachers considered linkages between student behaviors and the instructional aspects of the lesson. Within those discussions, teachers speculated about the impact other lesson adjustments might have and generated additional research questions. For example, in Studio 4, teachers were curious about the affordances and constraints of having students work in groups of four versus pairs. To investigate this, the same task was implemented in two Grade 6 classes, with students in one class working in table groups of four and the other class working in pairs. Teachers' observations of very diverse patterns of interaction among the student groups left them with new questions such as "how do power dynamics related to gender and/or status influence student learning" and "how do teachers best mitigate issues related to status?" This type of generative teacher discussion was common across the Studio sessions as teachers continued to hone their research skills, and this manner of inquiry became second nature.

4.1.2. Utilizing a Language of Affordances and Constraints

The continual consideration of the affordances and constraints of pedagogical decisions is perhaps the most salient feature of Mathematics Studio. Mathematics Studio is grounded in the stance that teaching is about decision-making; there is not one right answer or "best move"; rather, each decision provides affordances and constraints for student learning. The language of affordances and constraints was modeled early and quickly adopted by the teachers. Sometimes, the framing research question itself was stated in terms of affordances and constraints, as in Studios 1 and 4 (see Table 2), in which teachers gathered evidence related to the impacts of different ways of launching tasks or grouping students.

Other times, this language emerged naturally as teachers considered the relationships between the observed student actions and the instructional decisions. In Studio 2, for example, teachers considered how the differing levels of scaffolding provided in two observed lessons supported students' understanding of fractions. Teachers analyzed the evidence from the lessons to uncover "what helped and what got in the way?" When planning lessons, teachers made deliberate decisions about how to phrase the directions, what order to present tasks, which numbers to use, and what tools they should provide to students. In defending their choices, teachers consistently weighed affordances and constraints, which led them to grapple with several pedagogical issues such as accessibility, student agency, short-term versus long-term student learning goals, and the cognitive demand of tasks.

The excerpt below, taken from the post-observation discussion during Studio 5, provides a snapshot of how those discussions progressed. The research focus was again framed by questions teachers had around differentiation. These included, "What features of the task naturally allow for differentiation? What strategies would allow for more differentiation? How do these differentiation strategies support or hinder student learning?" During the classroom lesson, teachers observed how many students were slow to begin or struggled to understand the task. Based on this evidence, the group wondered whether some of the students' difficulties could have been avoided by launching the task with some form of joint reading.

Haley introduced the idea of a joint reading as a tool that might reduce the need for differentiation. Sam (the Studio teacher) then opened this up for group consideration.

Sam: So, what's the thinking on that? I mean I don't do that very much, joint reading. I make them read it and interpret it.

Haley: I don't know, what do we think about that?

As teachers began to debate the affordances and constraints of the strategy, they drew on both their previous experiential knowledge base, and the observational data from this specific lesson. After a few minutes of discussion, Haley summarized the ideas that had been suggested and encouraged further debate.

Haley: So, I'm going to go back to Sam's question because I see there are three ways you could do it. One is you don't read it to them you just say here is the task. The other is that you ask the kids to read it together in a group with some kind of structure. The third would be that you read it as a whole class. So, I would like to think about the affordances of those and the constraints to those.

Kelly: In the long run we would like them to be able to read it independently and figure it out on their own. So, I think the danger is if you always read it as a whole class, they never have the opportunity to practice the skill of reading it themselves and making sense out of it individually so that would be a real constraint if you did it all the time.

Sam: Right.

Nick: So, if you put in the structure, I am kind of thinking if we were to balance it, maybe the structure of just okay, stop and read individually, don't share, just read individually, just so they, okay, I have to read. Now, begin. Just to stop them to make them do it, but then they still have to be able to reason. But they may, or may not, be able to stop themselves and read it right? That is also something we would want to. . .

Kelly: But maybe it would develop a habit.

Nick: . . .yeah

Kelly: I mean the advantage of reading it out loud is then everybody knows what they are supposed to do at the beginning and so they probably will make more efficient use of their time. Maybe.

Sam: I wonder if that's less effective than making everybody read it quietly to themselves?

Kelly: Yeah.

Sam: Everybody read it, now turn to your partner and say, what you think it said. Because when I read, I don't think of any of those things half the time.

