TOWARD A FULL(ER) IMPLEMENTATION OF ACTIVE LEARNING

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ABSTRACT

Many university statistics instructors are interested in teaching with active-learning approaches in their classrooms. In this article, we attend to active learning in three ways. First, we review how the statistics education community has addressed issues surrounding active learning implementation to date. Second, we describe how our project used design experiment methodology to create active-learning materials. Finally, using embedded case study methodology, we report on factors that impacted the extent to which statistics instructors facilitated active learning using our project's materials. We describe properties of classroom interactions that led to full implementation of active learning and show how the unifying theme of relinquishing mathematical and statistical authority had explanatory power to inform ways instructors might effectively implement active learning.

Keywords: *Statistics education research; Mathematical authority; Statistical authority; Implementing instruction*

1. INTRODUCTION

Support for active learning is long-standing in the statistics education community (Cobb, 1993; Garfield, 1993; Snee, 1993). The American Statistical Association (ASA) encourages statistics instructors to "foster active learning" in introductory statistics courses (GAISE College Report ASA Revision Committee, 2016), and it is a regular practice among statistics instructors to share active-learning materials for various uses (Marasinghe, Duckworth, & Shin, 2004; Richardson & Haller, 2002; Rossman & Chance, 2008; Samsa, Thomas, Lee, & Neal, 2012). Teaching with active-learning

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strategies is a multifaceted endeavor, requiring instructors to attend to many factors including designing curriculum, choosing appropriate instructional goals, selecting tasks to achieve instructional goals, scaffolding student learning, and facilitating meaningful classroom discourse. Our work in the Modules for Teaching Statistics with Pedagogies using Active Learning (MTStatPAL) project seeks to speak to the field's active-learning endeavor and to contribute to our collective understanding of the critical elements at work in the implementation of statistics instruction in active-learning classrooms.

Since 2011, we have used design experiment methodology (Cobb, Confrey, diSessa, Lehrer, & Schauble, 2003) to develop materials that help university instructors foster active learning in their statistics classrooms effectively. Scholars have discussed obstacles to implementing active learning for years (e.g., Faust & Paulson, 1998), and we designed our materials to address potential obstacles, as we will describe in the sections that follow. Thus, we conceive of our materials as educative curriculum (Davis & Krajcik, 2005; Davis, Palincsar, Smith, Arias, & Kademian, 2017) aimed at supporting faculty members' efforts to enact active learning with their students, even if they have never done so previously. In this article, we situate our work within the statistics education literature on active learning, describe the design experiment process in which our materials were created, and report the results of the embedded case study we conducted to investigate classroom-specific obstacles to active-learning implementation that persisted while instructors utilized our educative curricular materials.

2. ACTIVE LEARNING IN STATISTICS EDUCATION

Reports in higher education have promoted active learning for over thirty years (GAISE College Report ASA Revision Committee, 2016; McKeachie, Pintrich, Lin, & Smith, 1987; The Mathematical Association of America, 2018), and U.S. universities large and small encourage faculty to adopt the practice. Indeed, evidence has mounted that active learning in university science, engineering, and mathematics courses is associated with substantial improvement in course passing rates (Freeman et al., 2014). Because active learning is part of the fabric of instructional conversations in higher education in the U.S. in general and statistics education in particular, we hold that it is important for instructors and researchers alike to wrestle with both what is meant by active learning and what must be addressed when the strategies are implemented.

So, what does the statistics education community mean by active learning? The GAISE college report builds on Bonwell and Eison's (1991) definition as "a set of approaches that involve students in *doing* things and *thinking* about what they are doing" (emphasis in the original) (GAISE College Report ASA Revision Committee, 2016, p. 18). Bonwell and Eison further characterize active learning as any teaching strategy that de-emphasizes information transmission and supports students in analyzing, synthesizing, and evaluating ideas while receiving feedback during class. Thus, students are active *with their thinking* during class, are the *main agent* in the classroom, and talk about, write about, and draw on *their own experiences* while learning. Accordingly, statistics instructors should never "underestimate the learning gains that can be achieved with activities" (GAISE College Report ASA Revision Committee, 2016, p. 18). Such an environment not only supports student motivation for, value of, and positive attitude toward learning (Bonwell & Eison, 1991), but also provides opportunities for students to build new understandings.

Active-learning strategies are most often implemented by instructors and researchers who adhere to theories of learning that place the process of students' coming to understand at the forefront of classroom teaching. Specifically, students build new understandings when they have experiences that disrupt their current ways of knowing and, through a process of reflecting on their experience and re-organizing their ways of understanding that experience, have opportunities to come to understand in new ways (Piaget, 1970; von Glasersfeld, 1995). Creating learning environments that allow for this kind of knowledge construction requires certain norms of participation and discourse to be in place (e.g., students ask and respond to statistical questions during class, share their ways of understanding with others during class, and/or regularly agree or disagree with others and explain alternative ways of thinking) (Yackel & Cobb, 1996). Additionally, this kind of learning environment challenges traditional notions of authority in the classroom. Indeed, teachers must work to negotiate new norms of what it means to hold authority (and who holds this authority) regarding both the logistics of the day-to-day classroom and the ways students come to agree upon the correctness of solutions shared in the learning community (Wood, Cobb, & Yackel, 1991).

In the sections that follow, we elaborate on how the statistics education community addresses issues specifically related to the implementation of active learning in articles that report teaching and research efforts in two leading journals in the field. A search for articles published in the *Journal of Statistics Education* (*JSE*) and the *Statistics Education Research Journal* (*SERJ*) for which active learning was identified in the title, abstract, or as a key word returned 41 *JSE* and 6 *SERJ* manuscripts. Our review focuses on how the literature speaks to instructor implementation of active learning as opposed to other potential outcomes of interest (e.g., student attitudes toward active learning or affective outcomes resulting from active learning). With this in mind, we organize the articles in our review into two types: activity sharing and research reports.

2.1. ACTIVITY-SHARING MANUSCRIPTS

The majority of *JSE* activity-sharing manuscripts describe an activity or sequence of activities that can be used to teach a statistical concept. These articles include activities for sampling distributions (Richardson & Haller, 2002; Warton, 2007), unique contexts for employing statistical methods such as an archeological dig (Richardson & Gajewski, 2003), simulation and bootstrapping techniques (Marasinghe et al., 2004; Ramler & Chapman, 2011; Wood, 2005), large class and group work active-learning strategies (Knypstra, 2009; Zacharopoulou, 2006), activities for various hypothesis testing scenarios (Brophy & Hahn, 2014; Lawton, 2009), Bayesian analysis (Pullenayegum, Guo, & Hopkins, 2012), regression analysis (Carter, Felton, & Schwertman, 2014), Monte Carlo methods (Sigal & Chalmers, 2016), and completing the statistical cycle (Nowacki, 2015).

Schwartz’s (2013) article on teaching one-way ANOVA using candy-coated chocolate pieces is representative of activity-sharing manuscripts. In it, he describes the materials needed for the activity, the students and the type of course in which the activity was used, and the necessary pre-class preparation steps for the instructor. He then describes the step-by-step instructions for implementing the activity with students. As is often the case with activity-sharing articles, the author includes practical advice for the readers regarding how to implement the activity successfully—based on the author’s practice-based experience—citing the amount of time to complete the activity and the ease of preparation for and teaching of the activity (Schwartz, 2013).

Most activity-sharing manuscripts include suggestions for instructors that are specific to the featured activities in the article. Some share more general suggestions for implementing active learning that appear to be based on teaching experience rather than tied to results garnered from an analysis of data. An example of these types of suggestions can be found in Woodard and McGowan (2012) in which the authors propose implementing GAISE recommendations in large sections of introductory classrooms by asking students to vote on key decisions during statistical decision making processes, having students read aloud and perform calculations during class, and asking whole-class multiple choice questions when making sense of numbers in problems.

Although these types of recommendations can be useful for the field, it is important for the statistics education community to distinguish between recommendations based on aggregate teaching experience and recommendations based on systematic data collection and analysis. For example, for recommendations such as these to carry greater weight, empirically-based evaluations should be conducted to provide evidence of how and whether implementing these recommendations allows instructors to successfully implement active learning according to a prescribed theory (e.g., de-emphasize information transmission, support students in analyzing ideas, and make the students the main agent in the classroom; Bonwell & Eison, 1991).

