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ORIGINAL ARTICLE

Sustained, Effective School-wide Lesson Study: How Do We Get There?

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ABSTRACT
Lesson Study, a form of collaborative, practice-based professional learning that originated in Japan, consists of cycles of experimentation and reflection on classroom instruction. This research examines three schools in the United States that have built and sustained effective School-wide Lesson Study, as indicated by: (1) Lesson Study participation by most or all teachers two years after the end of outside Lesson Study funding; and (2) evidence of impact on teaching and learning. Data from the two schools that use mathematics standardized tests designed to measure deep conceptual learning (but not the third school, where tests focus on procedural mastery) indicate substantial increases in mathematics achievement. All three schools serve mainly students from historically underserved populations, including students of color, English-language learners, and students from low-income families. Analysis of artifacts and observational notes from the three schools suggests four factors shaping effective, sustained Lesson Study: (1) teacher agency; (2) access to a sound instructional vision that values student thinking and makes it visible; (3) teachers' content study and access to content expertise; and (4) site-developed strategic management structures. The central role of teacher agency in sustainability is one implication of the study.

1. INTRODUCTION

Broadly, lasting change in teaching is remarkably difficult to achieve. For 40 years, U.S. reformers have advocated that problem-solving be at the heart of classroom mathematics instruction (NCTM, 1980, 2005, 2014), yet U.S. students continue to spend much time reproducing procedures modeled by teachers (Banilower et al., 2018). Changing instruction typically requires repeated cycles of experimentation and reflection by teachers (Clarke & Hollingsworth, 2002), and few U.S. schools have teacher learning routines to support that work (Hill, 2011). Reform is often pursued through top-down actions that yield superficial compliance rather than lasting instructional change; involvement of teachers as co-leaders of reform can improve likelihood of successful reform (Fullan et al., 2005).

Less on Study is a professional learning approach in which teams of educators conduct "Study-Plan-Teach-Reflect" cycles: Teams collaboratively *study* a topic in the curriculum; *plan* a unit to bring to life their ideas about how to teach the topic; have one team member *teach* a "research lesson" from the co-planned unit while others observe and collect data on student thinking; and *reflect* together on the data's implications for future instruction (Lewis & Hurd, 2011). In the two decades since publication of the first English-language articles on Lesson Study (Lewis & Tsuchida, 1997; Stigler & Hiebert, 1999), interest in Lesson Study has spread to many countries; the World Association of Lesson Study (WALS) website received 19,000 visits from 158 countries during 2021 (WALS, 2021).

School-wide Lesson Study, which is further described in the next section, is widespread in Japan (NIER, 2011). To date, few cases of sustained School-wide Lesson Study outside Japan have been documented (for some exceptions see Perry & Lewis, 2010, Lewis, 2002, and Kusanagi, 2021). We examine three U.S. schools that built School-wide Lesson Study and sustained it for at least two years following the end of external funding and that show positive impact on student learning. Our team (site-based educators and university-based researchers) examined artifacts, video and observation notes to answer the research question: What enables schools to create sustained, effective School-wide Lesson Study?

2. LITERATURE REVIEW

2.1. School-wide Lesson Study

In Japan, Lesson Study is practiced at different system levels, under various sponsorships, and the different forms of Lesson Study play complementary roles in the development, testing and spread of innovations (Lewis, 2014). For example, subject matter associations, university-attached demonstration schools, and schools with short-term grants as "Designated Research Schools" all conduct large public research lessons to test instructional innovations. Interested teachers from across Japan observe these research lessons and bring innovative ideas back to their own Lesson Study work at the regional, district or school level. School-wide Lesson Study plays a pivotal role in system-wide reform in Japan by allowing teachers to test research-based innovations developed outside the school, adapting them for their own students and school vision.

School-wide Lesson Study has several components: Teachers work together as a whole faculty to articulate their long-term vision for student development in a "research theme" that is brought to life in research lessons conducted by grade-band Lesson Study teams; faculty and invited outside commentators observe and discuss the research lessons and draw out implications for future instruction. For example, in the late 1990's, teachers at a school in Komae, Japan noticed students' growing interest in passive, solitary pursuits (such as video games), and focused their research theme on nurturing students who "value friendship, develop their own perspectives and ways of thinking, and enjoy science" (LSGAMC, 1999). At the same time, many science educators across Japan were testing innovations designed to nurture students' deep thinking and curiosity, and the Komae teachers consulted these ideas to build the theory of action for their research theme. Teams at each grade-band at Komae used the research theme to inform planning of a science unit and taught one research lesson that was observed and discussed by the whole faculty and by a knowledgeable science specialist. Over time, science instruction throughout the school shifted to emphasize student curiosity and thinking in response to challenging problems as the core of instruction, rather than teacher-led exercises.

School-wide Lesson Study embodies the assumption that written documents (such as standards, frameworks, and curriculum materials) are often insufficient to create instructional change, and that cycles of teacher-led experimentation are needed (Matsuzawa Elementary School, 2011; Takahashi & McDougal, 2016). In Japan, School-wide Lesson Study occurs within an eco-system where public research lessons, knowledgeable final commentators, and teacher-led instructional change are all expected features of professional learning (Lewis, 2014).