Kelly: That's a good point.

Haley: Can all of them read at grade level? I mean would that be another thing. So, if you are asking them to read, and they can't even get the idea of what it is they are trying to accomplish because they can't understand what is being asked of them.

As the teachers weighed the affordances and constraints of different joint reading structures, they considered issues of access and equity (e.g., can all students read at grade level?), as well as a combination of short- and long-term goals they have for students. Other aspects of the discussion worth noting include the use of "we" throughout, indicating joint responsibility and ownership, as well as the tentative stance taken. Teachers couched their suggestions with "probably", or "maybe", again reinforcing that there is no one "best" decision or teacher move. As illustrated here and in the previous vignette from Studio 3, teachers' adoption of a research lens and the considerations of affordances and constraints always centered on how specific aspects of instruction might affect student learning, leading to the third discourse practice.

4.1.3. Maintaining a Student Focus

The research focus of every Mathematics Studio centered on how particular pedagogical moves, structures, or in-the-moment teacher decisions affect student learning and engagement. Kelly summarized this student-oriented purpose in Studio 6 when she provided new attendees with a brief overview of Mathematics Studio:

Studio is about when I do this, this is what the kids do. When I do that, this is what the kids do. What do I want to elicit from the students? In this particular lesson, what are we really trying to get the students to do? Because that should guide the decisions that I make as a teacher about how I proceed and what kind of teacher actions I have.

Several features of Mathematics Studio supported this orientation. First, Studio lessons were purposefully designed to promote reasoning and problem solving and engage students in mathematical discourse. Thus, student thinking was generally visible during the lessons. Relatedly, there were multiple observers listening in on small group conversations, making student thinking even more accessible. Prior to the observations, teachers anticipated student thinking while working through the mathematics and discussed protocols they would use to record specific student words and actions during the lesson. The first debrief prompt was purposefully designed to start with the student data and teachers were continually reminded to avoid making broad claims or interpretations that did not explicitly tie back to student talk or actions evidenced during the lesson.

These final excerpts, from the initial debrief discussions of each of the two lessons observed in Studio 4, illustrate that push for evidence. The research question guiding this Studio was "What are the affordances and constraints of students working in groups of four vs. pairs?" After the first lesson, when students worked in pairs, Sam opened the debrief by sharing how he attended to access and participation when students moved to the second part of the task, which was to create a poster illustrating their work on the card sort. Haley (the instructional coach) quickly interrupted Sam and pressed him for details around his data collection methods.

Sam: When the poster making began, I began studying access—was it equal access or not? Every four minutes I walked around and did a tally. I found that when it was two girls paired together, they were more likely to have equal access. The second most likely to have equal access was—

Haley: (interrupting) What's your data?

Sam: You want all my data? There's way too much.

Haley: I want enough of it to have a sense of what you did.

Sam: As I walked around, I made three T-charts. One of them has two girls on the T-chart and underneath that was equal or not. And then I did a mixed group T-chart and I tracked whether the girl had the access, the boy had the access, or if it was equal. And then finally I did a two-boy group and measured the same.

Haley: And how did you determine equal or not equal?

Sam: I did it based on who had the poster in front of them and furthermore if, while I was watching, the person without the poster reached over and wrote—I. . .

Haley: Okay, so now I have a picture of how you did it, so now you can tell me what you inferred from that.

Sam: What I inferred was a pair of girls was most likely to have equal access. Second most likely was a pair of boys to have equal access. In the mixed group, it was uniformly the girls that had the access. Only one time out of four samples did a group have equal access when it was a mixed pair.

Nick: Was there any observation of if one was writing and one was talking, like if they had defined roles that way? How often did you find the person with the poster was doing both and one person was just watching?

Before Sam was allowed to share his inferences about different student groupings, Haley insisted that he detail his data collection decisions. This reinforced both the research lens and the focus on gathering evidence directly from students. Specifically, Sam was pressed to define what student actions he counted as "having access". As the discussion continued, teachers were pressed (by Haley, as well as other teachers) to describe exactly what the students they observed were saying and doing, and how those actions indicated whether students had equal access or took ownership of the mathematics.