2.2. RESEARCH REPORTS

A number of comparative research reports in both *JSE* and *SERJ* support the claim that the use of active learning is an effective instructional strategy. A small meta-analysis of research on active learning in undergraduate university classrooms showed that students in active-learning environments exhibited evidence of greater achievement when compared to students in lecture environments (Kalaian & Kasim, 2014). In addition, the majority of comparative studies show that some form of active learning appears to support higher gains in student learning in statistics classrooms (Enders & Diener-West, 2006; Tintle, Topliff, Vanderstoep, Holmes, & Swanson, 2012; Vaughn, 2009; Winquist & Carlson, 2014). Not surprisingly, it can be difficult to isolate variables and determine the precise effect of active learning on learning gains in these studies. For example, Tintle and colleagues (2012) were not able to determine whether the increased retention of statistical knowledge among students was attributable to active-learning methods or to the randomization-based curriculum they utilized for instruction, or to both. Although a few comparative studies report negative impacts of active learning (Pfaff & Weinberg, 2009; Weltman & Whiteside, 2010), others (Carlson & Winquist, 2011) critically examine the methods used in those negative impact studies (e.g., in one study the learning activity was only used during a portion of one class period) to show that the evidence against active learning does not appear to be strong.

One important theme in a number of *JSE* and *SERJ* studies relates to how active learning is implemented in the classroom. In one such study (Verkoeijen, Imbos, van de Wiel, Berger, & Schmidt, 2002), the authors reported disappointing results with regard to the support of students' conceptual understanding of statistics in the active-learning environment of interest. The structure of the course started with the instructor giving an introductory lecture, after which students met in collaborative groups to solve applied problems related to the lecture. The work in small groups was followed by student meetings with a tutor to clarify any misunderstandings, and then the instructor gave a final lecture on the topic after which students completed a conceptual understanding assessment. The researchers assumed this structure would encourage "the free exchange of ideas concerning statistical topics" in a way that would create a "constructive statistical learning environment [that] would stimulate the students to link statistical concepts together into rich knowledge representations" (Verkoeijen et al., 2002, n.p.)., In this study, however, students appeared to be completing typical application problems (i.e., they focused on procedures) that did not necessarily induce conceptual conversations among the students. Further, there was no description of specific ways the tutor or the instructor of the course elicited thinking from the students during the activities. As a result, the authors neither provided descritptions of ways students linked statistical concepts nor did they provide evidence that they used student thinking in subsequent instruction. These details indicate some obstacles to successful implementation of active learning and the nuance necessary to support student conceptual understanding.

In contrast, Libman (2010) describes successful active-learning interventions that helped students construct conceptual understandings of descriptive statistics while flexibly utilizing procedures to reason creatively about the context in which the data were produced. In this highly constructivist learning environment, the author stresses the importance of using expressions of students' thinking during the teaching process to help students develop conceptual understanding. Libman acknowledges instructors felt pressure to address a rigid list of topics in the curriculum and this pressure created worries for instructors with regard to losing control of the learning in the class. If control of the pace of learning was lost, instructors worried content coverage would be jeopardized.

Similarly, Lesser and Kephart (2011) acknowledge instructors may fear losing control when teaching in classrooms that ask students to share reasoning, question their own and others' reasoning, and reflect critically on proposed solutions. In their case study characterizing the implementation of a problem-based inquiry learning module in statistics, the authors suggest instructors should shed that fear. Indeed, they determined successful implementation of active learning was marked by tasks that required students to think broadly and entertain multiple possible solutions, an instructor who utilized both small group and whole class discussions to probe student thinking, and an instructor who was positioned as facilitator of learning—even a co-learner—during the activity. In a study that further exposes the unfoundedness of the fear of loss of control, Carlson and Winquist (2011) provide a description of a classroom that utilized a high- to moderate-structured active-learning environment and maintained the pace of the course. In this environment, the authors determined instructors must gain facility with re-voicing students' questions, applying statistical concepts to situations students ask about, and allowing students to work at diverse speeds. However, the issues instructors encounter when they go through the process of gaining this facility were not identified.

This review of the literature revealed many activity-sharing articles that describe active-learning techniques to use with statistics students. These articles sometimes include practice-based suggestions for how to implement the activities. In addition, research-based articles often show achievement in active-learning classrooms to be higher when compared with lecture environments. Although some studies suggest using class discussions to probe student thinking, positioning the instructor as facilitator

/ co-learner during active-learning sessions, and shedding the fear of losing control of learning, more research into the issues surrounding faculty members' implementation of instruction in active-learning statistics classrooms that foster conceptual understandings is needed. We seek to add to this strain of research by describing an embedded case study we conducted as part of the MTStatPAL project.

3. THE MTStatPAL PROJECT THEORETICAL FRAMEWORK AND DESIGN PROCESS

A framework for conceptualizing classroom learning environments is necessary in educational research so researchers have a lens though which to understand the complex human interactions occurring as students learn. In the MTStatPAL project, we frame the learning environment as a learning ecology—"a complex interacting system involving multiple elements of different types and levels" (Cobb et al., 2003, p. 9). A learning ecology includes five elements: the tasks students solve, classroom discourse, norms for participation, tools used for learning, and how the teacher orchestrates all of these elements. We utilized this ecology conceptualization in two ways. First, we employed design experiment methodology (Cobb et al., 2003) to develop and refine the MTStatPAL materials *based on how the learning ecology was impacted*. That process involved engaging in multiple repeated iterations of the following steps: theorizing how the materials would impact the elements of the ecology, designing materials, piloting materials, collecting data on student outcomes and materials implementation, analyzing the data, and refining the materials. Second, we used the elements of learning ecology as a lens through which to view the data during the analysis step of the design experiment process. The team determined that the elements of learning ecology segmented the features of an active-learning classroom into pieces that allowed us to attend to the unique aspects of the teaching and learning that were occurring during MTStatPAL materials implementation.

In this paper, we narrow our focus to the discourse aspect of the learning ecology (as opposed to, for example, the tasks students solve) because discourse is where we observed the largest amount of variation in the instructors' implementation of instruction with our materials. The project materials included instructor notes on how to implement the lessons, so each instructor tended to exert less control over other aspects of the learning ecology. For example, the learning tasks and tools for learning were pre-determined by the materials. As such, for those elements, instructors tended to adhere to the direction provided by the materials providing little variability in those aspects of the learning ecology across instructors. On the other hand, the classroom discourse varied from instructor to instructor. The data on classroom discourse offered observable instances that provided insight into norms of participation and how the instructor orchestrated all elements of the ecology. In this way, attending to classroom discourse allowed us to determine ways in which the ecology of each instructor's classroom varied, thus illuminating nuances in active-learning implementation—particularly with respect to students' construction of knowledge (von Glasersfeld, 1995) and norms of participation and authority (Yackel & Cobb, 1996).

In the remainder of this section, we describe the design process the MTStatPAL team used to develop the project materials. We do not intend for this section to be a report of research findings. Rather, we seek to describe how the MTStatPAL team collected and utilized data to make and test incremental changes in accordance with design research (Bryk, Gomez, & Grunow, 2010) during the development of the materials in order to provide context for the reported case study.

Design experiment methodology focuses on "cycles of invention and revision" that regularly take place (Cobb et al., 2003, p. 9) to generate theory. The iterative design makes it possible to refine and revise hypotheses; therefore, the MTStatPAL team members conducted several of these cycles during the lifetime of the project to hypothesize about and gain an understanding of the ways the materials would be used during instruction (see Figure 1). During the first cycle, team members adapted an existing activity (Duskirk & Young, 2001) to develop an active-learning module for regression that included teacher support materials (i.e., educative curriculum). In our project, a module is a set of materials (both student materials and teacher support materials) that address one instructional topic, typically spanning one or two days of instruction. With the teacher support materials, we sought to address potential obstacles such as instructors' concerns that teaching with active learning may increase preparation time, result in covering less material, or make them uncomfortable while teaching (Faust & Paulson, 1998; Miller & Metz, 2014). Our teacher support materials included documents with pedagogical suggestions related to preparing for specific lessons and attending to specific potential student responses during instruction. We also included a video of a MTStatPAL team member teaching the lesson with students that included real-time suggestions in the video using call-out text boxes.

