



Designing Effective Lesson Study Practices for Mathematics Education Students

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Abstract

This article presents the author's experiences over a decade of using a modified version of lesson study with mathematics education students and educators in the grades 7 – 12 public schools. The article also reviews two years of data from four teams of mathematics education students who engaged in collaborative planning, evaluations, and research lesson reflections. Five themes emerged from data analysis; innovation and success demand time, goal setting importance, making connections, and reinforcing and valuing discipline stewardship. Lesson study caused the mathematics education students to ponder their roles, responsibilities, and the complexity of teaching. The 7-12 educators viewed lesson study as an opportunity to learn more regarding how their own students process information and thus to view lessons through their students' eyes. Five modifications to lesson study practices are provided for using the full lesson study cycle with mathematics education students.

Introduction

Since the publication of *The Teaching Gap* (Stigler & Hiebert, 1999), lesson study has been gaining ground as a professional development model in the United States of America to deepen K-12 educators' content knowledge, increase their pedagogical understanding, and develop their ability to observe student learning (Burroughs & Luebeck, 2010). There have been successes, but unfortunately many school initiatives fade away. Takahashi and McDougal (2016) stated that teaching mathematics is a complex activity and "researchers, educators, and teachers around the world have attempted to use lesson study to improve teaching and learning" (p.514). However, these authors also acknowledged that determining why lesson study has been continually effective in Japan but not elsewhere is difficult; considerations included whether vital components of Japanese practices are badly translated, necessitating different explanation, or whether cultural differences prohibit its successful use by others (p. 514).

In Japan, many schools use *jugyo kenkyu* (a *research lesson*), to systematically improve their practice and profession. Although neither mandatory nor funded, many Japanese teachers organize research lessons within their schools for inquiry into their own teaching (Doig & Groves, 2011), and through studying these lessons they seek to systematically improve student learning, understanding, skills, attitudes, engagement, and behavior.

There also has been a movement to utilize lesson study in initial teacher education ([Baldry & Foster, 2019](#); [Larssen et al., 2018](#); [da Ponte, 2017](#)). [Wang-Iverson and Yoshida \(2005\)](#) stated, “Lesson study can also be a part of pre-service programs and first-year teacher education experience” (p.3) although they did not provide any accompanying procedure. Others have indicated that there is little research regarding procedures for including mathematics education students in lesson study and little on its impact ([Fernandez, 2002, 2010](#); [Hiebert, Morris & Glass, 2003](#); [Post & Varoz, 2008](#)).

It is important to note that K-12 educators in a school or district are traditionally considered the main participants of lesson study, with mathematics education students having a subsidiary role ([Burroughs & Luebeck, 2010](#); [Meiliasari, 2013](#); [Post & Varoz, 2008](#)). Lesson studies are “predominantly inservice teachers with a few preservice teachers mixed in” ([Lewis, 2019](#), p. 487). In a literature review by Larssen and colleagues (2018) only 17% of the 500 articles reviewed related to lesson study use in initial teacher education with only five discussing opportunities for the full lesson study cycle with mathematics education students conducting a research lesson in K-12 schools.

Aims of this article

[Stigler and Hiebert \(1999\)](#) stated, “If undergraduate methods courses were reconstructed to introduce students to collaboratively planning and testing lessons, new teachers would be ready to assume leadership roles more quickly” (p.158). This assertion fueled the author’s decade of investigating the use of the full lesson study cycle with secondary mathematics education students enrolled in a mathematics methods course taken prior to their year of student teaching.

The main aim of this article is to describe a modified form of lesson study tailored for positioning *mathematics education students* as its main participants, rather than K-12 teachers as traditionally utilized, or one where the “[methods] instructor plays a more dominant role” ([Lewis, 2019](#), p.492). A second aim of the article is reporting the reflections of mathematics education students and K-12 educators utilizing this modified form of lesson study, to show what they have most valued.

The emphasis on designing modifications so that the mathematics education students are positioned as the main participants arises from the observation that these students’ roles often become inconsequential when they are included in lesson studies among K-12 teachers. [Burroughs & Luebeck \(2010\)](#) proposed that this is because mathematics education students’ have limited classroom experience and therefore they are not able to correctly anticipate student thinking, identify misconceptions, and adjust the timing of a lesson during delivery. On the contrary, based on the author’s experiences, this article claims that given ample time for instructional materials research (*kyouzai kenkyuu*), and by placing them in positions of leadership, mathematics education students can be successful with all stages of lesson study and be highly reflective.

Important Modifications to Lesson Study

The modification of lesson study practices to meet the needs of mathematics education students has undergone ten years of development by the author, the instructor of the 7-12 Mathematics Methods course at a small liberal arts university. This work has been done in collaboration with six local area high and middle school educators. Although adjusted for small improvements and modifications yearly through data analysis and for changing

groups of students, the modified form has not significantly changed over the past nine years. It has been iterated yearly to make small refinements to practices and the lesson study schedule (see [Appendix 1](#)). This schedule assists the methods instructor and mathematics education students, by presenting the required tasks chronologically.

