Lesson Planning Practices of Undergraduate Mathematics Instructors: What Do We Know?

George Kuster, Christopher Newport U.
Sarah Hartman, Western Kentucky U.
Cassie Dick, Western Kentucky U.
Nicholas Fortune, Western Kentucky U.

We surveyed university mathematics instructors across the United States about their planning practices. We sought to better understand the complexities involved in the work that goes into preparing for instruction at the university level. Research indicates that the quality of instructors' lesson plans can be linked to the quality of their instruction (Akyuz et al., 2012). Instructors self-reported as either using inquiry-based practices, lecture-based practices, or an even mix of both. Instructors that indicated using both inquiry-based and lecture-based practices spend more time lesson planning, but often feel less supported by the lesson plans they create. These instructors attempt to do practices that both the inquiry-based instructors do (i.e., spend time preparing for and accounting for student thinking) and lecture-based instructors do (i.e., ensuring a clear understanding of the mathematics for themselves). We discuss implications for instructors and the undergraduate mathematics education community.

Keywords: lesson planning, university mathematics instructors, teaching practices

For decades researchers have investigated the teaching and learning of mathematics. Much of the focus has been on understanding how students think and learn particular topics or ideas, and what in-the-moment instructional practices support student learning. This work is crucial, and more recently some have pointed to the importance of carefully considering this type of information during the instructional planning process (e.g., Akyuz et al., 2012; Stephan et. al., 2017). Much of this work lives in the context of K-12 education, and though it is largely relevant to university education, there are some added complexities. More specifically, pedagogical freedom at the university level means not all instructors teach the same topics or even teach them the same way. This freedom also means individual instructoprs can significantly change pedagogies from semester to semester. Little is known, however, about how instructors build their lesson plans, what they consider when doing so, and how their pedagogical decisions impact their planning practices. This research paper describes an investigative journey into the planning practices of undergraduate mathematics instructors, aiming to better understand the complexities involved in the work that goes into preparing for instruction at the university level. We also explore some similarities and differences in these practices across broadly defined instructional categories: Inquiry-Based, Lecture-Based, and an Even Mix of Both.

Literature Review

While there is some literature about planning practices for K-12 teachers as either pre-service or in-service teachers, there is a lack of literature regarding the lesson planning practices of university mathematics instructors. For example, O'Donnell and Taylor (2007) investigated the relationship between preservice mathematics teachers' focus on student thinking in lesson analysis and lesson planning tasks. Their results highlighted a pedagogical lesson planning format consistent with Shulman's (1987) model of pedagogical reasoning and action which includes comprehension, transformation, instruction, evaluation, reflection, and new comprehensions. This model is used to theorize the knowledge required to develop the knowledge of teaching. Additionally, Amador (2016) investigated the role of teacher noticing during lesson design. Amador's findings emphasize the importance of supporting teachers

through professional development opportunities, specifically focusing on student outcomes, student mathematical understanding, and teacher noticing. Further, Amador (2016) raises questions about how to better support these teachers but also how to further support teachers more broadly as they work in the space between lesson planning and enactment. Additionally, this thinking can also be applied to middle grades educators. For instance, Akyuz et al. (2012) aimed to extract the planning practices middle school mathematics teachers used to create adequate assessments, introduce important ideas, and choose tasks that are appropriate given the objectives of lesson materials. The results mention five core practices that are the foundation of the development of effective planning: preparation, reflection, anticipation, assessment, and revision. These practices align with Shulman's (1987) dimensions. These five practices also align with Stephan et. al.'s discussion of Lesson Imaging (2017) - where they build on Schoenfeld's (1998) work on how teachers expect their plans to be enacted in the classroom. Stephan et. al. outline a visualization process through which K-12 STEM teachers can develop effective lessons by unpacking the goals, imaging the launch of the lesson, anticipating student thinking and reasoning, and then imagining how they will use that thinking and reasoning to support meaningful discussions. Though the previously mentioned literature focuses primarily on K-12 planning, we argue that the same notions may apply to researching the lesson planning practices of university instructors. However, literature about university instructor's lesson planning practices is limited, as the field continues to grow.