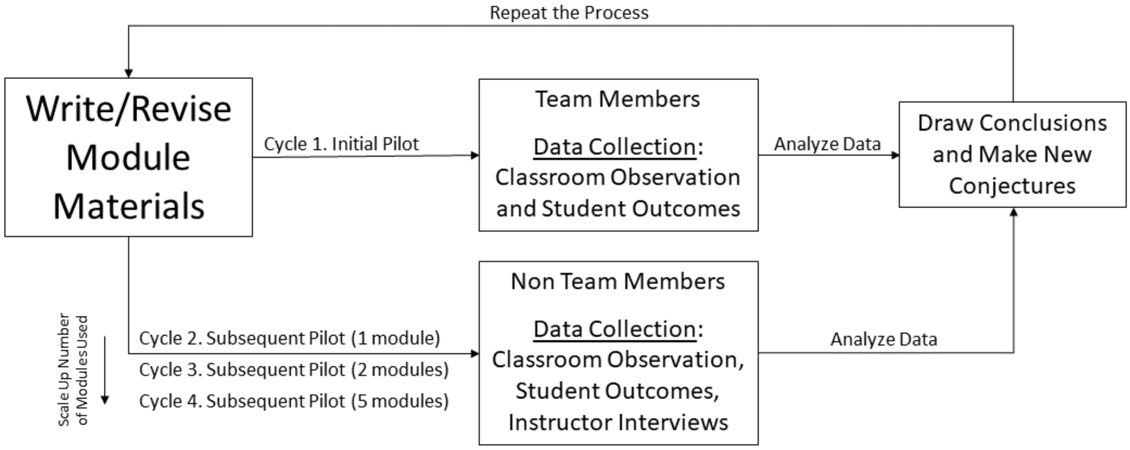

Figure 1. The design-cycle for MTStatPAL materials development

When a new module was developed, multiple team members piloted it in their own classes (Cycle 1). The team hypothesized the module would support active learning and students would be able to learn important concepts with the module. Other team members observed the implementation, taking field notes to collect data on what the teacher and students were doing and saying during the active-learning implementation in order to gain insight into the impact on classroom discourse, norms for participation, and how the teacher was orchestrating aspects of the learning ecology. Particular attention was paid to describing the ways the instructor and students talked to each other as well as the ways students talked to each other. Student outcomes on a statistics content pre-post measure provided an indication that students learned key concepts during the lesson. Further, analysis of field notes using a preliminary theme analysis found a rich learning environment was created when students were expressing their thinking. This observation, which the team described as *meaningful* student-to-student and student-to-teacher statistical conversations, prompted team members to revise the modules in an effort to increase opportunities for students to speak meaningfully about statistics during MTStatPAL lessons. We hypothesized this would have significant impact on classroom discourse and norms of participation.

As the team repeated the writing and piloting process in Cycle 1 for modules that addressed probability, the binomial distribution, confidence intervals, and *p*-values, the team also conducted a Cycle 2 pilot of the first module with three non-MTStatPAL team members teaching with the materials in multiple sections of introductory statistics. We asked piloting faculty to teach with the modules in one of their sections and to teach the same material *in their usual way*, which was traditional lecture, in the other sections. Two of these piloting faculty were inexperienced in teaching statistics and one had experience teaching introduction to statistics, so we added a conjecture: experienced statistics instructors would achieve greater success implementing active learning with the materials than their inexperienced counterparts. This marked the beginning of the second cycle of the design process. Similar to the first cycle, student outcome measures were collected, and project team members conducted observations in both the module and non-module classrooms. Additionally, instructors were interviewed to collect data on their experiences teaching with active learning before and after using the MTStatPAL materials—data that were useful for determining instructors' intentions with regard to how they orchestrated aspects of the learning ecology. Results showed the level of the instructor's teaching experience alone was not a meaningful predictor of their ability to encourage meaningful statistical conversations in the classroom (Strayer, McCormick, Gerstenschlager, Green, McDaniel, & Rowell, 2014).

The MTStatPAL team members conducted a third and fourth cycle of design to pilot all five modules with different non-MTStatPAL team members for each cycle. During these cycles, team members created and added to the teacher support materials an active-learning training video that described how to use the National Council for Teachers of Mathematics (NCTM) process standards (NCTM, 2000) as a basis for supporting active-learning instruction in a way that is consistent with Bonwell and Eison (1991). Additionally, based on the second round of observations, the team recognized the way active learning impacted the learning ecology was more complex than first anticipated. To help piloting faculty address these complexities, team members provided greater detail in the written instructor support materials regarding statistical responses to anticipate from students when the modules were implemented. This addition was important because it sought to develop instructors' statistical knowledge for teaching—that is, content knowledge specific to the work of teaching statistics. The first and second module were piloted in Cycle 3, and all five modules were piloted in Cycle 4.

At the culmination of the fourth cycle, the team reflected on the entire design process. Although student outcomes were consistently better for those learning with MTStatPAL materials, the team was intrigued by the wide variation observed in the implemented instruction with MTStatPAL materials—particularly with regard to the extent to which students expressed their own thinking and engaged in making statistical meaning themselves (Strayer et al., 2014; Strayer, Gerstenschlager, Rowell, Green, McCormick, & McDaniel, 2016). Therefore, we decided to draw on the interview and observation data collected during the second, third, and fourth cycles to conduct an embedded case study that empirically identifies issues that arise when faculty who have taught primarily using classroom lectures in the past adapt their teaching practices to implement active learning using the MTStatPAL modules.

4. RESEARCH QUESTION, PROPOSITIONS, AND METHODOLOGY

The research question guiding this study was "What issues arise when faculty who have taught primarily using classroom lectures in the past adapt their teaching practices and implement statistics instruction using an active-learning approach with educative curriculum materials?" Using an embedded case study design, an iterative interrogation of propositions directed and focused the investigation (Yin, 2014). Our propositions stated what we hoped to observe when instructors implemented active learning, specifically 1) faculty utilizing MTStatPAL modules will effectively facilitate active learning, and 2) faculty utilizing MTStatPAL modules will facilitate statistically rich student conversations in the classroom. By interrogating these propositions, we positioned ourselves to perceive and analyze both direct and indirect evidence that informed the research question.

4.1. EMBEDDED CASE STUDY METHODOLOGY

The primary unit of analysis for this embedded case study was university introductory statistics classrooms using MTStatPAL modules. We regarded each of the instructors who participated in the project and their classrooms as an embedded unit of analysis (i.e., each instructor was a specific case unit) within the larger primary case (i.e., all those who teach introductory statistics at the university using these modules), all housed under the context of "introductory statistics instructors" (Yin, 2014). The design research project within which this case study was conducted provided multiple data sources that documented ways the learning ecology was impacted when instructors used the materials for instruction. The team triangulated results during analysis via data collected from multiple lessons, multiple instructors, and interviews from multiple points in the semester. As is typical with embedded case studies (Creswell, 2012), this design allowed the team to offer a complete picture of active-learning module implementation, capture unexpected results, and interrogate quantitative results from earlier analyses in the larger project.

4.2. PARTICIPANTS

Seven faculty teaching a non-calculus based introductory statistics course at a regional university in the southern United States participated in this study. All seven faculty taught one section using MTStatPAL materials and one section using their usual lecture approach in Cycles 2–4 of the design cycle described in Section 3. One faculty member was a tenured professor and the other six were non-tenure track instructors. Three faculty members taught one module each during the second design cycle (see Figure 1), two faculty taught two modules each during the third design cycle, and although two faculty planned to teach five modules each during the fourth design cycle, one taught all five and the other taught four.

4.3. PROCEDURE

Participants taught up to five lessons with MTStatPAL materials as students learned about regression, basic probability, the binomial distribution, confidence intervals, and *p*-values using an active-learning approach. We utilized field notes and interviews to interrogate our two case study propositions in this context. Field notes provided data to gauge the modules' impact on the learning ecology, whether active learning was facilitated, and the richness of student conversations. Instructor interviews provided evidence as to whether and how the materials facilitated implementation of active learning from the instructors' points of view.

Data collection During Cycles 2–4, team members observed participants teaching both a lesson that used MTStatPAL module materials and a corresponding lesson over the same content in which the participant taught in their usual way (which was a traditional lecture, without exception). During the observations, team members recorded field notes guided by the learning ecology framework, particularly focusing on things the teacher and students said. All research team members observed multiple lessons during this phase of the research. The observation data provided insight into norms of participation, classroom discourse, and how the instructor orchestrated the parts of the learning ecology. The team observed a total of 18 module lessons and 13 non-module lessons. We sought to capture as much observation data as possible by having more than one researcher observe each lesson when feasible. This led to a total of 29 observations of module lessons and 19 observations of non-module lessons for a total of 48 sets of observation field notes.