[Larsen and colleagues \(2018\)](#) stated, “teacher educators need to be rigorous in the way they describe and discuss how they adapt LS for use in ITE [initial teacher education]” (p.19), and [Baldry and Foster \(2019\)](#) have indicated that several different models have emerged. In order to maintain high fidelity to the full lesson study cycle ([Lewis, 2002](#); [Lewis & Hurd, 2011](#)), and to demonstrate adherence to a set of institutional structures and practices deemed important for maximizing the impact of lesson study, the present modified form of lesson study retains an emphasis on the six main elements defined by [Takahashi & McDougal \(2016\)](#):

- A clear research theme
- Instructional materials research (*kyouzai kenkyuu*)
- A written research proposal for the lesson
- A live research lesson and discussion;
- The involvement of knowledgeable others; and
- Sharing of results.

Whilst detailed descriptions follow in the next section, the main modifications are summarized here.

Main participants:

Mathematics education students are placed in leadership roles in all aspects of the lesson study except in the role of moderator of the post-lesson discussion, which is reserved for the instructor. The hierarchy of importance of the roles, which changes very little during different stages of the lesson study cycle, is mathematics education students, instructor, K-12 educator(s), knowledgeable other(s), principal of the school

Source of research purpose:

The clear research purpose is driven by teachers’ reports of aspects of mathematics that are difficult for K-12 students and the main goal of the lesson study is building all stakeholders’ expertise and additional new learning regarding solving these problems or issues.

Clinical Interviewing:

When preparing for the lesson, in order to increase their understanding of student thinking, mathematics education students undertake some clinical interviews with K-12 students like those whom they will be teaching.

Lesson Recording:

Lessons are videotaped, usually with multiple cameras, and mathematics education students view these to examine the lesson’s impact upon K-12 students’ learning and the research theme.

Mathematics Faculty involvement:

The knowledgeable other(s) are recruited faculty from the university’s Mathematical Sciences Department who concurrently teach content-focused courses to the participating mathematics education students.

Detailed procedures

In 2002, [Lewis \(2002, p. 3\)](#) outlined the four stages of lesson study cycle as being Goal setting and Planning, Conducting the Research Lesson, Post-lesson Discussion and Consolidation of Learning. These four stages are utilized as headings in this section to organize further explanations of the main practices and schedule modifications.

Goal Setting and Planning

Selecting the lesson study topic

The *research lesson* produced is the centerpiece of *lesson study*. [Wang-Iverson and Yoshida \(2005\)](#) said, “It is especially important to think of lesson study as ongoing, self-directed, professional learning, not as teacher training and lesson development” (p.4). As such, the research lesson is designed to address a specific problem of practice or educational issue in a secondary school through a hypothesized trajectory (a lesson plan to attempt) created by a team of mathematics education students wearing ‘researcher hats’ during goal setting and planning.

Utilized in this way, the focus of research lessons remains on professional learning and not the training of new mathematics educators. Rather than requiring mathematics education students to produce a research topic, local educators are asked for possible topics. Ideally, they identify the lessons that are the most difficult for their students to understand or cause confusion, contain misconceptions, have naïve ideas associated with content, or relate to topics from the Common Core State Standards for Mathematics (CCSSM) that seem difficult to incorporate into lessons. Educators in schools appreciate this request, as they know that the mathematics education student teams will spend large amounts of time preparing, researching, and uncovering a new approach.

The goal, then, is for mathematics education students to select lessons of interest from this list of possibilities, typically from different courses (e.g., Algebra II & Geometry), and research the problems and issues identified by the classroom educators in order to expose something new and build their expertise of teaching K-12 students. Typically, during lesson study, K-12 educators devote 20 hours to working collaboratively ([Burroughs & Luebeck, 2010](#)), and more than five weeks over the duration of a lesson study cycle ([Takahashi & McDougal, 2016](#)). The university mathematics education students always exceed these benchmarks.

Instructional materials research

During the *kyuozai kenkyuu* (instructional materials research) phase, the mathematics education students examine published materials regarding the lesson topics. To facilitate, the methods instructor creates a shared online folder using Google Drive, containing subfolders for each of the lesson study teams. Mathematics education students and K-12 educators place all documents garnered from their instructional materials research into this shared space, with K-12 educators requested to contribute only their past attempts at teaching the topic, associated notes, and thoughts of why a plan failed or other issues and struggles faced by their students. When possible, they also submitted any previously used worksheets or student work.

Searching for engaging activities is the first desire of mathematics education students at the study's onset, as this resembles their previous planning experiences. This is not the intent of *kyouzai kenkyuu* which requires a deep study of materials, therefore certain aspects of research should be assigned to promote survey of a wider range of resources. As this beginning should not resemble previous lesson planning experiences, mathematics education students need prompting to go beyond looking for activities in familiar sites.