Undergraduate instructors' pedagogical decisions in the classroom are represented in literature. Uniquely, undergraduate mathematics educators have the choice to teach in certain ways, often in a lecture format (Fukawa-Connelly et al., 2016). This freedom to choose could impact lesson planning practices. Johnson et al. (2018) stated that the "distinction between lecture and non-lecture pedagogy is not clear cut, especially when looking at how instructors self-identify" (p. 256). In an attempt to investigate why instructors choose to lecture, Johnson (2018) detailed a survey of national abstract algebra instructors at masters and doctorate-granting institutions. Ultimately, Johnson provided insight into factors that influence pedagogical decisions in American abstract algebra classes as well as avenues for approaching and providing better support for those interested in implementing non-lecture teaching approaches (Johnson, 2018). Johnson et al. (2013) indicated an opportunity for the research field of undergraduate mathematics education to "gain insight into the factors and considerations that matter to mathematicians," (p. 2) specifically in teacher identity and stance towards instructional materials. Lastly, research indicates that the quality of instructors' lesson plans can be linked to the quality of their instruction (Akyuz et al., 2012). Thus, understanding undergraduate instructors' lesson planning practices can also shed some light on their instructional practices.

Methods

Our study investigated the lesson planning practices of university instructors through a survey with both quantitative and open-ended items.

Data Collection

Survey creation. We designed a survey using Akyuz et al. (2012)'s lesson planning practices as the overall dimensions that characterize lesson planning activity: preparation, reflection, anticipation, assessment, and revision. In addition to these dimensions we asked questions about different classroom environments, teaching styles, and university characteristics. In light of the discussion by Johnson and colleagues (2017) concerning reasons for making

certain pedagogical choices, we were particularly interested in how instructors defined success in terms of their lesson planning. In this work, we will focus primarily on the preparation and reflection dimensions. Preparation outlines any work prior to the start of instruction. Generally, it includes activities such as creating a learning trajectory, designing an instructional sequence, studying relevant literature, and considering the big ideas of the unit (Akyuz et al., 2012). Reflection involves taking a look into past teaching experiences and classroom interactions to assess quality instruction as well as evaluation of unexpected situations, misconceptions of students, and improvement of instruction (Akyuz et al., 2012).

Survey description and questions. The survey included 11 demographic questions such as instructor gender identity, university type, average class size, and how long they had been teaching. We also asked quantitative and qualitative questions about teaching styles. For example, we asked, "Which of the following best typifies your teaching style?" (with choices of inquiry-based, lectured-based, or a mix) and "Briefly describe why you teach this way. Please be detailed." Then each of the five main dimensions had both quantitative and qualitative items. For preparation, we asked questions such as "On a scale of often, sometimes, rarely, never, please indicate how frequently the following activities are part of how you prepare for a lesson. - Reading relevant education research on the topic (e.g., student learning of the topic)." The anticipation stem contained questions such as "Consider preparing for lessons. On a scale of strongly agree to strongly disagree, please select if you agree with the following statements. - I consider what might happen during a lesson." Questions such as "When teaching, approximately how often do the following occur on a scale of often, sometimes, rarely, never? - I stopped to consider how the students were thinking about the content" was used to assess the reflection stem. The assessment stem asked questions such as "Consider times when you used informal assessment. On a scale of strongly agree to strongly disagree or not applicable (N/A), please select if you agree with the following statements. - I change future lesson plans if grades are poor." Finally, questions including "Consider preparing for lessons. On a scale of strongly agree to strongly disagree, please select if you agree with the following statements. - I often change the order of the content from the textbook as a means to support student learning" were used to assess the revision stem. For quantitative questions, a scale was used for all 5 stems in order to get a clear response, while still offering a range of answer options.