Twelve interviews were conducted with instructors prior to and after teaching with the modules. Instructors were asked to share how they typically teach statistics lessons, their experiences teaching with active learning, how active learning impacts student learning, how students engage in the learning process during active learning, how their preparation for teaching is different when teaching with active learning, the pros and cons of teaching with active learning, and how well the MTStatPAL materials prepared them to teach with active learning. In the pre-interviews, we asked participants to give us their opinions or draw on their past experiences. During the post-interviews, we asked participants to reflect directly on their experiences teaching with the MTStatPAL materials. Table 1 describes the data collected in this study where the MTStatPAL modules were utilized.

Table 1. Data collected when MTStatPAL module materials were used

Design cycle number	Number of instructors	Number of modules per instructor	Number of module lessons observed[a]	Number of interviews[b]
2	3	1	3	2
3	2	2	6	4
4	2	5	9	6

[a]Twice, during cycle 3, an instructor taught the same module lesson a second time when the team was available to observe. This resulted in six observed lessons. During cycle 4, one instructor did not teach the last module lesson. This resulted in nine observed lessons.
[b]One of the participants in cycle 2 declined the interview, all instructors in cycle 3 were interviewed twice, and all instructors in cycle 4 were interviewed three times.

Data analysis We employed interpretive qualitative data analysis procedures (Creswell, 2012; Merriam, 2002) to describe and explain trends in the field notes and interview data. The entire data set was open coded by two team members who took the lead on the analysis (the first two authors of this article). These two team members' observations, when combined, accounted for a majority of the observations. The open coding process provided an initial portrayal of the instructors' implementation of the MTStatPAL materials. After open coding, the same two team members independently wrote analytic memos that characterized each class session according to the five learning ecology elements.

From the independent memos, the coders agreed upon a final negotiated memo. The resulting negotiated analytic memos for each class session were shared with one of the other research team members, who checked the memo against the classroom observation data as a validity check; memos were modified as necessary in response to the third team member's validity check.

Using the negotiated analytic memos of classroom implementation, two team members returned to the data to collapse open codes into categories. Within each category, properties and dimensional ranges were identified and related to one another in accordance with interpretive qualitative data analysis procedures. Through numerous cycles of analysis and returning to the data, the primary category of *active-learning implementation* and the associated *classroom interactions* category, described below with their properties and dimensional ranges, was formed. Toward the end of the analysis process, when we returned to the data to find confirming and disconfirming instances of our categorizations, we identified the unifying theme of *mathematical and statistical authority*. Similar to a core category in grounded theory analysis, our unifying theme was detected because it was central, reoccurred frequently, related to a large portion of the variation in the data, was related meaningfully and easily to other categories, and had explanatory power (Holton, 2007). We describe these results in detail in the Findings section that follows.

4.4. LIMITATIONS, DELIMITATIONS, AND TRANSFERABILITY

We identify three limitations and three delimitations in this study. The first limitation is the diversity of the backgrounds of the participating instructors. Each instructor was unique in terms of content, pedagogical expertise, and experience teaching introductory statistics. Although this was expected, each instructor's uniqueness makes the transferability of results challenging. We encourage readers to keep this in mind as they reflect on our results. The second limitation is the case study design, which does not allow us to generalize findings. We maintain, however, that our thorough description of the unit of analysis in the findings can allow for transferability of results to similar settings and participants. The final limitation is the professional relationships between the MTStatPAL staff and the participating instructors: participants may have felt pressure to succeed with the materials in order to maintain those relationships. This might have affected how participants responded when being observed or participating in interviews.

With regard to delimitations, we did not collect video records of instruction. Given the length of this project, that extra data point would have been helpful to identify nuances in the implementations for each participant, but we did not have the resources to include these points in the data corpus. Second, we only chose to implement between one and four modules during the semester in this particular data collection period. This led to no expectation that active learning should be implemented regularly in participants' classrooms throughout the semester. Finally, our study is delimited by a choice to only collect data on a small number of instructors.

5. FINDINGS

In this section, we describe how the development of active-learning implementation as the primary category and mathematical and statistical authority (MSA) as the unifying theme became evident in the data. We illuminate the unifying theme of MSA by presenting short representative cases that present "cross-case issues" (Yin, 2014 p. 186) identified in the data. In particular, participants' struggled, first, to relinquish MSA and, second, to maintain the relinquishing of MSA (i.e., to not take MSA back from the students) during those moments when they initially relinquished it.

5.1. ACTIVE-LEARNING IMPLEMENTATION

Our close interrogation of the case study propositions was facilitated by analyzing the negotiated analytic memos and the data associated with those memos using a process of collapsing codes into categories. In this process, the team identified categories with properties and dimensional ranges that informed our guiding research question. As an example of how this inductive process unfolded, consider the following situation. An analytic memo of one classroom session noted "students whispered, so there may be a feeling that they can't talk out loud" in the classroom discourse component of the learning ecology. In the same memo, in the norms of participation component, we noted "students were often cut off during their discourse with one another for a mini-lecture and some student questions were ignored." These, and other similar pieces of data, collapsed into a classroom interactions category including a student contributions property, which varied from superficial to substantive (the dimensional range). Multiple rounds of similar inductive processes revealed a primary category for the data with an associated second category that had explanatory power with regard to implementing active learning and facilitating rich conversations in the classroom—the foci of our study propositions.

Here, we use boldface font when referring to **categories**, underlined font when referring to <u>properties</u>, and italicized font when referring to the *dimensional range* of a property. Our inductive data analysis revealed the primary category of **active-learning implementation** with the property of <u>alignment with how the field defines successful active learning</u> (Bonwell & Eison, 1991; GAISE College Report ASA Revision Committee, 2016), which varied from *limited* to *full* (Figure 2). The **classroom interactions** category related to the **active-learning implementation** with properties that had explanatory power. The properties and their varying dimensional ranges included <u>student contributions,</u> which varied from *superficial* to *substantive*, <u>teacher contributions,</u> which varied from *explanation* to *facilitation*, <u>teacher questioning,</u> which varied from *I-R-E* (initiation-response-evaluate; Mehan, 1979) to *focusing*, and <u>student engagement,</u> which varied from *stepping through* to *taking ownership*. Note that the initiation-response-evaluate pattern of teacher questioning means the teacher poses a question to students with a correct answer in mind, the students respond, and the teacher evaluates their answer as correct or incorrect. In Figure 2 the further to the right the **classroom interaction** properties were on their dimensional ranges, the more aligned the active-learning implementation. Table 2 provides examples of the endpoints of the dimensional ranges of the **classroom interactions** category. The data reported come from classroom observation field notes.

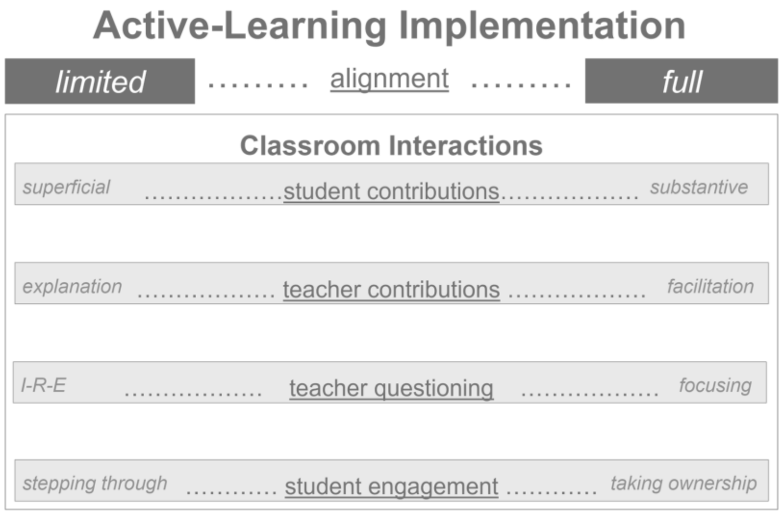

Figure 2. Categories, properties, and dimensional ranges related to active-learning implementation

Near the end of our analysis, we returned to the classroom observation field notes and interview data to find instances when a categorization was both confirmed and disconfirmed. This process revealed interesting patterns. For example, moments when teachers were operating on the *explanation* end (left side) of the <u>teacher contributions</u> property and students were simultaneously operating on the *substantive* end (right side) of the <u>student contributions</u> property resulted in palpable conflict in the classroom. Often, this conflict manifested itself in students continuing their conversations in hushed tones while the instructor spoke loudly to try to keep the whole class' attention. These moments were prevalent in the data and led us to consider how issues of mathematical and statistical authority (MSA) may have been at work, influencing the level of active-learning implementation.

