STATISTICS ATTITUDES AFTER USING GUIDED PROJECT-BASED LEARNING AS AN ANDRAGOGICAL STRATEGY IN A GRADUATE STATISTICS COURSE

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ABSTRACT

This study builds on previous studies that have examined guided project-based learning in undergraduate statistics courses to examine students' attitudes toward statistics after participating in a graduate-level statistics course that used guided project-based learning as an andragogical technique. This phenomenological qualitative case study utilized multiple student interviews and reflections over a semester-long statistics course in a doctoral education degree program. The results showed that guided project-based learning immersed students in the quantitative inquiry process and emboldened them to read and use statistics in their academic and professional lives. It also revealed several elements of guided project-based learning that are important for instructors looking to implement this approach in their own courses.

Keywords: *Statistics education research; Graduate education; Instructional techniques; Assessment; Statistics attitudes*

1. INTRODUCTION

Courses in statistics are oftentimes part of the foundational curriculum of graduate degree programs, and at least one statistics course is required for most students. There tends to be a negative outlook for these courses among many graduate students that is fueled by a variety of factors. As many as 80% of graduate students experience anxiety about taking a statistics course (Onwuegbuzie & Wilson, 2003). Research has shown that students with higher levels of statistics anxiety do not perform as well in statistics courses as their peers with lower levels of statistics anxiety (Onwuegbuzie et al., 2000). Additionally, many students exhibit negative perceptions of statistics including a general lack of interest in statistics and a lack of understanding regarding its practical use (Acee & Weinstein, 2010). The research on negative feelings toward statistics education points to the adverse effects that poor outlooks have on learning outcomes (Dempster & McCorry, 2009). Because the research shows how negative attitudes toward statistics are negatively related to learning outcomes, it is critical that statistics instructors develop courses that actively seek to engage students with the content in a meaningful way so that their attitudes toward statistics are more positive.

One research-based approach that has been implemented in statistics courses to try to improve students' attitudes toward statistics is project-based learning (e.g., Bayer, 2016). This student-centered, inquiry-driven instructional method is common in K–12 settings but is a relative newcomer in higher education (Lee et al., 2014). The positive effects of project-based learning in education are well documented in the literature, including in statistics courses (e.g., Ishtiaq et al., 2017). Studies in this area typically have been enacted in undergraduate introductory statistics courses, however. This leaves a dearth of research on the potential impact of project-based learning in graduate level statistics courses. This study sought to fill this void by examining the possibilities of project-based learning in statistics courses in graduate education programs. Specifically, the study sought to explore students' experiences with guided project-based learning when it was used as the primary andragogical technique in a doctoral level statistics course. The research question examined is, "What are the attitudes toward statistics of graduate students enrolled in a statistics course that utilizes guided project-based learning?"

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2. FRAMEWORK

This study stems from Knowles' (1980, 1984) work on andragogy, which differentiates adult learning from child learning. This concept has a set of underlying assumptions: (a) adult learners need to be involved in the planning and evaluation of their learning (i.e., adult learners are self-directed), (b) adults have extensive experiences to draw on throughout their learning, (c) relevance of content to students' personal or professional lives increases their willingness to learn, (d) learning should have a problem-centered orientation rather than a subject-centered one, (e) internal motivation is stronger than external motivation for adult learners, and (f) adults need to know why they should learn something. These assumptions are undergirded by Bandura's (1986) social cognitive theory, which frames learning as situated within a social context in which behavior, cognition, and the environment all influence one another. It presupposes that people self-regulate their motivation and performance and become "both products and producers of their environment" (Wood & Bandura, 1989, p. 362).

The foundation for this self-regulation is self-efficacy, which focuses on one's belief they can perform a specific action that will result in a certain outcome (Bandura, 1982). There are four sources of self-efficacy: (a) personal performance on tasks, (b) observing task performance in others, (c) verbal influence from others about task performance, and (d) physical and emotional reactions to the task (Bandura, 1977). The first source, called mastery experiences, is the most influential source of self-efficacy (Bandura, 1997). Building on the assumptions of adult learners put forth by Knowles (1980, 1984), this theoretical framework suggests that instruction tailored towards adult learners will increase their outcome expectancy, and when coupled with high self-efficacy fostered through mastery experiences, results in active engagement with the content and related tasks (Bandura, 1997).