2.2. Collaborative Lesson Research

Takahashi and McDougal (2016) use the term "Collaborative Lesson Research" to describe the well-developed form of School-wide Lesson Study practiced in Japan. They specify features of Collaborative Lesson Research that are sometimes overlooked outside Japan, including:

(1) a clear research purpose expressed in a research theme (i.e., a clear statement of what the team is trying to learn);
(2) *kyouzai kenkyuu* (study of academic content and teaching materials);
(3) a written research lesson proposal;
(4) a live research lesson and post-lesson discussion; and
(5) knowledgeable others (persons with strong content knowledge and knowledge of lesson study) to support the Lesson Study team in deepening their knowledge.

The cases we describe here qualify as Collaborative Lesson Research, although we use the more general term "School-wide Lesson Study" because some of these features emerged over time.

3. MATERIALS AND METHODS

3.1. Our Team and Project

In late 2014, authors A and C obtained funding to support School-wide Lesson Study in 1-2 sites in each of three urban districts and to develop video and print resources in collaboration with the sites. The proposal envisioned that

Lesson Study would establish new core routines of teacher learning within these schools, allowing teachers to engage in practice-based, collaborative inquiry cycles to improve instruction. We welcomed schools at any level (primary through secondary) and any disciplinary focus (e.g., mathematics, language arts) interested in the instructional vision of the Common Core State Standards (NGACBP & CCSSO, 2010). Initially, we thought that the main project work would be changing the core routines of teacher learning and documenting the changes so other sites could try them.

Starting in 2015, principals of 12 schools (in three districts) agreed to join the project of building School-wide Lesson Study. A few of these schools already had one Lesson Study team (or several teams, in the case of School C). Schools were encouraged to start with teams of interested teachers, who would try Lesson Study, supported by materials and processes like those at (reference blinded) and, once comfortable with it, would encourage other teams to form. The first whole-school activity asked each faculty to develop a school Research Theme (reference blinded) that expressed teachers' shared long-term vision for student development.

We initially assumed schools would use their locally-adopted instructional materials to improve instruction. However, during the 2015-16 school-year, it became clear that many instructional resources available to teachers, particularly in mathematics, did not support robust Lesson Study. For example, locally-adopted materials provided specific pedagogies (e.g., "3 reads," "math talks" "exit slips") but did not fully address core elements of mathematics instruction, such as how students become committed, capable problem-solvers. Teacher's manuals offered variable support for teachers' study of the underlying mathematics, their anticipation of student thinking, and their understanding of the rationale behind lesson and unit design. In response, several subject specialists (in mathematics, language arts, and history) were made available to sites on request, to recommend resources, conduct workshops, or take part in some Lesson Study activities (such as commenting on lesson plans in the draft stage or observing and commenting on research lessons). Several schools dropped out of the project after the first or second year when principals left or were not able to gain teacher interest, but others joined. At the end of 2018, when external funding for the project ended, 12 schools continued to participate in School-wide Lesson Study.

3.2. Selection of the Research Sample

In order to examine School-wide Lesson Study in three district contexts (with different assessment systems, curricula and professional learning), the research sample for this article selects one school from each district. Criteria for school selection were: (1) continued evidence of School-wide Lesson Study (most or all teachers participating) two years after the end of external funding; and (2) evidence of positive changes in teaching and learning since the beginning of School-wide Lesson Study. More than one school met the criteria in each district, and we chose the strongest example based on the two criteria, since our research question focuses on determinants of success. All three chosen schools focused their School-wide Lesson Study on mathematics (as did about three-quarters of the schools in the overall sample). The choice of school in District S and O was straightforward, since the schools with highest Lesson Study participation also showed the largest increases in mathematics achievement.

Choice of school was more challenging in District C, where two schools showed strong maintenance of School-wide Lesson Study but standardized test scores provided little guidance (see section 3.4). So we chose the school that conducted more frequent public research lessons. We reasoned that public research lessons provide both public indication of the school's commitment to School-wide Lesson Study and an opportunity for outsiders to judge the quality of teaching at the school. Outside educators (from across the United States and around the world) who attended School C's large public research lessons positively evaluated instructional quality; several lessons (with accompanying plans) are available online (LSGAMC, n.d.-a), so readers can judge instructional quality for themselves.

3.3. Sample Description

We use the same letter to name the district and its associated school. Schools O and F are elementary schools in two large, urban West Coast districts. School C is a PK-8 school in a large, urban midwestern district. As Table 1 shows, all three schools serve higher proportions of students from most historically underserved groups than do their respective districts.