Often, students appeal to the instructor or the textbook as the authority for determining what is mathematically or statistically correct while learning. In contrast, when students are the authors, critics, and justifiers of mathematical and statistical ideas (i.e., they take up MSA), they develop greater

Table 2. Examples of the dimensional ranges of properties in the classroom interactions category

Property	Limited Alignment	Full Alignment
	Superficial	*Substantive*
Student Contributions	While working on the regression activity, students describe the slope as "rebound height over drop height … it's *y* over *x*."	While working on the binomial distribution activity, Student 3 and Student 4 are discussing whether *X* is a binomial random variable and, if so, what the most common value of *X* would be. They are making meaning together in their conversation about what it means for the number of trials to be fixed and for trials to be independent. Student 2 is asking the group clarification questions related to these concepts in the activity.
	Explanation	*Facilitation*
Teacher Contributions	While a group is working on the binomial probability activity, the teacher floats around the room explaining to groups of students why the probability of success does not change from trial to trial.	While a group is collecting data for the binomial activity, students are dropping candy on a plate, the teacher watches, observes, and comments, "there are interesting strategies going on here." Student asks whether they need to drop one candy over and over or if they should drop multiple candies. The teacher does not directly answer and asks students what they think. After students respond, the teacher asks students to note on their data sheet which strategy they used.
	I-R-E	*Focusing*
Teacher Questioning	When completing a scatterplot for the regression problem, teacher asks, "What do you decide before inputting the data?" Student, "That the drop height is *x*." Teacher, "Why?" Student, "It's the independent because rebound depends on drop height, so rebound is *y*." Teacher, "So *x* is explanatory so it goes in …?" Students, "L1." Teacher, "Then rebound height is L2."	During data collecting for the regression activity, when dropping the ball from the same height, some students got the exact same rebound height and others got different values for the rebound height. The teacher asked, "Some of ours are the same. Is that okay?"
	Stepping Through	*Taking Ownership*
Student Engagement	When answering questions in an activity on confidence intervals for proportions, the following exchange occurred: Student 12 (working with Student 13 and Student 14), "What are we supposed to be doing? This stuff in the book?" Student 13, "What did you get?" Student 14, "I got 24." Student 15 (working with Student 16 and Student 17), "I think the population proportion is the number of heads for all of the flips." Student 16, "I think p-hat is that thingy." Student 17, "So you do 17/40?" Student 16, "Yeah. We did … I wish the guy who is absent was here today." Student 16 (reading a question in the materials), "What's the population proportion mean in the context of this problem? (pause) I don't know!" Student 15 and Student 16 talk about technical difficulties they had with the HW assignment.	When collecting data for the regression activity, Student 21 said, "Should we drop from 16 inches?" Then, Student 22 said, "Well that's too close to 15 that we already collected data on. Let's use 18." Student 21, "Then, let's use 10. Our data was really consistent in those ranges!"

conceptual understanding of the content under study (Langer-Osuna, 2017; Webel, 2010). Because active learning places students at the center of the learning process to give them opportunities to develop conceptual understandings of content, it is often necessary for students to take up MSA in the learning process. Reeve and Jang (2006) identified teacher actions that either support or thwart students' autonomy in the learning process. We applied these actions as moves that support or thwart students' taking up MSA (Table 3) and used them as a frame through which to understand the implementation of active learning and facilitation of rich statistical conversations while using the MTStatPAL materials. When returning to and viewing the data through this frame, we determined that MSA was an issue in most of the observed classroom sessions, and so we considered MSA as a unifying theme in the data.

Table 3. Teacher actions that support and thwart students' taking up MSA during teacher / student interactions, adapted from Reeve and Jang (2006)

Teacher actions that support sharing MSA with students	Teacher actions that thwart sharing MSA with students
• Provides non-evaluative response	• Presents only correct student work
• Positions students as competent sense-makers and resources for each other's learning	• Immediately praises / corrects student work
• Makes time for teacher listening and student talking	• Presents teacher's solutions
• Provides time for students to work in their own way	• Holds or monopolizes learning materials
• Responsive to student generated questions	• Steps in to clarify when students are stuck

5.2. MATHEMATICAL AND STATISTICAL AUTHORITY IN THE CLASSROOM

We elaborate on the MSA unifying theme by presenting a brief cross-case report (Yin, 2014). The two cross-case issues through which we illuminate MSA are participants' failure to relinquish MSA and participants struggle to maintain the relinquishing of MSA. We share data from two participants' classrooms. Brady and Simon (pseudonyms) were both male instructors teaching introductory statistics during one semester of the project. Brady and Simon both had experience teaching mathematics (Brady nine years and Simon eight years). For Brady, however, this was the first semester teaching introductory statistics. Simon had four years of experience teaching introductory statistics. Both Brady and Simon agreed to participate in the study, but admittedly were not familiar with implementing active-learning approaches in their teaching. As such, Brady and Simon were representative of the type of instructor we were interested in: those who typically lecture, but are interested in implementing active-learning strategies with students in introductory statistics classrooms.

Failure to relinquish MSA While teaching some of the active-learning lessons, there were moments when Brady and Simon did not relinquish MSA to students when the materials provided opportunities for this to happen. Here, we describe one instance in each instructor's classroom where this occurred. Although the materials were intended to be completed with some freedom by small groups of students, Brady would maintain control by asking groups of students to begin working and then simultaneously work to keep the entire class together. Brady would circulate the room either providing explanations, stepping in with small questions meant to help students who were struggling quickly, or asking whole-class questions to keep everyone moving at the same pace (i.e., he did not make time for teacher listening and student talking or provide time for students to work in their own way, Reeve & Jang, 2006). Students who wanted to think for themselves about the questions in the materials were left to work surreptitiously on the activities "under the radar."

This pattern of interaction occurred when Brady implemented the confidence interval activity, for example. He began by describing how to construct a confidence interval using the formula and the calculator. Then he asked students to work on the activity and, during this time, he visited students' groups, directing them how to complete portions of the activity. Although he did ask students questions to move their thinking forward, they were often questions meant to get them quickly to a pre-determined correct answer such as, "What is 40 here?" and "If it's a fair coin, what would we expect?" At one point in the activity, students were instructed to put their confidence intervals on the board and to reason together to determine whether the coin in the activity was fair. After students placed their confidence intervals on the board, Brady maintained control of the learning materials by interpreting the results for them. He stated, "How many of our confidence intervals captured the 50%? Most, right? So, we don't really have a reason to doubt that the coin is fair, right?" In this environment, students were not expressing their own thinking about the concepts in the problems. Instead, they were having short side conversations to make sure they were doing steps correctly, saying things like, "Are we supposed to divide by 100 now instead of 40?"

Simon implemented the hypothesis testing module in a similar fashion, failing to relinquish MSA. In addition, he often presented teacher solutions, an act we did not see in Brady's classroom. As an example, during the class, Simon asked students, "What do you think the null hypothesis is in words?" A student responded with, "That there is no difference between the people who pick condition 1 and the people who pick condition 2." Simon responded with the way he expected it to be worded, "Half of people pick condition 1. Anyone have something different?" Although we see Simon soliciting student responses, he failed to address the first student's response. Subsequently, no students responded to his second question soliciting additional answers. This exchange presented only the teacher's null hypothesis as the "correct" interpretation, did not position students as competent sense-makers, and was not responsive to the student contributions that *were* made. It is an example of failing to relinquish MSA to students in the classroom.

Struggle to maintain relinquishing MSA In some instances, Brady and Simon relinquished MSA when they invited students to share their thinking on various problems. Both Brady and Simon expressed during their interviews that when presented with opportunities to use student thinking or questions during instruction, they were unsure of how to proceed during those moments. This would often result in Brady and Simon taking back the MSA they had just relinquished to the students.