This consistent press to ground inferences in direct student words and actions was also present during the debrief of the second lesson in which students worked on the same task, only this time in groups of four. Liz, the first to share, and Mary who later adds on to Liz's observation, were both preservice teachers.

Liz: I had a group of four boys. They were interesting. They didn't get much math done—I called it a power struggle. As soon as they got the cards, Max (student pseudonym) took them and split them up so they didn't know what to do with them. They were very confused by what to do math-wise. So, they messed around with the paper, totally off task in that way.

Haley: What was the confusion about? What did the math look like?

Liz: They weren't sure how to sort it, or they weren't sure how to put in ratios, because even after they sorted it into three and four (piles), they didn't put the pieces together that it was the same ratio.

Randy: Didn't I come over there and help them sort it once?

Liz: I think you did, but even at the very end they labeled, this is a match, this is 1, and they wrote down the ratios with 3 boxes per truck, but I don't think they had a complete connection. And especially with the 1½ trucks, they kind of all shrugged. As soon as they were silent Jason (student) had a chance to put in a word. "Oh 4 boxes for the complete truck and 2 for the half a truck". And as soon as he said that Max just took over and Jason got shoved to the side again...

Sam: Over and over and over he would try to ask a question and he was shut out.

Haley: What did being shut out look like?

Mary: I actually wrote it down when Jason came up with that idea, the one and one-third ratio, and Max was like, "Oh that's a good idea" and then took his pen and wrote it down. Jason had a look on his face like, "But I wanted to write that". The paper was only on Max's desk, and he just took over. He was very in control of if they wrote anything on the paper.

Again, the purpose of the debrief was to provide substantive details regarding what students said and did during the lesson. Only with sufficient evidence could teachers make judgements regarding student learning and engagement. When the descriptions were too general, Haley was quick to ask teachers to provide more detail (e.g., what did being shut out look like?). Thus, this excerpt also illustrates norms that had been established regarding the level of specificity with which teachers were expected to record student data.

5. Discussion

This study extends prior research on lesson study adaptations and adds to current theory on professional learning designed to support teachers' incremental change in instruction [6]. Mathematics Studio, a local adaptation of lesson study, promoted pedagogically productive talk [18] that we claim supported inquiry, curiosity, and a willingness to make instructional changes. As teachers collectively grappled with problems of practice arising in their own classrooms, they drew on data from the shared observation to weigh the affordances and constraints of pedagogical decisions. The overall tone of teacher discussions (e.g., acknowledging the complexities of teaching, and considering multiple reasons for students' difficulties or seeming lack of engagement) was indicative of the generative orientation the group took toward their students and toward teaching dilemmas.

Through our analysis, we identified three interrelated discourse practices that were characteristic of pedagogically productive talk and a key to the success of Mathematics Studio. These practices included taking up a research lens, the language of affordances and constraints, and an orientation toward student learning. Below, we first review the significance of these discourse practices as related to the literature on incremental change before discussing how specific Studio adaptations created a more manageable professional learning experience that can lead to ongoing instructional improvement. We end with a short discussion of how Mathematics Studio serves a more long-term goal as a catalyst for generative teacher learning.

5.1. Discourse Practices Arising in Mathematics Studio

The adoption of a research lens, coupled with the continual foregrounding of direct evidence from students, allowed teachers to dig into authentic problems of practice and investigate varying effects of instructional choices. These attributes have been called out as critical to the success of lesson study, but are also difficult for US teachers to achieve [30,34]. In each Studio, teachers played a primary role in not only generating the research question, but also devising a method to test their hypotheses. Specific protocols, coupled with explicit expectations and group norms, kept the post-observation discussions grounded in data. This close study of practice helped teachers see how small changes make a difference (e.g., when the teacher provided less scaffolding, students were more dependent on peers for support; and different group dynamics emerged when students worked in pairs vs. groups of four). Most importantly, these investigations emerged from teachers' own context and illustrated accessible, practical changes that could be made—key characteristics of incremental instructional improvement [7,35].