Table 1. School and District Demographics

	Black	Latinx	Asian	White	English Learner	Low SES
School S	24.9%	51.6%	4.0%	2.7%	41.8%	84.0%
District S	7%	27%	35%	15%	28.1%	51.4%
School O	6.3%	89.5%	1.0%	2.1%	70.6%	92.0%

District O	23.9%	46.2%	11.8%	9.9%	31.2%	73.0%
School C	2.8%	96%	0.1%	0.5%	44.8%	89.2%
District C	36.6%	46.6	4.1%	10.5%	19.4%	77.9%

3.3. Standardized Tests

Schools O and S measure mathematics performance using SBAC (Smarter Balanced, n.d), the standardized test used in about a dozen U.S. states. School C uses NWEA MAP. These two mathematics standardized tests differ in nature. SBAC is the product of a major assessment initiative designed to capture the ambitious instruction expected by the Common Core State Standards (NGACBP & CCSSO, 2010). SBAC includes both multiple-choice and constructed-response items and addresses four domains: concepts and procedures; problem-solving; communicating reasoning; and modeling/data analysis. It is administered once a year (starting in grade 3) and takes about 3.5 hours. Its grade-specific forms are aligned with the Common Core State Standards for the corresponding grade level.

In contrast, the NWEA MAP (used by District C) is a fully multiple-choice assessment of 30-45 minutes, designed for repeated administrations three times during a school-year to provide formative feedback on students' mastery of specific mathematical content, so that teachers can remedy weaknesses. NWEA's adaptive structure (a single computerized item bank for grades 3-5, with item selection determined by student response to the prior questions) means that students who answer grade-level items correctly are presented with above-grade-level content. It seems likely that NWEA's overall structure (multiple choice, multiple grade-level items) rewards surface knowledge of future grade-level procedures and fails to measure in-depth understanding of current grade-level content, mathematical problem-solving or reasoning. As a further challenge, NWEA's adaptive format substitutes a different item when students pause for a certain time, a feature that may have been exploited to by some District C schools to raise scores, according to a district report that questions the test's validity as a way to compare schools (Burke & Kunichoff, 2020).

Figures 1-3 show mathematics standardized test data from the three schools from the year before School-wide Lesson Study (2014-15) through the 2018-19 school year. (Standardized tests were not conducted in 2019-20, due to COVID-19.) The bars show results for the school over time (for all students and demographic subgroups) and the x'd lines show district results. The difference between school and district results is striking. Schools S and O show dramatic increases over time (for the school and all subgroups), whereas district-wide profiles show modest or flat growth profiles.

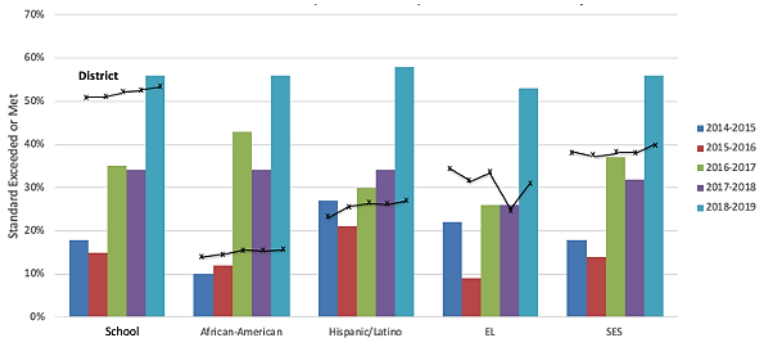

Figure 1. SBAC Mathematics Proficient or Above, 2014-19, School S (bars) vs. District (lines)

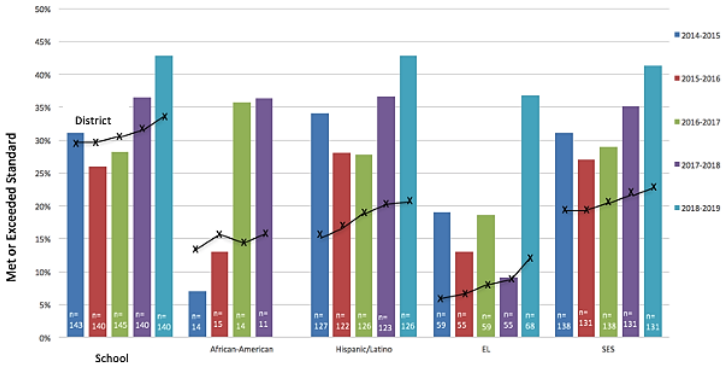

Figure 2. SBAC Mathematics Proficiency 2014-19, School O (bars) vs. District (lines); Percent of Students who Met or Exceeded Standard

Figure 3 shows school and district mathematics performance data for the two District C schools that showed the strongest maintenance of School-wide Lesson Study. As it shows, performance varied substantially from year to year.

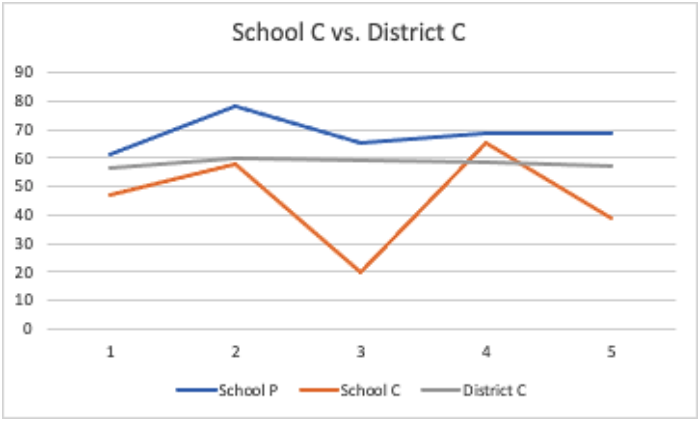

Figure 3. NWEA Mathematics Scores 2014-19, School C (orange line) vs. District (gray line)