As an example, during the regression activity in Simon's class, the materials directed students to make a prediction based on the experiment they had conducted. In response, students discussed in their groups ways they might make and check predictions. For example, one student suggested "Let's use 10. Our data was really consistent in those ranges." During this time in the lesson, Simon allowed students to talk and work in their own way, relinquishing the MSA to them. This allowed for the students to make sense of the question and their choices for input values. After students made predictions, Simon asked, "Did anyone get crazy values?" A few students shared values obtained from their prediction equations that did not make sense, and Simon proceeded to describe the difference between interpolation and extrapolation. Rather than allowing for students to work through the materials in their own way, providing non-evaluative responses to students, and making time to listen to student talk, Simon followed his initial description of interpolation and extrapolation with a series of small questions that had specific correct answers in an effort to step everyone through the remaining questions in the materials together. In this instance, although Simon initially allowed students to hold MSA, he was quick to monopolize the learning materials and repossess the MSA.

Brady also struggled to relinquish MSA to students consistently. During the binomial activity in Brady's class, he asked students to begin the activity, and after a few minutes, asked the class, "Does it matter which outcome we call a success?" Some students responded "yes" while others responded "no." Although students had been given time to make sense and work in their own way at the beginning of the instructional sequence, Brady did not provide opportunities for this to continue. Instead of asking students to explain their thinking, he quickly provided the definition of success in a binomial experiment, thus failing to maintain the relinquishment of MSA to the students. During an interview after the lesson, Brady reflected on his pedagogical actions in comparison to his typical way of teaching, saying, "It's very different . . . In my other class, I've got control, and I can pretty much manage every minute. But, like today, I was really conscious of time, and I think I managed it well. I bored them with some things that I thought they needed to be bored with." Here, Brady seems to be referring to his moments of providing explanations as telling them things "they needed to be bored with." This indicates he felt the need to step in when students were either struggling with a topic or did not respond to his questions in a way he determined indicated sufficient understanding.

Across these examples, we see moments when Brady and Simon allowed students to hold MSA for a time. Specifically, in these instances, students worked in their own way, used each other as resources, and were positioned as sense-makers in the classroom (Reeve & Jang, 2006). The time during which the students held the authority was limited, as both Brady and Simon quickly imposed actions that thwarted students' taking up MSA. This process of either failing to relinquish or struggling to maintain the relinquishment of MSA was common across all active-learning implementations for all participants, not just Brady and Simon.

5.3. MATHEMATICAL AND STATISTICAL AUTHORITY AS EXPRESSED IN PARTICIPANT INTERVIEWS

As this study has shown, successfully implementing active-learning materials with students is a complex endeavor, involving unique challenges that involve all aspects of the learning ecology (i.e., the tasks students solve, classroom discourse, norms for participation, tools used for learning, and how the teacher orchestrates these aspects). In this section, we allow the instructors from our cases to put these challenges in their own words so we can better understand *their* experience implementing active learning with the MTStatPAL materials. The following exchange occurred when Brady was asked to describe his experience teaching with the activities:

Brady: Well it's different. It's very different, I guess. I guess we're all a control freak to some degree, and I am as well. I feel like in my lecture class, I've got control and I can pretty much manage every minute, but like today I was really conscious of time. And I think managed it pretty well today, but the MTStatPAL class, I feel like it's supposed to be I guess designed "student centered" and a constructivist sort of process and all, but I feel um I feel like um. You know, I was teaching my sons how to ride a bike you know and you keep your hand on the seat and then all of a sudden you just let go and you just kind of think "Ok. Do I need to run after him? Do I need to keep my hand on the seat? Or do I just let him fall and skin his knees and then we'll worry about it later?" So, I get a little sense of that in there and not knowing exactly what to do you know trying to walk around and being present and hopefully saying something that makes sense to them. Yeah it's a little ... it's certainly different from what I'm used to.

Interviewer: What kinds of things are you looking to say or do when you are walking around in that teaching process?

Brady: Yeah, that's where I'm really ... grasping, you know. Um, I am. You know I don't do very good at that at all. Um, it's ... you know, probing questions – I've never been very good at that. I respond. You know if I respond to them I'm more comfortable with that you know. I know I need to get past the "How's it going?" kind of thing. But it's, you know, sometimes I give a response that's "ok, that sounded good coming out of my mouth." But I don't know if you can actually prepare for that. I suppose I could prepare for that ... and, I don't. But maybe that's something, and I'm just talking as I'm thinking here, maybe that's something that I could begin to do. You know situations are never exactly like we think they are going to be, but maybe something that, you know, practice preparation on ... maybe jot down a few questions maybe. Just 3, 4, 5 kind of questions would probably be a good idea. So, prepping for questions would be good for me.

In this exchange, we see Brady's thought process as he works to determine how to orchestrate the use of MTStatPAL materials, norms of participation, and classroom discourse in a way that fits with his image of himself as a teacher in his own teaching practice. Brady's use of the metaphor of teaching a child to ride a bike to describe classroom teaching provides insight into why many of his actions aligned with thwarting the relinquishment of MSA to students. As a care-giver, it makes sense to act in ways that avoid the "skinned knee." Therefore, presenting only correct work, praising correct work, clarifying when students are stuck, and monopolizing the learning materials (e.g., holding the bicycle seat) are all defendable actions within this metaphor.

Similarly, Simon addressed MSA in his interviews. In this segment, he discussed whether and how he relied on the materials to drive the classroom discourse while students completed the activities:

Simon: I think that when it was going well—especially when they were working on it themselves—like the activity, the book itself, drove a lot of the learning, because basically really the only reason we needed to talk about it was to keep students on track and make sure they were coming to the right conclusion. Because some of those activities, if they were engaging like they should with each other (and a lot of them were) theoretically if they came to the correct conclusions themselves, then the material took them there.

Interviewer: So, how is the teacher's role different when doing group work?

Simon: It means you're a facilitator instead of the one with all of the knowledge. So, if you do it lecture, then you are the one with all the knowledge. Where with the activity it's more like you're going to discover the knowledge and I'm going to keep you on the right track. And it's my habit. I have to tell myself, "Don't talk about it!" So, I think sometimes I used the materials to get to the thing that I would normally say—I may have said something instead of letting them completely do it by themselves.

In this exchange, Simon describes his role as a facilitator charged with keeping students on track. From this perspective, it makes sense that he would focus on correct student work, clarify when students were stuck, and present solutions when necessary (even when telling himself, "Don't talk about it!")—all actions that thwart the relinquishment of MSA to students.

We highlight these examples of tensions Brady and Simon faced to underscore the complexities involved when instructors implement active-learning materials with students. Even when instructors utilize materials that include teacher guides as educative curricula aimed at helping instructors implement active learning aligned with what research tells us about best practices, instructors need time and space to take up effective practices. Brady and Simon both said they utilized the teacher guides when preparing, particularly the videos of instruction, but they struggled to know how to take up active-learning teaching practices in their own classrooms.

6. DISCUSSION AND IMPLICATIONS FOR TEACHING

We close this paper with a discussion of our embedded case study, linking our findings with results from the literature, and discussing how our results address the case study propositions of 1) faculty utilizing MTStatPAL modules will effectively facilitate active learning, and 2) faculty utilizing MTStatPAL modules will facilitate statistically rich student conversations in the classroom. Additionally, we address implications for teaching statistics, specifically designing active-learning materials in the tertiary setting.

6.1. DISCUSSION

Many university statistics instructors are interested in teaching with active-learning approaches in their classrooms. Yet, there is a lot of work to be done between expressing interest and effectively implementing active learning. Because many university instructors have limited experience with active learning (perhaps never having learned in active-learning settings themselves), productive implementation can seem quite elusive. In this embedded case study, we saw the struggle to implement active learning in statistics classrooms play out in insightful ways. First, similar to results found in Carlson and Winquist (2011), Lesser and Kephart (2011), and Libman (2010), our participants expressed concern that engaging in active-learning practices could result in their losing control of not only how time is spent during class but also the very content that is discussed (see Brady's interview presented in Section 5.3). The rich learning ecology that existed in this case study resulted when these concerns were coupled with instructors utilizing MTStatPAL educative curricular materials that encouraged instructors to use expressions of students' thinking during instruction and use class discussions to probe student thinking. Findings revealed that these teaching practices are not easily taken up. Indeed the struggle to implement these practices contributed to the unifying theme of instructors' struggle to relinquish to students the mathematical and statistical authority (MSA) in the classroom.