The implementation of the guided project-based learning approach employed in this study drew from Savery's (2006) principles of problem-based learning. Problem-based learning is an instructional approach that centers the learning experience around an ill-defined problem. At its core, it puts the responsibility of learning in the hands of the students because they are responsible for identifying what they know and what they do not know as they engage with a problem. The instructor operates only as a facilitator—students are responsible for seeking out new knowledge, developing a solution to the problem, and reflecting on their learning. This directly aligns with the andragogical assumption about self-directed learning. Additionally, collaboration is a key element. Students should actively interact with their peers and with the instructor as they work through the problem. This is aligned to multiple elements in social cognitive theory and two sources of self-efficacy. Finally, this approach "must be the pedagogical base in the curriculum and not part of a didactic curriculum" (Savery, 2006, p. 14). This aligns to the andragogical assumption about problem-centered orientation.

A downside to problem-based learning is that it is unstructured. This is especially problematic in subjects that typically demand rigid sequence and structure to teach concepts and methods, such as statistics. For these types of courses, the research has shown that guided project-based learning is more effective than problem-based learning (Budé et al., 2009; Kirschner et al., 2006; Leppink et al., 2014). This approach differs from problem-based learning in two keyways: (a) a pre-defined product results from students' engagement with the ill-defined problem (Lehman et al., 2006), and (b) it allows for more direct instruction throughout the process to supplement and encourage free student inquiry (Hmelo-Silver, 2004). The course in this study was designed intentionally using guided project-based learning such that the core statistics concepts were delivered in a more traditional, direct instruction approach with practical examples and activities, and the major assessments consisted of project-based learning exercises with guided support structures embedded throughout. The guided project-based learning framework directed this study's exploration of social cognitive theory and how the andragogical assumptions can be applied in graduate statistics education.

3. COURSE CONTEXT AND STRUCTURE

This study was conducted in a statistics course in a practitioner-oriented doctoral program in educational leadership at a university in the southeastern United States. Students in this program all worked full-time as teachers, school administrators, and central office administrators; they were, therefore, part-time graduate students. All the students were adult learners, with most of the students ranging between 30 and 50 years of age.

This course was the only required statistics course in the program. Nearly all students, however, took an additional online prerequisite statistics class before enrolling in the required course. The few students who did not take that class typically took an introductory statistics course in their master's level coursework. The doctoral program course was taken approximately one year into the doctoral program and, if applicable, a couple of semesters after the online introductory statistics course. The primary objectives of this course were for students to be able to describe, utilize, and differentiate between common parametric inferential tests including *t*-tests, ANOVA, and linear regression, as well as basic nonparametric tests, in preparation for their dissertation research. The course included a 3-hour workshop one night per week. The development of the course and the use of guided project-based learning was grounded in the American Statistical Association's ([ASA] 2016) *Guidelines for Assessment and Instruction in Statistics Education*, which promotes the teaching of statistical thinking as a problem-solving process with a focus on conceptual understanding using real-world data, active learning, and statistical analysis software.

First, students were introduced to concepts in a lecture-format that focused on major ideas and incorporated practical examples with real educational data. The emphasis was on application of the different concepts and tests using statistical software; students were not expected to do hand calculations. Resource materials were provided to students that identified the key procedures that should be followed in running the various statistical analyses after the discussion of the concept. This was in alignment with the recommendations of the ASA (2016) and was supported by research on the use of guiding resources for problem-solving processes (Nadolski et al., 2005). After the material was introduced, students worked with the instructor and with each other in class to apply the concept that was taught with a large educational dataset. In accordance with the guiding framework, this modeled the process of identifying a problem, developing research questions/hypotheses, testing assumptions, running inferential tests, and drawing appropriate conclusions with an emphasis on the complex nature of educational contexts. Each week, students were given a brief homework assignment to complete that afforded them the opportunity to independently practice applying the concepts from that lesson using an assigned dataset from the textbook. The expectation was that students were to attempt the homework and check their answers before the next class meeting so that any questions or concerns could be addressed. These assignments were not graded for accuracy.