3.5. Study Methods

Our team includes university-based researchers who introduced School-wide Lesson Study and documented its development at the three schools (Authors A, B, C), a District S professional learning supervisor (Author D); and a School S teacher who became an instructional coach and then school principal over the 2014-20 period (Author E). Author B also provided expertise in mathematics teaching (in workshops, review of lesson plans, and lesson final commentary). Video, observation notes and artifacts from 6-8 Lesson Study cycles conducted at each of the three schools, along with emails and notes from related meetings and workshops, comprise the data for this paper. Two of the researchers reviewed the available data, selected pertinent materials and identified themes related to the Research Question "What enables schools to create sustained, effective School-wide Lesson Study?" All authors reviewed the assembled materials, confirmed or challenged the choice of materials and themes, and came to a consensus on the ideas laid out in the results section.

4. RESULTS AND DISCUSSION

4.1. Teacher Agency

Teacher agency is the first major theme that emerges from the data. What we mean by "teacher agency" is that teachers were key agents and co-designers of the work-for example, they crafted the school research theme based on their long-term vision for students and revisited and refined it each year in order to incorporate learnings from Lesson Study (see Table 2). Teachers chose the curriculum unit to study based on their authentic questions and concerns, and they developed unit and lesson plans to fit what they saw as the interests and needs of their students and their school vision. As Figure 4 shows, inquiry started with teachers' own instructional knowledge. Although teachers were the key agents of the work, they used outside expertise in crucial ways, as Section 4.3 discusses. Teacher leadership structures for managing School-wide Lesson Study are discussed in Section 4.4.

Table 2. Research Theme and Participating Staff at School S, 2015-19

Year	Research Theme	Participating Teachers (Number) Research Lessons Observed
2015-2016	…learners are empowered to excel in academic achievement, build character, affirm cultural and linguistic diversity while fostering an interconnected global community.	5 Observed 1 lesson
2016-2017	Our research lessons will provide opportunities for students to create a positive and confident academic self-identity by building number and place value understanding in order to *construct viable arguments and critique the reasoning of others.*	15 Observed 1 lesson

2017-2018	Nurture students' mathematical agency and identity through the design of lessons that engage students in problem solving and productive talk.	15 Observed 4 lessons; held large public lesson
2018-2019	Students will use evidence to reason and construct viable arguments so that they are confident, independent learners.	21 Observed 4 lessons; held large public lesson

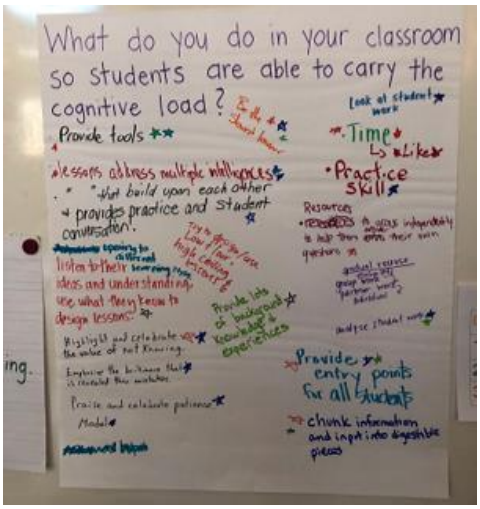

Figure 4. Teachers Share Ideas About a Teacher-Chosen Problem of Practice

4.2. A Sound Instructional Vision That Values Student Thinking and Makes It Visible

Our second theme combines three major ideas that we found hard to separate. All three sites focused school-wide on a single instructional vision, Mathematics Teaching Through Problem-solving. This did not hold true for the larger group of 12 schools, where some schools had a dual subject focus on both mathematics and language arts, and some schools focused on mathematics but not on a comprehensive vision such as Teaching Through Problem-solving. (For example, one school focused on a mathematics "problem of the month" that could be used at different grade levels. As the name suggests, the approach focused on a periodic activity, not a comprehensive vision, although its intent was probably to spark change with a small first step.)

We provide further background on mathematics Teaching Through Problem-solving (TTP), since it was so central to the work at the three schools. TTP originated in Japan and is often credited for Japan's strong achievement on international tests (Takahashi, 2021). TTP asks students to do what mathematicians do: to build new mathematical concepts and procedures using their prior knowledge and mathematical practices (Watanabe, 2014; Fujii, 2016). For example, students who have never been taught how to add fractions with unlike denominators might confront the problem "How much juice do we have all together if we have ½ liter of juice in one bottle and 1/3 liter of juice in another bottle?" Students work in reflective mathematics journals (see Figures 5-6) to devise solution methods individually and then, as a class, examine and discuss several students' strategies and reason through why some methods work (such as creating diagrams that break each quantity into sixths) and others do not (such as adding the numerators and denominators and getting the answer ⅖).