The language of affordances and constraints modeled by the facilitator and taken up by teachers ensured that post-lesson discussions avoided quick interpretation and evaluation—qualities that often shut down learning opportunities [36]. Instead, the Studio promoted the perspective that teaching was a complex endeavor with no one "right" or "wrong" way to teach. Teachers were inspired to slow down and carefully consider their goals for student learning and engagement to make more informed instructional decisions. Important to incremental change [5], discussions about the affordances and constraints were grounded in a shared vision of mathematics instruction aligned with research-based effective mathematics teaching practices (e.g., [37]). In other words, the lesson modifications that teachers investigated, while consistent with teachers' current practice, were designed to create a richer learning environment for students [5,6].

5.2. Mathematics Studio as a Feasible Pathway to Instructional Change

Lesson study in the US has been criticized for giving insufficient time to the lesson planning process [38] and prior study of the mathematical content to be addressed in the lesson [39]. Admittedly, Mathematics Studio, as conceived by this group of middle school teachers, is open to similar criticisms. While teachers, sometimes in consultation with the instructional coach, do spend time considering curricular resources related to the lesson in advance, the full Studio cycle of planning, implementing, and reflecting occurs in a single day, limiting the depth of that study. However, Mathematics Studio still adheres to lesson study's underlying principles with the goal to promote teacher learning [29,40].

Further, we contend that many of the structural characteristics of Mathematics Studio that deviate from traditional lesson study are the very ones that make this form of professional learning not only feasible in a US context but also more immediately impactful.

The fact that the cycle takes place in one day creates a sense of urgency to focus on the investigation at hand, and subsequently reduces the chances that conversations stray toward logistics or pacing issues which may detract from teacher learning [14]. Teachers do not need to commit to long-term curricular study prior to the Studio, nor do they create a formal research report at its conclusion. However, the Studio still includes time to engage in mathematics together, allowing teachers to anticipate student approaches or trouble spots, expand teachers' knowledge of standards and expectations across grade bands, and enhance their ability to support student access to tasks [41]. Together, teachers plan one or more parts of the lesson together, often co-creating questions to encourage more student discourse, or making intentional decisions about how to group students or what resources they need to provide. This co-planning not only creates a sense of ownership in the lesson, but also offers tangible instructional adjustments that teachers may then implement in their own classroom. Indeed, each Studio ends with individual teachers identifying a change they will make based on their learning. Often, these are modest modifications such as starting the next day's lesson with a Notice and Wonder activity [42] or being more explicit with students about group roles.

5.3. Mathematics Studio as a Catalyst for Generative Teacher Learning

Generative teacher learning requires a disposition toward learning in and from practice [15,43] characterized by teachers' ability to continue to learn from their students' thinking [44]. The non-negotiable component of Mathematics Studio, and what distinguishes lesson study from many other forms of professional development, is the shared observation of a live lesson. Rather than merely speculate on how students will engage with a particular task or react to a teacher question, the group gets immediate feedback and can explore classroom interactions in their full complexity. This joint observation does not necessarily guarantee that conversations stay grounded in the data. However, the likelihood of pedagogically productive talk is dramatically increased.

As illustrated in the excerpts above, discussions were generative in the sense that teachers saw their classrooms as places to try out new instructional strategies and build principled knowledge to support instructional decision-making [44]. Mathematics Studio structures and norms demand that teaching decisions, and the rationale behind them, be made explicit [32]. This explication was aided by a continual press to consider affordances and constraints of instructional moves. Situating teacher learning directly within classrooms that are familiar maximizes the chances teachers can apply their new learning in future teaching situations [10]. This is especially true when the instructional innovation is recognizable by teachers and is consistent with the contextual constraints within which they work [35].

6. Conclusions

Successfully bringing research closer to teaching will require a cultural shift in roles [2,4]. Researchers need to become more accountable for solving specific problems in teachers' classrooms and teachers need to be willing to experiment with different instructional approaches. Our study revealed how Mathematics Studio facilitated this shift and supported teachers' commitments to incremental change by starting with often ubiquitous instructional practices teachers recognized and supported [6,7]. Teachers were empowered to examine genuine problems of practice and take responsibility for making instructional shifts to improve student learning and engagement. We began this study encouraged by teachers' long-term participation in and enthusiasm for Mathematics Studio. Our hope is that this work provides a starting point for mathematics educators and professional development providers to design similar learning opportunities with teachers, for teachers [2], that support continuous, incremental instructional change.

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