Qualitative questions on the survey included inquiries such as "How does the teaching style you use impact your lesson planning practices?" These questions were designed to differentiate the planning practices of university instructors with different teaching styles and provide us with more data to compare to our quantitative results.

Survey population. The sample for our survey utilized several email listservs as well as directly emailing mathematics department chairs. Listservs included Research in Undergraduate Mathematics Education (RUME), Associate of Mathematics Teacher Educators' (AMTE) Service, Teaching, and Research (STaR), and the American Mathematical Society (AMS) directory of institutions. Potential participants were told that they had to be full-time instructors and that they had to teach mathematics content classes (i.e., general education, mathematics content classes for future teachers, or mathematics majors classes). We received 65 complete survey responses.

Data Analysis

We broke the respondents into three groups based on their responses to a question asking which teaching style they best fit into. We then conducted a series of Analyses of Variance

(ANOVA) to examine the relationships between their chosen instructional style and the responses to the various survey items. Norman (2010) and Carifio and Perla (2008) note that when examining multiple likert-scale items, using a method that compares means and standard deviations (such as ANOVA) is appropriate and yields valid results. We found many statistically significant differences in the way the respondents in the three groups tended to answer the survey questions. All open ended survey items were coded by three of the researchers using thematic analysis (Braun & Clarke, 2006). All three researchers did a first pass of coding then met to discuss codes and repeat the process until a codebook was developed. Then we all coded the data to be able to describe themes from the open-ended items. All disagreements were discussed by all three coders. Lastly, the qualitative data gave us a deeper understanding of what we found from results from the quantitative data and it supported some quantitative findings.

Results

Demographics & Teaching Style

The average length a respondent had taught was 16 years. 80% of respondents worked at 4-year public universities. Likewise, 80% worked at universities that granted PhDs or Masters. 36% of respondents taught K-12 prior to their current teaching position. 25% had degrees in mathematics education and the rest in some field of mathematics. 32 respondents identified as female, 26 as male, 1 as nonbinary, and 6 that preferred not to answer.

Participants were asked "which of the following best typifies your teaching style?" 18 said inquiry-based (i.e., student centered), 15 said lecture-based (i.e., teacher centered), and 32 said an even mix of lecture and inquiry activities. We also asked respondents the following question: "When teaching, approximately how often do the following occur on a scale of often, sometimes, rarely, never? - I stop to consider how the students are thinking about the content." Inquiry-based instructors stop significantly more often to think about student thinking than even-mixed ($p=0.026$) and lecture-based ($p<0.001$), and even-mixed stop significantly more often to think about student thinking than lecture-based ($p=0.048$). This, to us, aligns with a broad interpretation of these teaching styles. In the most basic sense, the role that student thinking plays in these teaching styles is crucial. Instructors that identify as lecture-based indicated they stopped significantly less frequently than even-mixed or inquiry-based instructors.

Lesson Planning

Respondents who identified as inquiry-based do not spend as much time making or reviewing their lesson plans; however, they feel more supported by them. When asked Q21_4: "On a scale of strongly agree to strongly disagree, rate the following statement: I use a textbook to determine how I teach material," respondents who identified as an even mix of teaching styles said that they agree significantly more with this statement than either lecture-based or inquiry-based ($p=0.01$).

Similarly, when asked Q20_8: "On a scale of often, sometimes, rarely, never, please indicate how frequently the following activities are part of how you prepare for a lesson - Reviewing from course materials (e.g., textbook, notes)", respondents who identified as an even mix of teaching styles reviewed course materials significantly more than inquiry-based respondents ($p=0.003$), but there was no significant difference between even mixed and lecture-based and inquiry-based and lecture-based.

However, on Q21_7 despite indicating that they do not create detailed lessons, inquiry-based respondents indicate that they feel supported by their lesson plans, significantly more so than

respondents who identified as an even mix of teaching styles ($p=0.014$). There was no significant difference between other groups.