In a TTP classroom, teachers do not present new concepts/procedures through lecture or demonstrations. Instead, teachers carefully select a problem that allows *students* to build the new mathematical concept/procedure. Teachers anticipate student responses to the problem and strategically plan the selection of student work for the board and the key questions to guide discussion. Although problem-solving-centered instruction has been central to U.S. reform visions for at least 40 years (NCTM, 1980), it remains elusive (Banilower et al., 2018). Indeed, mathematics is often taught as "a large number of apparently-unrelated procedures that must be memorized" (Stigler et al., 2010, p.6). Rote teaching is particularly prevalent in schools serving low-income and historically marginalized student groups (Darling-Hammond, 2010; Owens et al., 2016; Rittle-Johnson et al., 2020). In contrast, TTP focuses on robust understanding of mathematical concepts and procedures, developed through problem-solving, perseverance, and communication (Takahashi, 2021).

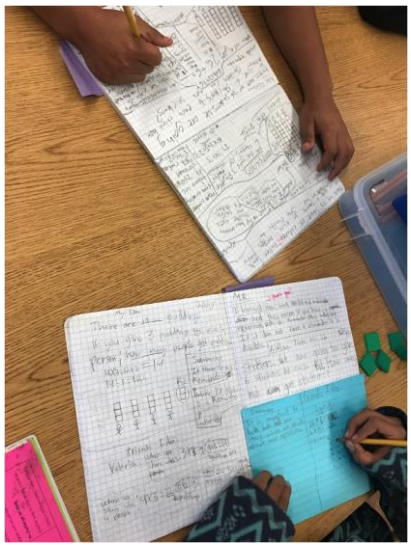

Figure 5. Students' Reflective Mathematics Journals

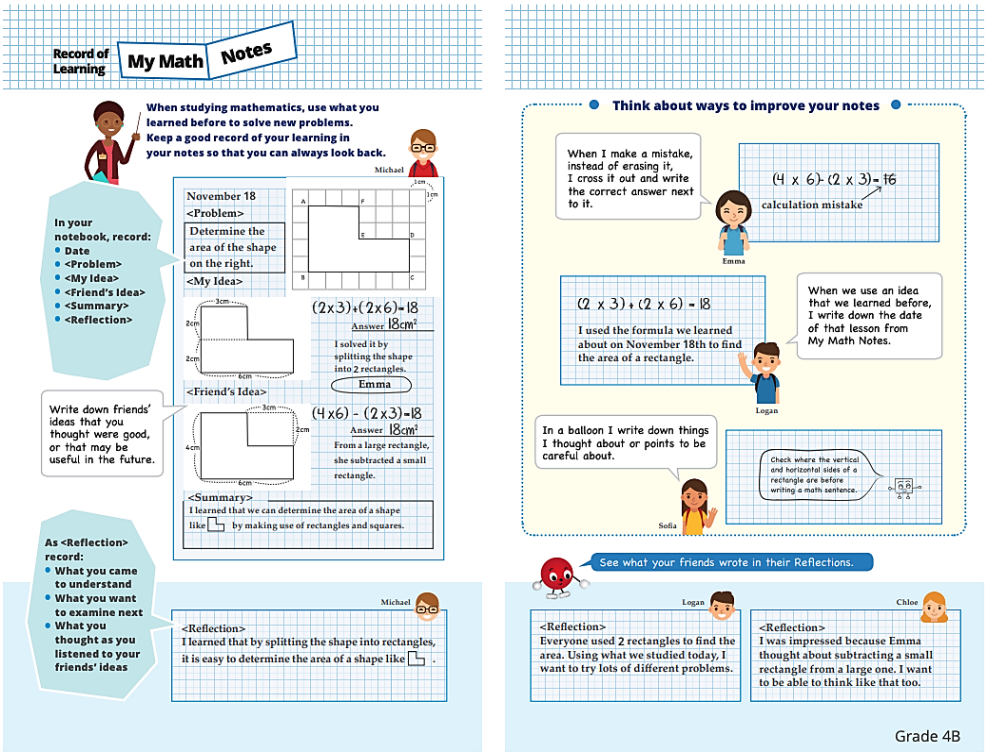

Figure 6. Reflective Mathematics Journal Model

The TTP instructional vision had two further characteristics: it *valued student thinking* and included instructional routines to *make student thinking visible*. Figures 7-8 illustrate how TTP routines of student reflective mathematics journals and planned board work make student thinking visible. The board is organized in a consistent way across lessons (with headings for Problem, Friends' Ideas, Summary, Reflections, etc.), so students know just where to look for the problem, classmates' solution ideas (with diagrams, mathematical expressions, and explanations), etc. Students can compare different strategies since they remain visible rather than disappearing as on an overhead projector. Students can refer to their journals when explaining their thinking to classmates. Mathematics lessons typically begin with a discussion of several student reflections from the prior lesson (Figure 9), further making student thinking visible and using it to drive learning.