Three major projects served as the summative assessments of the course. Each of these projects required students to identify a problem; develop research questions related to a problem, which would guide the project; collect and configure data from a publicly available database (the General Social Survey; https://gss.norc.org/); analyze the data using the statistical techniques learned in the class (two different inferential tests per project); and draw conclusions from the analysis. The only specific guideline given to the students for each project (other than the required components of the written report outlined above) was the focus that each had to have: the first project had to focus on comparing group differences, the second project had to focus on both comparing group differences and examining relationships, and the third project had to focus on examining relationships and/or making predictions. Students were free to choose any variables from the dataset, but they could not repeat the same statistical analysis. The only exception to this rule was for the third project because students were allowed to use multiple regression twice if their identified problem and questions warranted it. Students were given the option of completing each project independently or as a self-selected pair. If they chose to work independently, they still were able (and encouraged) to discuss their project with their peers and with the instructor. At the end of the semester, students chose two of their analyses to present to the class.

4. METHODS AND DATA SOURCES

This study utilized a phenomenological design consisting of multiple phases spanning the length of the semester-long graduate level statistics course. The phenomenon explored was participation in a graduate statistics course that utilized guided project-based learning. Figure 1 presents a visual of the phases and data collection periods over the course of the semester. The overarching design involved semi-structured interviews at various sequenced points of primary data collection based on samples selected from statistics attitudinal survey scores. Concurrently, secondary data including observations and documents were collected throughout the duration of the study. This design allowed for an empirical investigation into how guided project-based learning played a role in graduate students' learning of, experience with, and attitudes toward statistics, and the emphasis on qualitative data provided value for advancing understanding of statistics education (e.g., Groth, 2010). Eleven students were enrolled in the course, all of whom had previously had the same instructor for a different research methods course. Participation in each phase of data collection was optional, and students were assured that participation or non-participation in the study had no bearing whatsoever on their performance in the course.

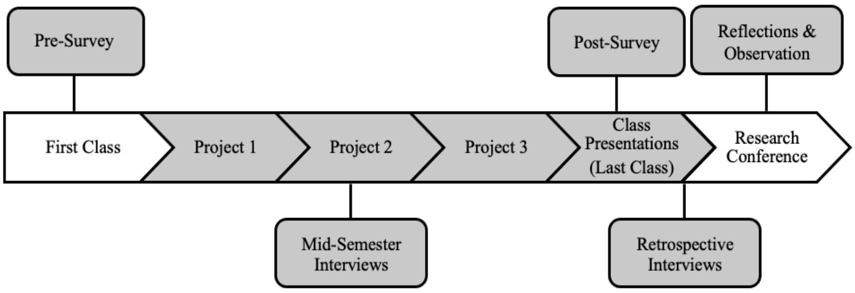

Figure 1. Visual of the phenomenological research design. Each phase is presented along the timeline of the semester with data points shaded in gray.

4.1. PRIMARY DATA COLLECTION AND ANALYSIS

There were five phases of data collection that focused on four primary sources of data. The first phase of data collection occurred at the beginning of the semester. Before the first class meeting, all enrolled students were asked to complete the Survey of Attitudes Toward Statistics (SATS-36). The SATS-36 measures students' feelings about statistics (*affect)*, their attitudes about their intellect when applied to statistics (*cognitive competence*), their perceptions of the worth of statistics in their profession (*value*), feelings about the difficulty of statistics (*difficulty*), their individual interest in statistics (*interest*), and the amount of work they expect to expend learning statistics (*effort*; Schau, 2003). Higher scores on these constructs are reflective of more positive attitudes toward statistics. The SATS-36 has been identified as the best instrument for assessing students' attitudes toward statistics (Xu & Schau, 2019), though there is limited validity evidence for graduate student populations (Whitaker et al., 2022). This study only used SATS-36 scores for the purpose of participant selection and not as a response variable, so this did not pose a limitation to the study.