It is important to note that participants in our study did demonstrate uptake of some of the practices and intentions found in the MTStatPAL project materials. These moments of uptake provided the variation in our data that allowed for our categorization of active-learning implementation to range from limited to full. Specifically, we observed participants engaging students in conversations and asking questions provided in the materials, and this helped the participants to implement active learning in ways that were consistent with the description of the benefits of active learning in the literature. This successful use of the MTStatPAL materials is consistent with Davis et al.'s (2017) findings that teachers utilizing educative curricula will use and adapt the materials based upon their understanding of their students' knowledge, their concerns about time, and their own perceived needs. The challenge in designing such curricula is to provide suggestions for multiple ways to adapt the materials, provide sufficient detail in the descriptions of teaching practice in the teacher guides (and how it is different from typical current practices), and provide support for the increased subject matter knowledge demands on the teacher that will occur when relinquishing MSA to students (Davis et al., 2017).

Considering our participants' struggle with relinquishing MSA and their selective uptake and modification of MTStatPAL materials in light of our case study propositions, we see how differences in implementation influenced the ways in which students discussed important statistical ideas. Specifically, although it was not intended by our participants, we saw instances where students were hindered from engaging in rich conversations due to participants' struggle with relinquishing MSA. Interestingly, even in these situations, we sometimes noticed students surreptitiously continued these conversations. Despite these struggles, it is promising to note that the participants in the embedded case study did show instances of relinquishing MSA as well as engaging in practices aligned with pedagogical strategies present in the MTStatPAL modules.

6.2. IMPLICATIONS FOR TEACHING AND CURRICULUM DESIGN

Although teacher participants in this study faced struggles when implementing the MTStatPAL modules, full implementation of active learning as described by the right-hand side of Figure 2 was not necessary to provide students with an opportunity to engage in rich statistical conversations. We hypothesize these conversations would have happened more frequently had more lessons aligned with the right-hand side of Figure 2. This leads to another implication of the research: engaging students in active learning that aligns with the right-hand side of Figure 2 requires a relinquishing of the MSA, something that instructors might be hesitant to do initially. As Brady and Simon show us, relinquishing MSA to students is not simple. First, it is not all or nothing—instructors must work to maintain giving students the authority for deciding mathematical and statistical correctness as they learn in active-learning settings. Second, instructors need support as they work through what this looks like in their own teaching practice.

As we reflect on the supports we provided to all of our participants, particularly in light of Davis et al.'s (2017) recent list of design principals for educative curricula, we recognize the need to provide even more diverse types of supports for instructors who are new to active learning. For example, it might have helped our participants, and Brady and Simon specifically, if they had descriptions of multiple alternative ways the lesson could have unfolded. This might have given participants comfort in knowing, even when lessons unfold differently than expected, instructors can still arrive at and achieve appropriate learning goals. Additionally, it may have been beneficial for the participants to know how relinquishing authority positions the instructor in the classroom and how it requires a shift in classroom norms. As mentioned in Yackel and Cobb (1996), instructors may assume this means they becomes a passive member of the classroom, when, in actuality, relinquishing authority requires them to take on a *different* and not necessarily less active role. Yackel and Cobb describe this teacher as one who "guides the development of a community of validators and thus encourages the devolution of responsibility" (p. 473). This type of teacher has different norms in place for discourse and orchestrates the classroom differently. Having a conversation with the participants about how they individually envision themselves taking on this different kind of role may have helped them to better understand the purpose and benefit of this type of instruction, as well as how relinquishing authority plays a part in active learning classrooms.

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REFERENCES

Bonwell, C. C., & Eison, J. A. (1991). *Active learning: Creating excitement in the classroom* (ASHE-ERIC Higher Education Report No. 1). Washington, D.C.: The George Washington University, School of Education and Human Development.
[Online: https://www.ydae.purdue.edu/lct/HBCU/documents/Active_Learning_Creating_Excitement_in_the_Classroom.pdf]

Brophy, C., & Hahn, L. (2014). Engaging students in a large lecture: An experiment using sudoku puzzles. *Journal of Statistics Education*, *22*(1), 1–20.
[Online: http://jse.amstat.org/v22n1/brophy.pdf]

Bryk, A. S., Gomez, L. M., & Grunow, A. (2010). *Getting ideas into action: Building networked improvement communities in education*. Stanford, CA: Carnegie Foundation for the Advancement of Teaching.
[Online: www.carnegiefoundation.org/resources/publications/getting-ideas-action-building-networked-improvement-communities-education/]

Carlson, K. A., & Winquist, J. R. (2011). Evaluating an active learning approach to teaching introductory statistics: A classroom workbook approach. *Journal of Statistics Education*, *19*(1), 1–23.
[Online: http://doi.org/10.1080/10691898.2011.11889596]

Carter, N., Felton, N., & Schwertman, N. (2014). A classroom investigation of the effect of population size and income on success in the London 2012 Olympics. *Journal of Statistics Education*, *22*(2), 1–20.
[Online: https://doi.org/0.1080/10691898.2014.11889698]

Cobb, G. W. (1993). Reconsidering statistics education: A National Science Foundation conference, *Journal of Statistics Education*, *1*(1).
[Online: https://doi.org/10.1080/10691898.1993.11910454]

Cobb, P., Confrey, J., diSessa, A., Lehrer, R., & Schauble, L. (2003). Design experiments in educational research. *Educational Researcher*, *32*(1), 9–13.

Creswell, J. W. (2012). *Qualitative inquiry and research design: Choosing among five approaches* (3rd ed.). Thousand Oaks, CA: SAGE.

Davis, E. A., & Krajcik, J. S. (2005). Designing educative curriculum materials to promote teacher learning. *Educational Researcher*, *34*(3), 3–14.

Davis, E. A., Palincsar, A. S., Smith, S. P., Arias, A. M., & Kademian, S. M. (2017). Educative curriculum materials: Uptake, impact, and implications for research and design. *Educational Researcher*, *46*(6), 293–304.
[Online: https://doi.org/10.3102/0013189X17727502]

Duskirk, T., & Young, L. J. (2001). “Regression on the rebound,” *STAR Library*.
[Online: https://www.causeweb.org/repository/StarLibrary/activities/buskirk_young2001/]

Enders, F. B., & Diener-West, M. (2006). Methods of learning in statistical education: A randomized trial of public health graduate students. *Statistics Education Research Journal*, *5*(1), 5–19.
[Online: http://iase-web.org/documents/SERJ/SERJ5(1)_Enders_West.pdf]

Faust, J. L., & Paulson, D. R. (1998). Active learning in the college classroom. *Journal on Excellence in College Teaching*, *9*(2), 3–24.

Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences of the United States*, *111*(23), 8410–8415.
[Online: https://doi.org/10.1073/pnas.1319030111]

GAISE College Report ASA Revision Committee. (2016). *Guidelines for assessment and instruction in statistics education college report 2016*. American Statistical Association.
[Online: http://www.amstat.org/education/gaise]

Garfield, J. (1993). Teaching statistics using small-group cooperative learning. *Journal of Statistics Education*, *1*(1).
[Online: http://www.amstat.org/publications/jse/v1n1/garfield.html]

Holton, J. A. (2007). The coding process and its challenges. In A. Bryant & K. Chamaz (Eds.), *The Sage handbook of grounded theory* (pp. 265–289). Thousand Oaks, CA: Sage.

Kalaian, S. A., & Kasim, R. M. (2014). A meta-analytic review of studies of the effectiveness of small-group learning methods on statistics achievement. *Journal of Statistics Education*, *22*(1), 1–20.
[Online: http://jse.amstat.org/v22n1/kalaian.pdf]

Knypstra, S. (2009). Teaching statistics in an activity encouraging format. *Journal of Statistics Education*, *17*(2), 1–8.
[Online: https://doi.org/10.1080/10691898.2009.11889518]

Langer-Osuna, J. M. (2017). Authority, identity, and collaborative mathematics. *Journal for Research in Mathematics Education*, *48*(3), 237–247.