Figure 7. Students Examine Solution Strategy Under "Friend's Idea" on Board

Figure 8. Student Refers to Her Reflective Math Journal While Teacher Reproduces Her Solution Strategy on Board

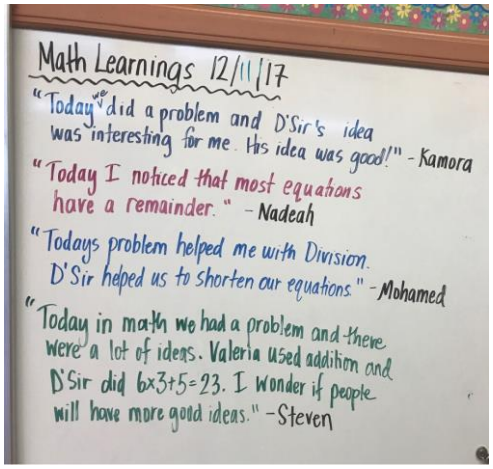

Figure 9. Selected Student Math Learnings from Prior Day's Journal Reflections Begin Each Math Lesson

Why might it be useful for schools to focus on a single subject area and on an instructional vision that values student thinking and makes it visible? These two features probably made it easier for teachers to grasp students' thinking and to exchange useful information with colleagues. Shared instructional routines probably increase the ease and value of sharing information with colleagues; for example, once School S teachers saw the power of using the board to organize the lesson's flow of mathematical ideas, they spontaneously began sharing board photographs with colleagues during breaktime. Visible student thinking (in journals, discussions, and on the board), provided valuable information and motivation for teachers to redesign instruction. Figure 10, student work "proving" that 4/8 meter is longer than ½ meter, revealed challenges in student thinking about eighths and about comparing two (different length) meters. When asked, in 2020, what she wished she had known when beginning the work in 2015, a School S teacher-leader said: "All the professional learning we need we can learn from listening to our students. I've learned more in the last 5 years listening to my students than I did in the prior 10 years."

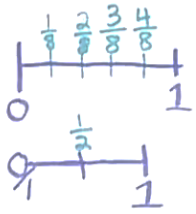

Figure 10. Student Work "Proving" That ½ Is Less Than 4/8 (Reproduced on Board)

We do not imply that School-wide Lesson Study must mandate a single instructional vision. Teachers at the three schools learned about and embraced TTP only gradually over time as they saw the impact of some elements (such as journals) on their students; TTP was not mandated or even presented fully at the outset. School S teachers experimented with three different instructional programs, before settling on TTP about three years into the work. Likewise, all three schools added a second subject-area focus (language arts) several years into the work, after the routines and value of learning from colleagues and from students were well-established.

4.3. Teachers' Content Study and Access to Content Expertise

A third major theme within the data is teachers' study of mathematical content. Asked in 2020 what they wish they had known about School-wide Lesson Study in 2015, one District S teacher-leader said: "High expectations for teachers to learn content knowledge." All three of the schools created content study routines within Lesson Study and cultivated relationships with specialists who provided further mathematical expertise. For example, all three schools regularly invited Author B or another mathematics specialist to provide final commentary on their research lessons and invited a different outside specialist to comment on a draft of each research lesson plan. Specialists included both university-based and district-based mathematics specialists. The research lesson planning templates used by all three schools prompted content study and provided a space to report it; see Figure 9. While the suggestion to conduct a content study and consult specialists was made to all 12 schools in the larger sample, not all schools found these suggestions useful. For example, some teams initially studied resources that they did not find useful, so they discontinued resource study. Some teams invited final commentators but did not find their comments helpful. Some teams met in cross-disciplinary configurations and could not find a productive common focus within the content.