To motivate a broader search, the methods instructor can read a segment from research concerning common misconceptions or naive intuitions unfamiliar to the student teams and ask how this information might affect their choices during planning. To refocus their research, mathematics education students are tasked to locate several peer-reviewed journal articles on their respective topic from mathematics education journals. Each chooses a favorite article and summarizes for the methods class, emphasizing the key pieces of information or research they feel the teams should know before beginning planning.

A second focusing task is the team's completion of the Collaborative Planning Document presented in [Appendix 2](#). This was modified by the instructor from the work of others, and contains a set of provocative, guiding questions. Frequently, these questions prompt the team to engage in additional searches. Through this work, the shared folder grows to include items such as learning trajectories; possible tools, models, manipulatives, or materials; high-level, cognitively demanding tasks; instructional strategies for the topic; and relevant Standards of Mathematical Practice that may be applied to the instructional approaches or strategies being considered.

[Burroughs & Luebeck \(2010\)](#) predicted "their [mathematics education students] limited classroom experience would make it difficult for them to anticipate student responses and misconceptions or to estimate timing of the lesson elements" (p.392). Since the desire is for mathematics education students to engage deeply in all of stages of lesson study, their research is outlined, assigned, and structured. This is also facilitated through the Collaborative Planning Document (see [Appendix 2](#)) and the methods instructor checking the history of changes to this dynamic document and who is making them.

Armed with hours of research, mathematics education students have a better capacity for anticipating secondary students' thinking, something with which even experienced educators struggle, as reported by [Burroughs and Luebeck's \(2010\)](#) finding that "in-service teachers were also weak in this area" (p.399). Focused research of the guiding questions in the *kyouzai kenkyuu* stage allows mathematics education students to be relatively successful with this highly cognitive and difficult planning stage.

Clinical interviews

Another added practice that assists mathematics education students in accurately predicting K-12 student generated responses and solutions, along with addressing misconceptions, is having them conduct brief clinical interviews during the collaborative planning stage. These interviews are with one or two randomly selected students from a mathematics course that is similar to the one in which they will be conducting the lesson study later in the semester (although possibly a different section).

Individual, structured interviews regarding a topic reveal what K-12 students understand as well as any, specific difficulties or confusions. They can assist the mathematics education students in recognizing how learners think and make sense of a topic and the associated concepts. The interviews especially assist the mathematics education students to identify factors contributing to learners' confusions or misconceptions, and thereby helps them in facilitating learners' construction of valid concepts ([Stepans, Schmidt, Welsh & Reins, 2005](#)).

Finalizing the plan

The research for lesson development is completed by the mathematics education students during their regularly scheduled class time. They synthesize their ideas and place them into a 3-column lesson study plan ([Lewis, 2002](#); [Matthews, Hlas & Finken, 2009](#)). The required template is downloaded from the Lesson Study Alliance Group ([Lesson Study Alliance Group, no date](#)). This template provides spaces for lesson steps, learning activities, key teacher questions and expected student reactions and responses, teacher support (teacher responses to student reactions; items to remember), and evaluation (goals and methods). Its completion requires that the design teams think about questions for the observers of their lesson. It is recommended that the completed 3-column lesson plan is given in advance to all involved with the lesson study, as it helps observers focus their attention on things that the design team would like them to observe and consider during the research lesson. These things are highlighted in yellow in the 3-column plan at the time it is distributed to the observers.

[Appendix 3](#) shows a checklist for preparing for a research lesson to be taught at the high school level. It sets a timeline for the methods instructor and the mathematics education students for some of the key considerations of this modified form of lesson study.

Conducting the Research Lesson

Teaching and observing the lesson

At an appropriate time of the year when the lesson topic is scheduled in the local high school's curriculum, a block period (90-minute class) is selected for the research lesson to be taught. The teaching is done by a pair of mathematics education students from the design team. Although other team members may teach the lesson to other classes, for each team only one high school period is chosen for videotaping and lesson study observation. A major difference from other lesson study practices (e.g., [Lewis, 2019](#)) is that university mathematics education students are teaching the lesson whilst the methods instructor and K-12 educators are observers.

Outside experts observe the particular lesson taught, and here the mathematics education students turn to the Mathematical Sciences Department for partnership with faculty teaching related courses such as Modern Geometry for Teachers, Abstract Algebra, College Algebra, or Calculus, and invite a particular faculty member to serve as a knowledgeable other. Mathematical Sciences faculty have extensive content knowledge and their reflections on the lesson are important during the post-lesson discussion, offering insights concerning the lesson's mathematics and how it was structured and presented by the design team. The methods instructor also serves earlier in this process as a knowledgeable other for the planning and proposal development, leveraging his or her pedagogical expertise.

Video-taping the lesson

One high-quality camera is placed on a tripod at the side or back of the room to capture the lesson. It captures the broad landscape of the room, showing the mathematics education students presenting the lesson and the high school class as a whole. The remaining mathematics education students have small video cameras that can quickly and unobtrusively be turned on and off to capture small group discussions and actions of high school students during the lesson.

All videos are placed on the university's streaming server on the same day as the lesson is taught. This affords mathematics education students the opportunity to step back, consider the goals and objectives of the lesson and research theme, perceive more minute details, and locate supporting evidence. In short, video clips show missing the mark and attainments of goals and instances of how the lesson affected the high school students' learning.