The second phase of data collection utilized the results of the pre-survey SATS-36 administration to select two students for interviews that were conducted halfway through the course (the first primary data source). Extreme-case sampling was used to identify the students with the highest and lowest overall attitudes toward statistics based on their SATS-36 responses (Onwuegbuzie & Collins, 2007). Semi-structured interviews lasting approximately 30 minutes each were conducted with each of these students via *Google Meet*. The interview began with the students being asked to elaborate on their initial responses to the SATS-36 to gain a more thorough understanding of the students' background that informed their perceptions of statistics. As the interview progressed, the students were asked a variety of questions about how working on the course projects affected their perception of the various constructs measured by the SATS-36. The interviews also included a discussion about the balance of guidance and freedom allowed with the projects. At the time of the interviews, the students had completed the first project, received feedback on it, and had just submitted their second project. These interviews were audio-recorded and transcribed. The transcripts were analyzed using abductive constant comparison (Leech & Onwuegbuzie, 2007).

The third and fourth phases of data collection occurred at the conclusion of the semester. The third phase involved administering a post-survey of the SATS-36 to all the students at the end of the last class meeting. Students' responses to the post-survey were matched to their responses from the pre-survey. These data were analyzed using a descriptive examination of the change in scores for each construct for each student. The fourth phase of data collection involved semi-structured interviews following the same general protocol as the one used in the second phase (the second primary data source). Extreme-case sampling was used to identify the two students who showed the largest overall increase and decrease in attitudes toward statistics across the measured constructs (Onwuegbuzie &

Collins, 2007). The two students with the largest increase and decrease in statistics attitudes were different from the two students selected for the first set of interviews. The only difference of note was that this set of interviews focused more on the ways in which the projects changed the students' perceptions of statistics. Abductive constant comparison was again used to analyze the data from these interviews (Leech & Onwuegbuzie, 2007).

The fifth and final phase of data collection occurred a couple of months after the semester ended when four different students presented selected portions of their projects as part of a symposium at an educational research conference. All students were encouraged to submit proposals to present their projects, but only these four students volunteered to do so. None of the presenters were participants in the earlier qualitative phases of the study. As part of their presentation, each presenter shared a reflection about the projects and the role they played in the students' learning of statistics (the third primary data source). An educational research professor in attendance at the session shared a written summary and reflection of her observations and insights from the students' presentations (the fourth primary data source). The constant comparison was used to analyze these data as well, but deductive coding was used in this round with the codes that were created from earlier stages (Leech & Onwuegbuzie, 2007). In total, primary qualitative data were collected from eight students and one peer research professor.

4.2. QUALITATIVE PARTICIPANTS

Score distributions for the pre- and post-surveys for all students in the course are presented in Figure 2 to provide context for the selected participants in comparison to the overall class. On average, the 11 students in the class started the semester with ambivalent feelings about doing statistics, relatively high attitudes about their intellect/skills applied to statistics as well as the value of statistics to their personal and professional lives, and a high level of interest in the subject area. The students also demonstrated a clear pessimistic outlook about the difficulty of statistics at the onset of the course (higher scores for *Difficulty* correspond to higher perceptions of perceived easiness). From the post-survey, on average, students finished the course with high perceptions of the value of statistics and high interest in the subject, moderately negative views about the difficulty of the content, as well as relatively neutral feelings towards doing statistics and applying their knowledge and skills in statistics.