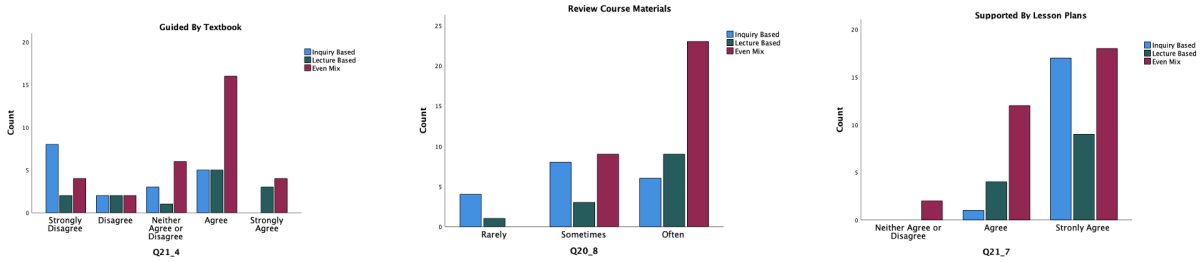

Figure 1. Bar charts showing all responses to Q21_4, Q20_8, and Q21_7.

These results also appeared in the qualitative data. Respondents were asked "How does the teaching style you use impact your lesson planning practices?" and "Please fill in the blank, and be detailed: I feel like I am prepared for a lesson when I have ____." Respondents who identified as lecture-based indicated overwhelmingly that their lesson plans are good because they know what they are going to talk about and the lesson plans are their notes (although those notes varied in format of in their head, on paper, in a PowerPoint, etc.). One participant said, "My planning process is mostly deciding which examples I want to include in class. I usually work through a few examples for each topic. The topic may be explained as I work through the first example." Inquiry-based respondents indicated on open-ended survey items that because they are sensitive to student thinking, their lesson plans are intentionally fluid to account for this. One participant said, "Because I teach in an inquiry-based style, it is important to carefully structure student interaction with each other and the course material to set the stage for their mathematical connections and discoveries." Respondents who indicated using an even mix of teaching styles said that their lesson planning notes are guided by the development of the mathematics, but they know they need to be sensitive to how students are reacting to it. One participant said,

> Rather than a lesson plan "template" that uses the same template or outline for every lesson, at the college level, once I consider the content and the students' needs for that content, then I prepare lesson materials that are most appropriate for that lesson in that moment, whether it be lecture notes, guided notes, activity/inquiry/discovery instructions for the students to engage, problems for the students to explore in problem-based learning, etc. Regardless, I typically will have in my notes (increasingly on Google Docs) a timeline with short notes about process, and more detailed notes where I see fit.

Reading research plays a role in lesson planning. Unsurprisingly, those that engage in inquiry-based teaching or an even mix of teaching styles are more interested in performing research on teaching and learning ($p<0.001$, $p<0.001$) and are more interested in reading literature on teaching and learning ($p=0.009$, $p=0.018$). However, while even mixed respondents are interested in research and anticipating student thinking, they are not doing it as often as inquiry-based respondents ($p=0.002$).

Lesson Reflection

Respondents were asked Q31_4: "On a scale of strongly agree to strongly disagree or not applicable (N/A), please select if you agree with the following statements. - I change future lesson plans if students indicate the content is not clear to them." Even-mixed instructors are more likely to change their lesson plans if students are struggling to understand than both inquiry-based and lecture-based ($p=0.015$). One even-mixed participant said they are prepared when they have:

> ...A goal in mind for that lesson. I am prepared if I have activities that will support that goal and have anticipated questions that the students may ask. I also like to have a means of measuring learning by providing closing questions or homework that I can monitor to see how the material is being understood. This measure allows me to reflect on how the next lesson will begin.