Post-lesson discussion and consolidation of learning

The lesson debriefing and reflection is held at the university within a few days of the lesson. It begins with a welcome from the moderator (i.e., mathematics methods instructor), and then proceeds with the lead mathematics education student(s) (who taught the lesson) sharing impressions of the lesson, followed by the other design team members, then other mathematics education students and observers. The discussion and questions consider whether the purpose and goals of the lesson were achieved, decisions in the original plan and deviations from it, and high school students' responses and discourse reflecting their understanding of the lesson, including connections made among mathematics, prior knowledge, and the real world.

Baldry & Foster (2019) call for the necessity of "having a 'stop' protocol that anyone can enact if they perceive a drift" (p.155), with the methods instructor serving as moderator and maintaining a focused, evidence-based analysis. The mathematics education students are encouraged to bring into the discussion evidence from the Lesson Study Discussion template (see [Appendix 4](#)) that they complete directly after the lesson and before the post-lesson discussion. It is here that they answer the all-important question, "How did the lesson affect student thinking and learning?" The moderator has the additional task of summarizing the salient points, concluding with recommendations for changes to the lesson based on commentary made.

Final report

The mathematics education students are charged with revising the lesson and its materials based on the post-lesson discussion, determining which recommended changes will be utilized. They then write a final reflection of the lesson taught, selecting high school student work to be included with the lesson. They send their revised materials to the K-12 educator and observers. When possible, a celebration of the lesson occurs in the mathematics methods course with food and drink and the K-12 teacher is invited and presented with a small gift.

Reports of Lesson Study Experiences

This section reports on the experiences of mathematics education students and the K-12 educators who have participated in these modified lesson studies. The section relays reflections of those involved regarding the practices, processes, and impact of this modified form of lesson study.

Data Collection and Analysis

Data on the experience of the modified lesson study form was collected by the author (course instructor) from 16 mathematics education students from two consecutive years of the 7-12 Mathematics Methods course and the two participating K-12 educators from the local high school. Two lesson studies were conducted each year making a total of four. Over the decade of developing this modified version there have been six different K-12 educators participating. For the two years of data collection, the same two educators volunteered participation. Yearly engagement from K-12 educators is common.

Methodology

The data analysis methodology was based on [Creswell's \(2007\)](#) four data analysis procedures of data managing; reading and memoing; describing, classifying, and interpreting data; and representing data. The data sources were open ended essay questions from final exams, written reflections of the mathematics education students, lesson study Collaborative Planning Documents (see [Appendix 2](#)), and structured email interviews were produced. The researcher developed open-ended, non-scored questions for mathematics education students to answer in essay form at the end of their final exam, with the instruction to freely write whatever came to mind. Sample questions include:

- What do you think the process of Lesson Study has taught you about lesson planning and teaching a mathematics lesson?
- What will you implement as a result of having gone through this process in the planning of your future math lessons?

The participating K-12 educators were asked structured questions in an email, with questions such as:

- How have our lesson studies impacted you?
- What do you think this does for the partnership between the University and the high school? What is gained?
- What do you think are the benefits of lesson study and this collaboration? To you? To your students? To mathematics education students?

Although guided by structured questions, the style of inquiry allowed the interviewee to tell his or her story ([Rubin & Rubin, 2011](#)), as participants were directed to write freely whatever came to mind. Follow-up emails were used if clarification of responses was necessary. These data were read and re-read by the researcher while making notes, which revealed emerging themes.

Mathematics Education Students' Reflections

The following themes emerged from the mathematics education students' reflections on the complexity of teaching their research lessons.

Innovation and success demand time

One of mathematics education students' most frequent reflections concerns the work and effort necessary to consider deeply their individual teaching and high school student thinking. One mathematics education student commented,

"I realized that a good lesson plan does not just appear overnight. It takes time to look up good resources and determine what tasks are good, okay, and bad for the lesson."

This was continued by another mathematics education student:

"My major take-aways from the lesson study are that innovative and successful lessons take time to develop. I also learned that in order to improve lessons, I constantly need to reflect back on them."

It is important for mathematics education students to enter their subsequent full year of student teaching *already* understanding the choices they must make in planning quality lessons, with lesson study allowing to understand the time and resources necessary for more successful lessons.

Importance of goal setting

Mathematics education students see the importance of patience in setting lesson goals. This form of lesson study encourages them to not rush into this, and to review their goals frequently:

"One thing that I learned is that even though you may have a bunch of ideas for what you want to do with students, you have to first identify the goals and objectives. That is something many of us struggled with during the lesson study...that you cannot just jump into tasks of a lesson without establishing what your goals of the lesson are first."