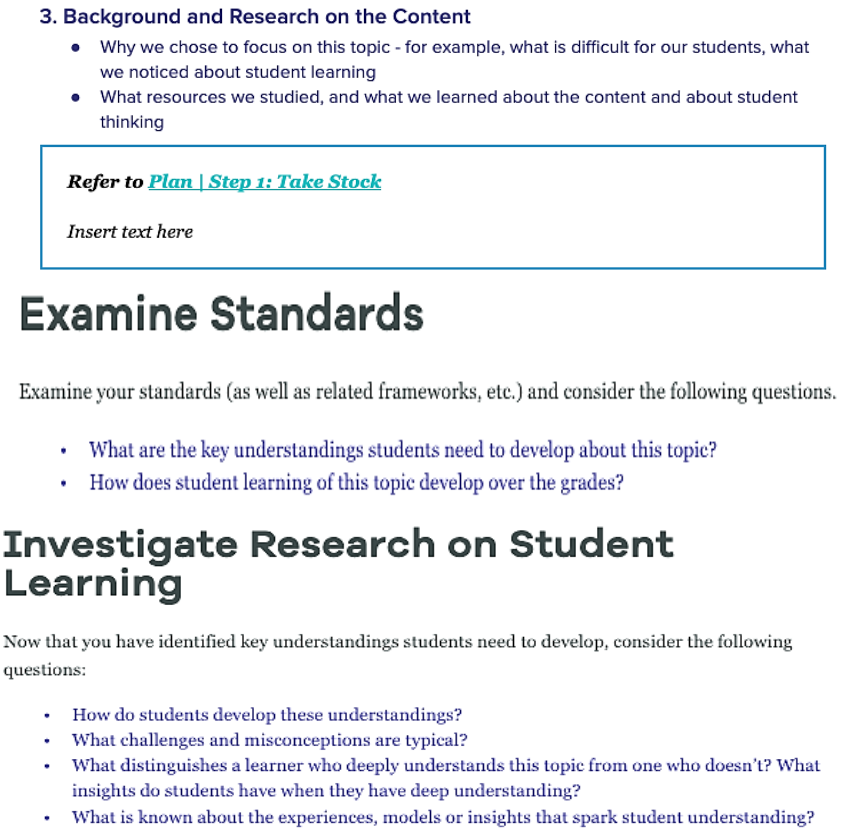

Figure 9. Template for Teaching-Learning Plan Includes Content Study Prompts

Another way that teachers at Schools C, S and O built content knowledge was by conducting and attending large public research lessons (75-150 educators observing). These events (in all 3 districts) expanded the teachers' access to mathematical expertise, since several mathematics specialists typically provided commentary at each event. The lessons also prompted teams to engage in especially thorough content study, since they would present their findings in a large public forum; it is likely these events also strengthened teachers' identities as serious inquirers into mathematics.

4.4. Site-developed Strategic Management Structures

The three districts had different professional learning supports, and teachers used them to design supports for School-wide Lesson Study. For example, District S allowed teachers with at least three years' teaching experience to apply for selection as "teacher fellows" who facilitated a Lesson Study group at their school site while remaining full-time teachers. Teacher fellows received an annual salary bonus from the district and took part in monthly professional learning sessions, where they studied leadership for equity and shared learning and challenges related to Lesson Study. School S teachers used the teacher-fellow program to become Lesson Study facilitators at their school; they also formed an "Instructional Leadership Team Steering Committee" with site administrators to strategize and manage School-wide Lesson Study. School O did not have a district-based teacher fellow system, but the School O principal designated teachers at several grade-bands as teacher-leaders of the mathematics Lesson Study work. The principal and these teacher-leaders formed a steering committee that oversaw Lesson Study. School C had a school-based mathematics coach (previously a full-time teacher at the school) who coached teachers and also taught some student mathematics classes; in the early years, this coach organized the master lesson study schedule and visited each grade-level team to support teams' planning work and content study. As teachers became better acquainted with Lesson Study, grade-band teacher representatives joined the coach and administrators to manage School-wide Lesson Study.

All three schools thus had some version of a steering committee (called by various names) that had overall responsibility for professional learning, and that strategized how to use Lesson Study to support the school vision. A 2019 presentation by educators from School S summarized the role of the Steering Committee as follows:

Manages logistics: - Scheduling team meetings, research lesson, and substitute teachers; - Provides team agendas, protocols and facilitation of public lessons.

Manages organizational support: - Anticipates and monitors challenges; - Protects time for the work.

Aids knowledge flow across teams: - Strategically plans knowledge flow across settings (whole-faculty, teams, individual classrooms).

Strategizes knowledge flow into and out of school: - Identifies and coordinates knowledge resources to help realize the school vision; - Identifies expert commentators to observe and provide feedback on the research lessons, inform the schools theory of action and suggest useful resources.

Dec.	12/4	Staff Meeting: Restorative Practices and Second Step	12/6	GLC: 2-Day District Wide Public Lessons Grade 1 and 5 Public Lesson
	12/11	ILT: Fishbone & Defining "Independent Learners" as a staff (plan for Staff Meeting)	12/13	PD: Lesson Study Meeting 5
	12/18	Staff Meeting: Fishbone & Defining "Independent Learners" as a staff	12/20	GLC:
	12/25	**WINTER BREAK**	12/27	**WINTER BREAK**
Jan. F&P and RI Assessments	1/8	ILT Steering Committee	1/10	PD: Lesson Study Meeting 6
	1/15	Staff Meeting (Cont. defining Independent Learners as a staff + first whole school lesson logistics)	1/17	GLC
	1/22	ILT Steering Committee	1/24	**PD: Public Lesson 1- Second Grade Team**
	1/29	Staff Meeting (Health Advocate/Committee Black History Month Planning)	1/31	GLC
Feb. Data Meetings	2/5	Staff Meeting: Lunar New Year	2/7	**PD: Lesson Study Meeting 7** ***K/1:*** Final before Public ***2nd***: Reflection Day ***3rd***: Unit Planning ***⅘:*** Unit Planning
	2/12	ILT Steering Committee	2/14	GLC
	2/19	Staff Meeting: 2nd Grade LS Learnings, then team reflections Implication for our next lesson study cycle	2/21	**PD: Public Lesson 2- Kinder/First Grade Team**
	2/26	ILT Steering Committee	2/28	GLC

Figure 10. School A Schedule, Showing Whole-School, Steering Committee and Lesson Study Team Meetings

Figure 10 excerpts an annual professional learning schedule that shows both whole-staff meetings and grade-band lesson study cycles. All three schools had some similar documents, which showed the interplay among whole-staff meetings (e.g., to develop the school research theme or learn about a new instructional strategy), grade-band Lesson Study cycles, and teacher observation of the research lessons conducted at other grade-levels.

The Steering Committees also noticed and solved challenges. For example, at School O, teacher leaders noticed that teams struggled to conduct a content study using their adopted textbook, and they arranged for an outside mathematics specialist to visit the school and work on a content study with the lower-grades team using a state-published framework as the text for their work.