When asked Q24_4: "On a scale of often, sometimes, rarely, never, please indicate how frequently you discuss how a lesson went with colleagues" inquiry-based instructors do this significantly more than either other group ($p=0.005$, $p=0.028$).

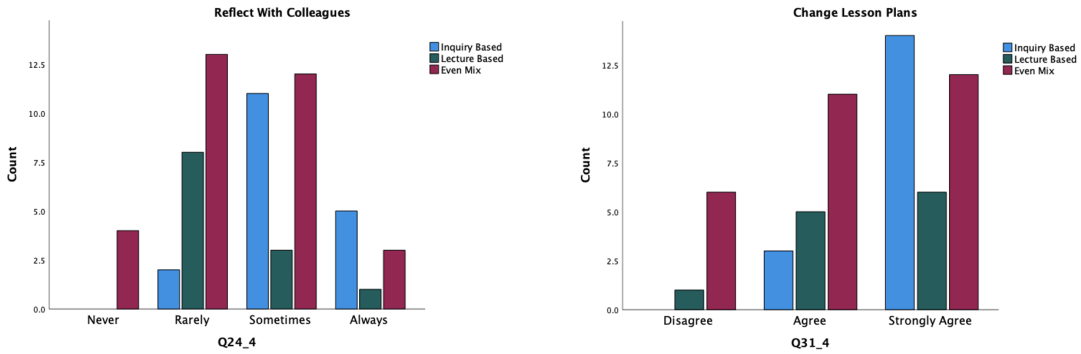

Figure 2. Bar charts showing all responses to Q24_4 and Q31_4.

Limitations

Before discussing our results, we want to acknowledge important limitations of this work. First, 65 responses, while large, is still small in terms of the power of our study. Second, as the data are self-reported, all reference to self-identifying their preferred teaching style was based on their selection of those three categories. Importantly, teaching practices are more than three categories, it is a continuum and it's not easy to distinguish between the ends of that continuum (Johnson et al., 2018). Additionally, we acknowledge that just because someone self-selected into a category, we do not have actual data from their classroom to confirm that their teaching practices in fact do align with these categories. Nevertheless, we believe our study sheds important light on the lesson planning practices of university mathematics faculty.

Discussion, Conclusion, and Next Steps

Our data indicates that different teaching styles do indeed relate to different planning practices. Respondents who identified that they use both inquiry-based and lecture-based teaching styles plan more than either inquiry-based or lecture-based instructors. However, even-

mixed instructors do not feel as supported by their lesson plans compared to both inquiry-based and lecture-based instructors. This begs the question, what are the three groups including in their lesson plans to cause these differences and how do they relate to their goals?

Inquiry-based instructors do not report prioritizing doing the mathematics for themselves prior to a lesson as part of their lesson planning. Lecture-based instructors report having a strong sense of the mathematics for themselves. Whereas, even-mixed instructors seem to be pulled in both directions. They reported that they wanted to ensure they knew the mathematical progression of the content for themselves but still provided enough space to let student thinking drive the lesson. This aligns with the fact that their lesson plans and lesson planning are more involved; they appear to indicate a need to be prepared for everything (i.e., supporting the students' thinking and the mathematics).

Even-mixed instructors also indicated that they are most willing to change their lessons and lesson plans based on student reactions and their perception of how lessons are going. This further indicates the potential that even-mixed faculty are pulled in different directions. Both inquiry-based and lecture-based instructors stay their course, reporting they do not as frequently change lesson plans. Despite inquiry-based instructors reporting they reflect on their lessons more frequently than the other groups, even-mixed faculty make changes to their lessons more often. This further provides insight into why their lesson plans and lesson planning practices are more involved. Perhaps changing their lesson plans so frequently leads to less certainty in the success of lessons.