Affording mathematics education students ample time for in-depth *kyouzai kenkyuu* in the methods course allows them to see the linchpin of the research lesson as setting and assessing their goals. They have the ability to reflect deeply upon this:

"I learned how to closely analyze the curriculum so that I could develop and set goals such as setting content, overarching, connection, and development goals for the students. The lesson study also required me to think about how we would help the students achieve these goals that we set for them. Before the lesson study I had simply only thought about content goals and I had also not thought about what would be required of me as a teacher to help these students reach these goals. In the future, I plan on deeply analyzing

my textbook/curriculum so that I can set all of these goals for all my lessons. I've realized that if I do not spend time doing this, my lessons will lack direction and students will more than likely miss the bigger picture. The goals are also there to remind me what I need to be teaching to students and they can be used as a checkpoint."

When university methods instructors act more as facilitators of *kyouzai kenkyuu*, allowing the design team more autonomy, mathematics education students realize that goals and goal setting are important. If methods instructors and K-12 educators have too much influence during this stage, the major understandings of (1) establishing goals before tasks, (2) alignment of different types of goals is necessary based upon lesson aims, and (3) how best to assist and assess high school students in meeting their goals, may not emerge as major learning outcomes of lesson study. Mathematics education students should not be robbed of this opportunity to think deeply about goal selection, its importance and alignment to research, and how to provide evidence to relay what was valued in their lesson development.

Making connections

Making connections within mathematics has become a stronger focus since the [National Council of Teachers of Mathematics 2015](#) publication, *Principles to Actions: Ensuring Mathematical Success for All*. Although discussed in a separate module of the university methods course, mathematics education students demonstrated its value by incorporating connections into the lesson studies:

"A major connection that I made was that I need to help my students develop connections with the material. I've realized that a lot of student confusion and lack of success comes down to students not understanding the connections in mathematics... In our lesson study, we used Desmos to develop connections between transformations on graphs and the equations... I guess before I took this course, I knew connections were important, but I did not realize how important. Because of this, I am going to try to help my students to always make connections to something that they already know."

The significance of teaching connections within mathematics appeared as an important aspect of lesson study, which may be influenced by instructional materials found during the research phase, or questions found on the Collaborative Planning Document (see [Appendix 2](#)).

Reinforcing stewards of the discipline

Mathematics education students view lesson studies as a reaffirmation and invigoration of their anticipation regarding teaching. One stated,

"A major take-away from our Lesson Study is probably the most important that could happen. I have reinforced my drive to become a good teacher."

This finding is in line with [Gunnarsdóttir & Pálsdóttir \(2011\)](#) as mathematics education students in their study, "developed their professional identity," (p.2667) realizing that they have become eager and stronger in their ability to deal with the complexity of teaching mathematics, and that they desire to be successful. Another mathematics education student shared,

“Going in depth about the lesson you are planning when it comes to particularly tough topics to plan for is good because you can see many different views on the topic and try to plan the best possible lesson based off of everyone’s viewpoints.”

These mathematics education students felt the collaborative aspect of the planning stage was important for growth as a professional.

To be a steward of the discipline means managing resources effectively, and involvement in such scholarly work as lesson studies involves a set of roles, responsibilities, and skills, all of which ensure competence and principles of teaching that lead to the establishment of a moral compass (Bass, 2006). This reinforcement of drive to be ‘good’ is easily manifested within the “integrity of the community” of lesson study (Bass, 2006, p. 113). Gunnarsdóttir and Pálsdóttir (2011) also found that students come to realize how important it is to think and plan collaboratively. A student motto in the methods course was, “Ten minds are better than one at solving this problem of practice.”

K-12 Educators’ Reflections

K-12 educators have also been receptive and reflective of lesson study. One educator has repeatedly made the same post-lesson request, “Can you please send me all of the materials for the lesson?” indicating the desire to use the lesson with those not having experienced it. A strong relationship has been built between the university and the K-12 educators regularly volunteering their classrooms for the use of lesson study.

Understanding students’ thinking

In the decade of experience, several educators have mentioned that they desire to remain fresh and naïve to the design team’s lesson and not preview it, so as to fully experience it with their high school students:

“Your lesson studies have let me sit as a student and view inquiry learning and collaborative learning through my student’s eyes. This helps me as a teacher when planning my own activities and lessons to foresee what students will understand or maybe struggle with comprehending.”

This response indicates that the K-12 educator values lesson study as an opportunity to view and better understand student thinking so that they can improve their own teaching. As Wang-Iverson and Yoshida (2005) proposed, “The ultimate purpose of these activities is to yield new ideas about teaching and learning based upon a better understanding of student thinking” (p.5). When asked about the benefits of lesson study and its collaboration, this same K-12 educator reported:

“Whenever you try something new in the classroom, everyone learns. The teacher discovers new ways of presentation and communication. The students comprehend new material or gain further understanding and pre-service teachers get to experience the role of a teacher.”

Valuing discipline stewardship

All participants gain new knowledge, and K-12 educators not only value the opportunity to assist in the enculturation of aspiring new teachers. As discipline stewards, they feel obligated to share their knowledge and support mathematics education students in considering how the lesson affected their high school students, since they know them better than any of the other lesson observers. This sharing of thoughts on the lesson is greatly valued, and these educators feel empowered when mathematics education students look toward them for wisdom,

“As the lesson is being taught, I often get wanted assurance or feedback from the student of how the lesson is going. The student will often look to me for agreement or explanation help when he/she seems to struggle.”