At all three schools, the Steering Committees adapted Lesson Study structures over time, as they noticed new opportunities and challenges within the school-wide work. For example, at School S, research lessons were initially observed just by the teachers on the Lesson Study team. The Steering Committee spread promising ideas from these lessons through a newsletter with photos and descriptions of practices such as planned board work and journals. By summer 2018, a teacher-fellow at School S advocated "significant changes to the way our school does lesson study from a logistics point of view. I want…all teachers to be present at the public lessons and …to use our Thursday early release time to accomplish this." All three schools found ways to redesign their schedules so that all teachers (or at School C, all teachers of mathematics) could observe all research lessons. The schools also found ways to keep Lesson Study from being a one-off "event" and instead make it central to ongoing improvement. For example, the Steering Committee at School S created bi-weekly data collection prompts, asking teachers throughout the school to bring classroom artifacts (e.g., student work, photos, tasks) to their grade-band team meeting. The prompts focused on challenges noticed by the teacher-leaders, such as the need for discussion norms and prompts. As teachers regularly discussed classroom artifacts with their grade-band teams, working on the school research theme became a routine part of teachers' work in between Lesson Study cycles.

4.5. Synergy of the Four Factors

To recap, data suggest four factors associated with sustained, effective Lesson Study: (1) teacher agency; (2) an instructional vision that values student thinking and makes it visible; (3) teachers' content study and access to content expertise; and (4) site-developed structures to manage and strategize School-wide Lesson Study. It should be noted, however, that these factors were not necessarily present at the outset; they developed over time, building on each other. Table 3 characterizes the factors in 2015 and 2019. From the outset, the intervention design valued teacher agency, by starting with interested volunteers and by eliciting *teachers'* vision as the basis for the School Research Theme and having *teachers* determine the mathematical content and resources they would focus on. School S teachers initially chose to study resources from three different mathematics instructional programs before eventually concentrating their focus on TTP in year 3 of the work. Teachers' embrace of TTP emerged slowly over time, as teachers realized TTP components such as journals made student thinking visible, and as students responded positively. In other words, *teachers'* observations of what was valuable for student learning and teacher learning drove the redesign of teacher learning routines.

Table 3. Comparison of the Four Factors in 2015 and 2019

Dimension	2015	2019
Teacher Agency	Individual or team experimentation with instruction and curriculum	Shared, public, teacher-led experimentation. Collective responsibility to achieve school vision by refining instruction, curriculum and teacher learning routines
Content Study and Access to Expertise	Variable across individuals, not integrated with the observation of instruction	Content Study routines integrated into Lesson Study planning and observation practiced by all teachers choose outside content experts to invite
Mathematics Instructional Vision	Strategies, tips, and tricks, some related to problem-solving	A comprehensive vision of how students learn mathematics through problem-solving, with practical tools to make student thinking visible and use it in the classroom (journals, board work, etc.)
Management Structures	Variable and multiple, may focus on discrete goals (e.g. formative assessment) rather than school vision	The steering committee maintains focus on achieving the school vision by improving student and teacher learning routines

5. CONCLUSION

In summary, the sites that developed and continued School-wide Lesson Study were characterized by strong teacher agency; an instructional vision that values and makes visible student thinking; teachers' content study and access to

content expertise; and the development of structures to strategically manage School-wide Lesson Study. The central role of teachers' learning within the development of School-wide Lesson Study probably accounts for an interesting feature of Figures 1 and 2: the slight *decrease* in mathematics performance from the baseline year to the first year of School-wide Lesson Study (for most demographic subgroups). This decrease likely reflects the challenge of learning to teach in new ways; teachers gave up teacher-led modeling of new concepts/procedures, but had not yet established strong routines to support problem-solving, such as journals and boardwork. A performance dip is typical for innovations that require teachers to develop new skills and understandings, and how educational administrators respond to the performance dip can play a critical role in a reform's success or failure (Fullan et al., 2005). In the case of these three schools, the principals, teacher-leaders and outside commentators helped teachers focus on *leading* indicators of change, such as students' interest in problem-solving, visible student thinking on the board and in journals, and teachers' content study, while ignoring the *lagging* indicator of change (standardized test scores). We can imagine a very different outcome if educational leaders had focused on the standardized test score dip in 2015-16. A second important point is that teacher agency, and efficacy probably fueled the other areas of development. Teachers began by articulating their long-term vision for students, studying what was known about the content and its teaching, and testing changes to instruction. As they saw the impact of small actions-for example, of eliciting student thinking in journals-they became confident in taking bigger actions to change both classroom instructional routines and teacher learning routines and to provide instructional leadership for their schools. Third, our research confirms prior research suggesting the importance of access to content expertise and to problem-solving-based instructional materials, for mathematics Lesson Study conducted outside Japan (Clivaz & Takahashi, 2018; Groves et al., 2016). Finally, our findings suggest that teacher agency is central to designing sustainable School-wide Lesson Study. Schools embarking on School-wide Lesson Study should involve teachers as key players in work from the start while also providing access to content expertise and a high-quality instructional approach centered on student thinking. When teachers have an opportunity to consider their long-term vision for student development (LSGAMC, n.d.-b), to enact and refine it through Lesson Study, and to access content knowledge, they will be positioned, like teachers at these three schools, to change the future for their students.

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