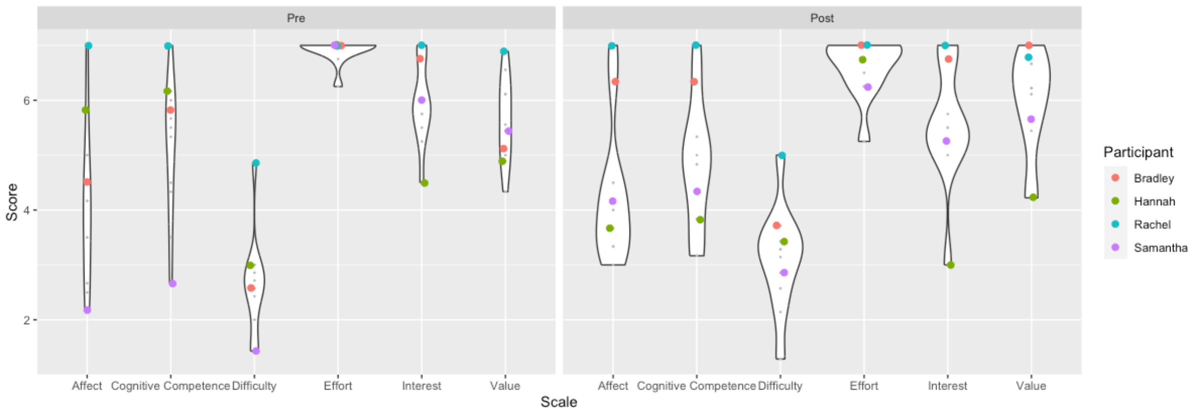

Figure 2. Domain distributions of pre- and post-surveys of the SATS-36. Interview participants' scores are highlighted within each distribution.

Interviews were conducted with purposefully selected students at multiple phases of the study. Figure 2 identifies the seven domain scores on both the pre-survey and post-survey SATS-36 for each participant selected for interviews. Pseudonyms are used to protect participants' identities. Samantha was selected for an interview in Phase 2 because she had the lowest scores overall out of all the students in the class on the pre-survey SATS-36, while Rachel was selected because she had the highest overall scores. Hannah was selected for an interview at the conclusion of the course in Phase 4 because she showed relatively large decreases for nearly every domain; conversely, Bradley was selected because he showed the greatest overall increases out of the 11 students.

Samantha was a 48-year-old elementary science and social studies teacher who indicated she felt she was relatively good at math and was confident that she could master introductory statistics, but she also indicated she would not have taken any statistics courses if they had not been required. She indicated she expected to use statistics regularly in her job. Rachel, 50 years of age, was a middle school mathematics teacher who showed great confidence in her mathematical and statistical abilities and an eager excitement about taking statistics courses and using statistics in her profession. Hannah was a 29-year-old high school business applications teacher who felt assured in her mathematics abilities and described herself as confident she could master statistics, though she was indecisive about choosing to take the course had it been optional and did not expect to use statistics after the class. Bradley, a 31-year-old middle school social studies teacher, identified his mathematics ability as average and was only slightly confident he would be able to master statistics, but he did expect to use statistics beyond the course even though he would not have chosen to take the course had it not been mandatory. All four of these participants had taken the online statistics course a few semesters before taking the course in this study.

4.3. SECONDARY DATA COLLECTION AND ANALYSIS

In addition to the four primary data collection elements previously described, secondary data were also collected throughout the entirety of the semester. Namely, the instructor/researcher took note of students' interactions with and reactions to the course content and the projects via informal observations during class meetings and out-of-class conversations with students (i.e., emails and meetings during office hours). Students' performance on each project was also observed, with special care taken to assess (a) how well students were able to apply the concepts and, (b) the depth of knowledge demonstrated. These observations were anecdotally compared to records of student learning from previous semesters (e.g., examinations). Any feedback about the course organization and delivery from the end-of-course teaching evaluation was also considered—especially any comments related specifically to the projects. These reflective data elements were used to inform additional probing questions in the interviews and conference panel discussion. Additionally, the observations and insights from these secondary data sources were useful throughout the qualitative data analysis process using constant comparison.

4.4. TRUSTWORTHINESS

Trustworthiness of the qualitative analyses was established by attending to multiple criteria of trustworthiness (Hays & Singh, 2012). Triangulation of data sources and units of analysis established credibility, transferability, confirmability, and sampling adequacy. Member checking was conducted with the interview participants to enhance descriptive and interpretive validity. The peer debriefing that was conducted by the educational research professor at the conference further supported the trustworthiness of the findings. Furthermore, the researcher was intentional about reflecting on his potential biases throughout the duration of the study and had multiple conversations with the research professor throughout data collection and analysis to check for and address any biases. In total, eight of the eleven students in the course directly participated in the primary qualitative data collection methods for this study, and all eleven were represented in the secondary data.

5. RESULTS

The overarching goal of this study was to examine how the use of guided project-based learning in a graduate-level statistics course informed students' attitudes toward statistics. Analysis of the four qualitative interviews and the notes from the student conference presentations—as well as analysis of the concurrent secondary data (i.e., students' work, feedback on teaching evaluations, email records, and informal classroom conversations)—revealed three major themes. First, the use of guided project-based learning exposed students to and immersed them in the inquiry process in quantitative research. Second, it emboldened students to read and use statistics in their academic and professional lives. Finally, it revealed crucial elements of guided project-based learning necessary for successful implementation in doctoral-level statistics courses.