A true spirit of collaboration and mentorship into stewards of the discipline develops between the mathematics education students and the K-12 educators, even though their time together is relatively brief (3-6 interactions over a month and a half). The mathematics education students also exert influence on the high school students they are teaching in the research lesson as the high school students bombarded them with questions before and after their research lesson (*What made you want to become a math teacher? or Why would choose this profession?*). As upper-level high school students are increasingly facing life's decisions, they question what they are meant to do in and after college. A K-12 educator observed these interactions and commented,

“For these [high school] students to then see what other young adults [mathematics education students] are doing and to ask them questions helps pave the path for themselves”.

Perhaps, paths as future mathematics educators.

Discussion and Recommendations

It may appear that these university-school partnerships are flourishing and blossoming on their own, but their fruition requires hard work and planning as can be seen by the modified lesson study practices and schedule. University mathematics methods courses can be structured so as to assist mathematics education students in considering how pedagogical choices affect K-12 students' thinking, learning, skills, attitudes, behavior, and engagement. Methods instructors might accomplish this purpose by maintaining a full lesson study cycle at the forefront of their course with these five key modified practices:

- Positioning mathematics education students as main participants.
- Clearly centering the research purpose on K-12 mathematics students' problems as identified by their teachers.
- Utilizing video footage of the lesson and affording mathematics education students time to reflect deeply with respect to the foci.
- Recruiting knowledgeable others from university Mathematical Sciences departments to observe lessons.
- Giving the mathematics education students the responsibility for the final revisions and dissemination of the lesson plan back to the K-12 educator(s).

As such, research lessons focus on student thinking and learning; something that can best be encountered in a secondary classroom, not a university lecture hall. As [Meiliasari \(2013\)](#) stated, “[a] lesson study model for [a] teaching practice course can be the bridge that minimize[s] the gap between coursework and fieldwork” (p.10)

Lesson study has been practiced successfully in Japan for decades as a means for promoting and achieving inquiry-based teaching with K-12 educators ([Lewis & Tsuchida, 1998](#)). Without modification, it might not be as impactful with mathematics education students, but with well-researched modified forms, it should be considered a valuable tool for enculturating the next generation of mathematics teachers. When modified, it can become a powerful way to assist students in learning to plan via the Common Core State Standard’s vision for teaching mathematics; examine specific pedagogical approaches, strategies and techniques; view intensely the content they will be teaching; and to comprehend all of these through a lens of K-12 student thinking and learning.

The above analysis of comments from mathematics education students showed that after participating in a modified version of lesson study, they consider their roles, responsibilities, and the complexity of teaching differently (also supported by [Burroughs & Luebeck, 2010](#)). It propels them down a trajectory of self-examination, self-regulation, and self-improvement more quickly, while awakening them to the realization that this learning about ‘self’ is best accomplished through a community of practice. It requires a classroom of high school and university mathematics education students, K-12 educators, and Mathematical Sciences and Education faculty working collaboratively to enculturate mathematics students into the profession. By entrusting to them the integrity, quality, and robustness of the field of mathematics education, it is desired that they will in turn become stewards of the discipline.

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Appendices

Appendix 1 - Lesson Study schedule for methods instructor and mathematics education students

- Find local cooperating K-12 educators to volunteer their time, students, and classrooms; potentially from two different high school classes: Algebra I, Geometry, Algebra II, Pre-Calculus, or Statistics.
- Examine schedules of the mathematics education students, K-12 educators, and the time of the secondary mathematics methods course at the University.
- Find times that we can, as a methods class, collaboratively conduct lesson studies (preferably aligned with the methods course time) and choose a period of the day according to the high school schedule.
- Request a list of possible problems of practice from K-12 educators - individual lessons from each of the two courses which cause high school students to struggle, have confusion, misconceptions, or naïve ideas associated with it, and have possibilities of enhancement. Ideally these lesson studies are spread throughout the semester rather than conducted within a short time, but both have worked.
- Select an appropriate number of lessons for the mathematics methods class and assign to small teams of mathematics education students (3-5 students per team).
- Build into the method course schedule, times prior to each lesson study to collaboratively design and provide input to each of the lessons.
- Examine goals for the overarching unit, broad goals of the subject area, long-term goals for student development, and decide on a research theme for the lesson.
- Set goals for the individual lesson - content, overarching, connection, affective, dispositional, and development goals.
- Research materials and report best practices and teaching and learning research.
- Revisit learning goals in light of instructional research materials.
- Create ideas for gathering evidence of learning, motivation, and student development.
- Mathematics education students create a flowchart for the lesson - incorporating selected ideas discussed and put them into a 3-column lesson template.
- Observe the high school classroom and anticipate student thinking through clinical interviews and modify the lesson template.
- Swap 3-column lesson plans among the lesson study teams for feedback to each other's lesson and make revisions based on feedback.
- Make final preparations for the teaching of the lesson.
- Rehearse the lesson in the methods course.