Lawton, L. (2009). An exercise for illustrating the logic of hypothesis testing. *Journal of Statistics Education*, *17*(2), 1–9.
[Online: http://jse.amstat.org/v17n2/lawton.html]

Lesser, L. M., & Kephart, K. (2011). Setting the tone: A discursive case study of problem-based inquiry learning to start a graduate stastistics course for in-service teachers. *Journal of Statistics Education*, *19*(3), 1–29.
[Online: http://jse.amstat.org/v19n3/lesser.pdf]

Libman, Z. (2010). Integrating real-life data analysis in teaching descriptive statistics: A constructivist approach. *Journal of Statistics Education*, *18*(1), 1–23.
[Online: https://doi.org/10.1080/10691898.2010.11889477]

Marasinghe, M., Duckworth, W. M., & Shin, T.-S. (2004). Tools for teaching regression concepts using dynamic graphics. *Journal of Statistics Education*, *12*(2), 1–17.
[Online: https://doi.org/10.1080/10691898.2004.11910733]

McKeachie, W. J., Pintrich, P. R., Lin, Y.-G., & Smith, D. A. F. (1987). *Teaching and learning in the college classroom. A review of the research literature*. Ann Arbor, MI: National Center for Research to Improve Postsecondary Teaching and Learning.

Mehan, H. (1979). *Learning lessons: Social organization in the classroom*. Cambridge, MA: Harvard University Press.

Merriam, S. B. (2002). *Qualitative research in practice: Examples for discussion and analysis*. San Francisco: Jossey-Bass.

Miller, C. J., & Metz, M. J. (2014). A comparison of professional-level faculty and student perceptions of active learning: Its current use, effectiveness, and barriers. *Advances in Physiology Education*, *38*(3), 246–252.

NCTM. (2000). *Principles and standards for school mathematics*. Reston, VA: NCTM.

Nowacki, A. S. (2015). Teaching statistics from the operating table: Minimally invasive and maximally educational. *Journal of Statistics Education*, *23*(1).
[Online: https://doi.org/10.1080/10691898.2015.11889726]

Pfaff, T. J., & Weinberg, A. (2009). Do hands-on activities increase student understanding?: A case study. *Journal of Statistics Education*, *17*(3), 1–34.
[Online: https://www.tandfonline.com/doi/full/10.1080/10691898.2009.11889536]

Piaget, J. (1970). *Genetic epistemology*. New York: W.W. Norton & Co.

Pullenayegum, E. M., Guo, Q., & Hopkins, R. B. (2012). Developing critical thinking about reporting of Bayesian analyses. *Journal of Statistics Education*, *20*(1).
[Online: http://jse.amstat.org/v20n1/pullenayegum.pdf]

Ramler, I., & Chapman, J. (2011). Introducing statistical research to undergraduate mathematical statistics students using the Guitar Hero video game series. *Journal of Statistics Education*, *19*(3).
[Online: http://jse.amstat.org/v19n3/ramler.pdf]

Reeve, J., & Jang, H. (2006). What teachers say and do to support students' autonomy during a learning activity. *Journal of Educational Psychology*, *98*(1), 209–218.

Richardson, M., & Gajewski, B. (2003). Archaeological sampling strategies. *Journal of Statistics Education*, *11*(1).
[Online: https://doi.org/10.1080/10691898.2003.11910693]

Richardson, M., & Haller, S. (2002). What is the probability of a kiss? (It's not what you think). *Journal of Statistics Education*, *10*(3).

[Online: http://jse.amstat.org/v10n3/haller.html]

Rossman, A. J., & Chance, B. L. (2008). *Workshop statistics: Discovery with data* (3rd ed.). New York: Key College Publishing.

Samsa, G. P., Thomas, L., Lee, L. S., & Neal, E. M. (2012). An active learning approach to teach advanced multi-predictor modeling concepts to clinicians. *Journal of Statistics Education*, *20*(1), 1–34.
[Online: http://jse.amstat.org/v20n1/samsa.pdf]

Schwartz, T. A. (2013). Teaching principles of one-way analysis of variance using M&M's candy. *Journal of Statistics Education*, *21*(1), 1–14.
[Online: https://doi.org/10.1080/10691898.2013.11889662]

Sigal, M. J., & Chalmers, R. P. (2016). Play it again: Teaching statistics with Monte Carlo simulation. *Journal of Statistics Education*, *24*(3), 136–156.
[Online: https://doi.org/10.1080/10691898.2016.1246953]

Snee, R. D. (1993). What's missing in statistical education? *The American Statistician*, (2), 149−154.

Strayer, J. F., Gerstenschlager, N. E., Rowell, G. H., Green, L., McCormick, N., & McDaniel, S. (2016). University statistics instructors' border crossings: From lecture to active learning. In M. B. Wood, E. E. Turner, M. Civil, & J. A. Eli (Eds.), *Proceedings of the 38th annual meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education* (p. 1013). Tuscon, AZ: The University of Arizona.

Strayer, J.F., McCormick, N., Gerstenschlager, N., Green, L., McDaniel, S., Rowell, G. (2014). Observations of implementation of an active learning module in introductory statistics. In K. Makar, B. de Sousa, & R. Gould (Eds.), *Sustainability in Statistics Education*. *Proceedings of the Ninth International Conference on Teaching Statistics (ICOTS-9)*, Flagstaff, Arizona, USA. Voorburg, The Netherlands: International Statistical Institute.
[Online: https://icots.info/9/proceedings/pdfs/ICOTS9_C145_STRAYER.pdf]

The Mathematical Association of America. (2018). *MAA Instructional Practices Guide*.
[Online: https://www.maa.org/node/789682/]

Tintle, N., Topliff, K., Vanderstoep, J., Holmes, V.-L., & Swanson, T. (2012). Retention of statistical concepts in a preliminary randomization-based introductory statistics curriculum. *Statistics Education Research Journal*, *11*(1), 21–40.
[Online: http://iase-web.org/documents/SERJ/SERJ11(1)_Tintle.pdf]

Vaughn, B. K. (2009). An empirical consideration of a balanced amalgamation of learning strategies in graduate introductory statistics classes. *Statistics Education Research Journal*, *8*(1), 106–130.
[Online: https://iase-web.org/documents/SERJ/SERJ8(1)_Vaughn.pdf]

Verkoeijen, P. P. J. L., Imbos, T., van de Wiel, M. W. J., Berger, M. P. F., & Schmidt, H. (2002). Assessing knowledge structures in a constructive statistical learning environment. *Journal of Statistics Education*, *10*(2).
[Online: http://jse.amstat.org/v10n2/verkoeijen.html]

von Glasersfeld, E. (1995). *Radical constructivism*. London: Routledge.

Warton, D. I. (2007). How many words do you know? An integrated assessment task for introductory statistics students. *Journal of Statistics Education*, *15*(3), 1–9.
[Online: http://jse.amstat.org/v15n3/warton.html]

Webel, C. (2010). Connecting research to teaching: Shifting mathematical authority from teacher to community. *Mathematics Teacher*, *104*(4), 315–318.

Weltman, D., & Whiteside, M. (2010). Comparing the effectiveness of traditional and active learning methods in business statistics: Convergence to the mean. *Journal of Statistics Education*, *18*(1), 1–13.
[Online: http://jse.amstat.org/v18n1/weltman.pdf]

Winquist, J. R., & Carlson, K. A. (2014). Flipped statistics class results: Better performance than lecture over one year later. *Journal of Statistics Education*, *22*(3), 1–10.
[Online: http://jse.amstat.org/v22n3/winquist.pdf]

Wood, T., Cobb, P., & Yackel, E. (1991). Change in teaching mathematics: A case study. *American Educational Research Journal*, *28*(3), 587–616.

Wood, M. (2005). The role of simulation approaches in statistics. *Journal of Statistics Education*, *13*(3), 1–9.
[Online: http://jse.amstat.org/v13n3/wood.html]

Woodard, R., & McGowan, H. (2012). Redesigning a large introductory course to incorporate the GAISE guidelines. *Journal of Statistics Education*, *20*(3), 1–24.
[Online: http://jse.amstat.org/v20n3/woodard.pdf]

Yackel, E., & Cobb, P. (1996). Sociomathematical norms, argumentation, and autonomy in mathematics. *Journal for Research in Mathematics Education*, *27*(4), 458–477.

Yin, R. K. (2014). *Case study research: Design and methods* (5th ed.). Los Angeles: SAGE.

Zacharopoulou, H. (2006). Two learning activities for a large introductory statistics class. *Journal of Statistics Education*, *14*(1), 1–10.
[Online: http://jse.amstat.org/v14n1/zacharopoulou.html]

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