5.1. QUANTITATIVE INQUIRY PROCESS

The inquiry process in quantitative research is complex. Researchers must be able to identify a problem and propose research questions/hypotheses, collect data using appropriate variables, test assumptions of statistical tests before running them, and draw appropriate conclusions from the results of those tests. The results of this study showed that students consistently expressed the benefits of using guided project-based learning to help them fully understand the inquiry process and the inherent challenges involved. Rachel summarized this sentiment well when she explained that the challenge of the projects prepared her to fully understand and execute this process more so than practice exercises:

> The projects [became] more challenging because you're having to really dig deep in your own thought about the work you're doing, about how it's going to apply. … I find the projects [provided] that critical connection that is needed to what the homework looks like and how challenging it's going to be when it's applied to the real world. … It's almost like a step. A step that's going from that not-so-difficult homework that steps you into being more critically thinking about statistics as a whole.

Bradley echoed these ideas when he described how the projects helped him to "comprehend what you were doing, the steps that it takes to run the test, and why you have to follow that specific order." Students expressed gratitude for working on the projects and articulated how the projects helped remove some of the apprehension they had about conducting dissertation research.

All the students emphasized that the initial stages of this process—identifying a problem and selecting appropriate variables to address that problem—were the most difficult for them. Samantha explained that "it was so hard picking out the variables" because she had to think about how they were measured and what they were measuring, and that she needed to make sure that they "made sense" for the problem she identified. Hannah found "choosing everything for all of the variables" to be "a little overwhelming" and "the most challenging part," but found that once she finished the process of "cleaning everything up and making sure that it worked and it flowed, … everything else was easier." She said that if variables had already been picked out for her as is typically done in homework assignments or examinations, she could "rock and roll." The students frequently expressed appreciation for having to work through these initial phases of the inquiry process and the time that was spent on it before conducting the inferential tests.

Another benefit of guided project-based learning was that, by engaging students with the full quantitative research inquiry process, they were also able to develop the critical thinking skills necessary to appreciate and deal with the complexity of statistics in real-world settings. Rachel described how the projects allowed her to "understand and think more critically and more creatively about what [she could] do with the data." Samantha discussed how her increased understanding of this process led her to think more critically about the research she reads, and Hannah shared that this approach was best because the students "learn by doing," which allows for "a deeper understanding of the content and of statistics in general" compared to being assessed on the concepts in a more traditional manner. Like Rachel, the students shared that they felt this knowledge and skillset was long-lasting and, because the emphasis was on going through the full process, easily applicable to "what you're going to do in real life—whatever field you we go into—and how we're going to use statistics to solve any problem."

This awareness also fostered an eagerness and excitement about more complex statistical analyses instead of a fear of them. Bradley shared how he went beyond the minimum requirements for the regression project, wanting to use four or five variables when the requirement was fewer—even though this added additional complexity and difficulty to the project. Samantha shared how she was excited to do the regression project because it seemed the most interesting. Rachel summarized well why the students were quick to embrace the multivariate, complex nature of real-world problems: "The first [project] was just very, very simple … I couldn't dig deep into the work." She elaborated by mentioning she enjoyed the later projects with more complex analyses because, "You can start digging deeper into the problem—what if this and what if that and what would happen if all of these things applied?" Rachel specifically related the projects to her desire to "keep wanting to do more" and to "apply using statistics to solve all problems."

Examination of the students' projects, their class presentations, and review of the conference presentation panel provided additional support for this theme. Each student's project was a well-thought-out, small-scale research study indicative of students learning the quantitative inquiry process. For example, multiple students included discussions about variable selection and modification in their methodology section as well as a thoughtful discussion about potential validity threats or concerns related to generalizability in their discussion section. This was further reinforced in the panel discussion with the four students who presented their projects at a conference. Multiple students shared extensive time on the front-end thinking of problems and exploring variables. One student even went so far as to say, while she got frustrated with how much time she was spending on it, she persisted because she wanted to figure out the best possible combination of variables from which she could get the most information. This is an additional indication these projects required students to grapple with the complexity of quantitative inquiry and the multivariate nature of the world, and that the experience materialized into a fully developed, coherent study that is suitable for presentation or publication.