- Develop criteria for analyzing the video.
- Teach and observe the lesson. One or two mathematics education students teach the lesson while the remaining mathematics education students, the university methods instructor, the high school teacher(s), and invited knowledgeable others, make observations of the lesson's impact on student learning and examine the impact of the lesson with respect to the lesson's goals. The lesson is also videotaped.
- Mathematics education students iteratively watch the video tape of the lesson attending primarily to the criteria for analyzing the video. They complete a template aiding the analysis, choosing video segments as evidence (see Appendix 4).
- Debrief the lesson with design team, mathematics education students outside the team, and knowledgeable others present for the lesson in a meeting room at the university.
- Everyone makes suggestions for improvements to the lesson and to instruction.
- Mathematics education students revise the lesson based on the suggestions in the debrief.
- Mathematics education students write a report that has the revised 3-column lesson plan, collected student data if possible, reflections on what was learned, and an analysis of instructional planning.
- Design team sends the report to the K-12 educators and the knowledgeable others who were present.

Appendix 2 - Collaborative Planning Document

Ask yourself and your lesson study team members these questions after you select your topic:

- What is the relationship of the lesson's topic to the CCSSM and other framework documents like the Focus in High School Mathematics: Reasoning and Sense Making? Focus in High School Mathematics: Reasoning and Sense Making in Algebra? Or Reasoning and Sense Making in Geometry? Or Reasoning and Sense Making in Statistics and Probability?
- What are the students' previously learned knowledge and current understanding of the topic?
- What prior knowledge and ideas can be used as a foundation for this new idea?
- What builds from this new idea in the future?
- How does their textbook present it?
- What are some main goals and concepts of the unit in their textbook?
- What is the relationship of this curriculum within and outside of the course?

Remember that *kyouzai kenkyuu* is the study of instructional materials. This means studying:

- a variety of teaching and learning materials, such as alternative textbooks, Internet resources, teacher's guides, worksheets
- how other textbooks and materials may be treating/presenting the topic
- a variety of teaching approaches (e.g., Realistic Mathematics Education (RME), inquiry, discovery, contrasting cases, CRA or CSA, demonstration) that might work for the topic

- the process of student learning, including students' typical misunderstandings, naïve conceptions, common mistakes, and anticipated solutions to typical problems as well as how teachers react to them
- the state of students' learning (what they know and what they can do – what is developmentally appropriate)
- research on teaching and learning of the topic
- learning trajectories of the topic.

Next you should be discussing the specifics of the research lesson (don't move on to this phase too quickly)

- What are the goals of the research lesson? (content? overarching? connection? affective? dispositional? development goals?)
- What is the central problem the research lesson will focus on?
- What do we want students to learn?
- How will we start the lesson to engage and interest students?
- What is the main question/challenge to ask to promote student thinking?
- What instructional tools, models, and manipulatives should we use?
- What task(s) shall we use?
 - How is the particular task useful in helping students develop the new idea?
 - How might this task relate to one they have seen in the past?
 - What is the level of cognitive demand of the task?
 - What equations/expressions/numbers shall we use?
 - How can we make the task accessible to ALL students?
 - What aspects might be sticking points? How shall we deal with them?
 - What errors might students make? How will we deal with them?
 - What are all of the possible ways of solving the task that you can come up with? That a middle/high school student might come up with?
- What handouts and note taking tools should we use?
- How should we organize the whiteboard and make use of other media?
- How will the lesson progress and flow?
- How will we make it coherent? Within mathematics? From one activity or lesson to the next?
- How might we use the design principles of RME appropriately?
- How and where should we end the lesson?
- How should we evaluate the lesson?
- What will be our exit ticket?
- What formative assessment techniques might we implement?
- How will we provide evidence to our goals? How will we know that students have attained them?

Also consider educational issues during this stage

- How will the lesson foster various student skills to solve mathematical problems (e.g., drawing diagrams, tables, graphs, ordering, categorizing, mathematizing, modeling, simulating)?
- How does the lesson ensure equity and access for ALL students?

Modified from p. 8-9, [Wang-Iverson & Yoshida \(2005\)](#).

Appendix 3 - Checklist for Preparing for a Research Lesson (Instructor and students)

1-2 months before the lesson

- Finalize the date of the lesson
- Invite a knowledgeable other (relevant university Mathematical Sciences faculty, e.g., Modern Geometry professor, Abstract Algebra professor) to provide mathematical content and presentation commentary.
- Choose a moderator for the post-lesson discussion (usually the mathematics methods instructor).
- Decide whether to make your lesson public; if so, let the methods instructor know whom else to invite, for example, other K-12 educators.

1-2 weeks before the lesson

- Swap lesson plans among the lesson study teams to provide feedback to each other's lessons.
- Simulate the lesson with the design team to check for "bugs" and to create a board plan (bansho).
- Send lesson plan to knowledgeable others for feedback - even if not final version.
- Schedule "kampai" and invite everyone! (Location: K-12 educator's classroom)
- Establish who will be responsible for taking notes during the post-lesson discussion and videotaping with handheld cameras - consider someone from the other lesson study team to assist in videotaping.