Collectively, our results indicate that the instructional goals and preferred teaching styles of instructors impacts their lesson planning practices. But more specifically, while most of our respondents indicated they used both inquiry-based and lecture-based teaching practices, that same group also indicated being the least comfortable doing so. Research on teaching practices tells us that instructors use both inquiry-based and lecture-based practices often (Johnson et al., 2018). In fact, as indicated earlier, teaching practices are on a continuum and are not dicotomous. However, regularly shifting along that continuum appears to be the most difficult in terms of preparing for those lessons.

Next Steps

In this work, we only discussed the lesson preparation and reflection (Akyuz et al., 2012) dimensions concerning how university mathematics instructors plan lessons. There is a clear indication that some faculty who try to use both inquiry-based and lecture-based teaching practices need support. Considering our results with those of Johnson et al. (2018), even-mixed instructors often feel overwhelmed by their lesson planning processes and they often change their plans as they go; more so than instructors who self-identify as lecture-based or inquiry-based. Thus, we wonder what support do these faculty need? The undergraduate mathematics education community has provided many professional supports (e.g., TIMES NSF#1431641, SEMINAL NSF#1624643), but it appears that institutional support is just as needed. The average years of teaching was 16 years (which was roughly the same for each teaching category as well) and our data did not find significant differences in terms of how supported instructors feel from their institutions. However, even-mixed instructors did indicate feeling the least supported by their institutions and departments. And these instructors are the ones doing more lesson planning.

References

Akyuz, D., Dixon, J. K., & Stephan, M. (2013). Improving the quality of mathematics teaching with effective planning practices. *Teacher Development*, *17*(1), 92–106. https://doi.org/10.1080/13664530.2012.753939

Amador, J. M. (2016). Teachers' considerations of students' thinking during mathematics lesson design. *School Science and Mathematics*, *116*(5), 239–252. https://doi.org/10.1111/ssm.12175

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative research in psychology*, *3*(2), 77-101.

Carifio J & Perla R. Resolving the 50-year debate around using and misusing Likert scales. Med Educ. 2008 Dec;42(12):1150-2. doi: 10.1111/j.1365-2923.2008.03172.x. PMID: 19120943.

Fukawa-Connelly, T., Johnson, E., & Keller, R. (2016). Can math education research improve the teaching of abstract algebra? *Notices of the AMS*, *63*(3), 276-281.

Johnson, E., Caughman, J., Fredericks, J., & Gibson, L. (2013). Implementing inquiry-oriented curriculum: From the mathematicians' perspective. *The Journal of Mathematical Behavior*, *32*(4), 743–760. https://doi.org/10.1016/j.jmathb.2013.03.003

Johnson, E., Keller, R., & Fukawa-Connelly, T. (2017). Results from a survey of abstract algebra instructors across the United States: Understanding the choice to (not) lecture. *International Journal of Research in Undergraduate Mathematics Education*, *4*(2), 254–285. https://doi.org/10.1007/s40753-017-0058-1

Norman, Geoffrey. (2010). LIkert scales, levels of measurement and the "laws" of statistics. Advances in health sciences education : theory and practice. 15. 625-32. 10.1007/s10459-010-9222-y.

O'Donnell, B. & Taylor, A. (2007). Research, reflection, practice: A lesson plan as professional development? You've got to be kidding! *Teaching Children Mathematics*, *13*(5), 272–278. https://doi.org/10.5951/tcm.13.5.0272

Schoenfeld, A. H. (1998). Toward a theory of teaching-in-context. *Issues in education*, *4*(1), 1-94.

Shulman, L. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard educational review*, *57*(1), 1-23.

Stephan, M., Pugalee, D., Cline, J., & Cline, C. (2016). *Lesson imaging in math and science: Anticipating student ideas and questions for deeper STEM learning*. ASCD.

Taylan, R. D. (2016). The relationship between pre-service mathematics teachers' focus on student thinking in lesson analysis and lesson planning tasks. *International Journal of Science and Mathematics Education*, *16*(2), 337–356. https://doi.org/10.1007/s10763-016-9778-y