1-3 days before

- Email/distribute your lesson study materials (3-column template) to observers so they can read everything ahead of time.
- Prepare materials for the lesson (handouts, manipulatives, posters).
- Prepare handouts for observers:
 - Copies of final lesson plan - single-sided (so people can use the back to take notes),
 - Copies of any student handouts (may be shrunk to save paper),
 - Copies of the seating chart, drawn from the observer's perspective.

During the lesson

- Bring clipboard + pen/pencil for taking notes while standing (or LessonNote app on iPads).
- Take lots of notes! Record student writing, student comments, student affect. Record your notes on the lesson plan, or on copies of a seating chart, or blank paper. When you have a little experience, try LessonNote (for iPad).
- Do not interact with the students.
- No side conversations, as they might distract the students.
- Stay out of the teacher's way.

Post-lesson discussion (within a couple days of the lesson)

- This is a professional conversation. It is not a 'debrief', not just a 'reporting out', but a discussion.

Objectives

- To shed light on how the lesson, its design and implementation, impacted student thinking, behavior, and affect, relative to the goals of the lesson and relative to the research theme.
- To discuss mathematics education students' selected video clips.
- To identify misconceptions that will need to be addressed in future lessons, and to discuss how they might be combatted.
- To generate ideas for how to address the research theme.

Key personnel

- Moderator (university mathematics methods instructor).
- Knowledgeable other(s) (relevant university Mathematical Sciences faculty).
- Notetakers (all mathematics education students not teaching).

Protocol

- Mathematics education students who taught the lesson will give first comments: How did the lesson go compared to what was planned? What did the teacher(s) observe? If the teacher(s) deviated significantly from the plan, why and what was the result? Did new questions arise that the teacher(s) would like to discuss?
- Other team members are then invited to contribute observations and raise questions.
- Moderator will identify topics for discussion and invite observations and discussion by the whole group including knowledgeable others.
- Observers should support opinions with data; mathematics education students may be able to do this with selected video clips.
- At the end, the moderator will give about 20-30 minutes of uninterrupted, synthesizing remarks.

After the lesson, Kampai! (within a week of the lesson)

- Thank the K-12 educator(s) with a small gift (possibly university swag) and invite them to a celebration.
- Celebrate the hard work of the team with food and drink in the methods course!

Final reflection (within a week of the lesson)

- Obtain notes from the note-takers and scan them. Write a joint reflection of three paragraphs or so describing what was learned from teaching the research lesson and from the post-lesson discussion.
- Append the final reflection to the lesson plan, and send the final version to the K-12 educators and post to a website.
- Share your learning with colleagues at the University, e.g. via a one-page brief (it's nice to include photos!).

Appendix 4 - Lesson Study Discussion Template

Lesson Study's Title:

LS#1 - *Circles are not Pointless: Applications of the Equation of the Circle*

LS#2 - *Thinking Inside the Box: Maximizing the Volume of a Box*

Lesson Study's Date:

04/05/2019

LS#1 - Geometry - Deriving and Using the Equation of the Circle

Research Theme:

Use reasoning and sense making to derive the area of a circle formula. Use the equation of a circle by applying it to real world models.

LS#2 - Algebra II - Maximizing Volume with Cubic Polynomials

Research Theme:

Using reasoning abstractly and quantitatively, students will maximize the volume of a given solid using a cubic polynomial modeling that given solid.

Name:

(also include your name in the title as you make a copy)

Bulleted list of comments that center on the two foci:

LS#1 - Geometry 5th period - How did the lesson affect student thinking and learning?

-
-
- (can be more than three bullets <- delete this)

LS#1 - Geometry 5th period - How did the lesson go?

-
-
- (can be more than three bullets <- delete this)

LS#2 - Algebra II 7th period - - How did the lesson affect student thinking and learning?

-
-
- (can be more than three bullets <- delete this)

LS#2 - Algebra II 7th period - How did the lesson go?

-
-
- (can be more than three bullets <- delete this)

Bulleted list of recommended changes to the lesson design with rationale provided:

LS#1 - Geometry 5th period

- Suggested change bolded. Rationale... unbolded...
- Suggested change bolded. Rationale... unbolded...
- (can be more than three bullets <- delete this)

LS#2 - Algebra II 7th period

- Suggested change bolded. Rationale... unbolded...
- Suggested change bolded. Rationale... unbolded...
- (can be more than three bullets <- delete this)

Video Segments:

Link to streaming video from handheld cameras: <include university streaming server link here>

Link to streaming of main camera: <include university streaming server link here>

Video segment choice #1; From time: _____ to time: _____

Rationale for choosing the clip:

Video segment choice #2; From time: _____ to time: _____

Rationale for choosing the clip:

Note: Align video segment choices to the two foci (high school students' thinking and learning centered on the goals/objectives of the lesson and the research theme); you can have more than two video segments just prioritize/rank them.

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