5.2. CONFIDENCE IN USING STATISTICS

An enduring theme prevalent across all the participants was that guided project-based learning built students' confidence in their ability to understand, do, and use statistics. Students expressed "the struggle" of working through the projects increased their confidence. Having to work through the various difficulties of the projects such as having to go and find information to help them solve the problem showed, as Samantha put it, "… that I *can* do it." Bradley explained that he felt more confident looking at various statistical items and "being able to understand what [he was] looking at." The projects not only built the students' confidence in their own problem-solving capabilities using statistics, but also bolstered their confidence as consumers of quantitative research. Rachel shared:

> I honestly don't have a fear hitting any study and being able to understand anyone that I would grab my hands on because I think that I have enough background to understand it, but I also know how to research and understand what I'm reading, you know, where there's resources available.

When Samantha was asked to describe her experience using outside resources such as internet help forums to assist her in finding solutions to issues that she faced as she worked on her projects, she explained that she was able to "most of the time." She demonstrated her confidence in her ability to seek out these answers when she said,

> It is hard sometimes. I have to look for the ones that are not written by—that are more on my level. Because some of them are so, like, I have no idea what they're saying! So, it does cause me to have to go and read a few things, but eventually I can find something that will help me.

It is noteworthy that Rachel and Samantha were identified as the students with the highest and lowest initial attitudes toward statistics, respectively, and that participating in the problem-solving process as they worked on the projects increased their confidence in both their abilities to understand statistical research.

Students also expressed confidence in their ability to be a resource for each other and for colleagues in their workplace. Samantha shared a vignette about how she helped an assistant principal at another school analyze some data he was working with using statistical software, saying, "My very limited knowledge has already benefitted somebody else." She and Bradley also shared how they felt self-assured enough to help each other with various problems they encountered as they worked on the projects, with Bradley saying he found this to be "fun and enlightening" for him. This was also mentioned by students in the conference panel when they shared how they would communicate questions to their classmates, and that they were able to work together to find the solution.

This confidence in applied statistical inquiry was also evident in students' responses when they said that they wanted to begin implementing more rigorous analyses of data in their classrooms, schools, and districts. They were able to specifically articulate new ways they could work with real data in the workplace: Rachel described how she wanted to begin examining causal relationships with curriculum standards and standardized test performance; Bradley shared how he wanted to see his district begin using statistical software to analyze data more thoroughly. Samantha acknowledged that her experience with the projects helped her to realize "how important" statistics are in education and learning about statistics helped her to question data use and interpretation in her school. She also talked about how she was now interested in using statistics to examine a variety of other issues like opinions on premarital sex (the topic for her second project) and suicides among veterans. Students on the conference panel had similar comments, with several of them specifically mentioning that they felt working on the projects built their confidence in doing statistics far more than if they had simply taken a test.

5.3. NECESSARY ELEMENTS OF GUIDED PROJECT-BASED LEARNING

Data from the interviews revealed several elements of guided project-based learning students found to be beneficial—or even crucial—for it to be successful. Since students must spend an extensive amount of time with the problem they are investigating in the project, the topic under investigation needs to be meaningful or interesting, and students should have some autonomy with their analytical choices. Students in this study showed an appreciation for being able to choose their own topics. Samantha stated she appreciated getting to work with data that was not directly related to the field of education, elaborating, "Sometimes I just get bogged down with all the education things because I work with that all day, and I think it makes it more clear to me when I can do it in a different topic." Hannah expressed a similar sentiment when she talked about getting to examine differences in time spent watching television by demographics. Conversely, some students, including Rachel and Bradley, wished they could have worked with more data that was explicitly related to education, though they explained that they appreciated having the freedom to choose the problem and variables they worked with. Students on the panel also shared their appreciation of being able to make the choice. The reflection of the professor in attendance stated the students were visibly interested and knowledgeable about the topics they studied.

Some elements of guided project-based learning the students identified as crucial for success were the provision of clear foundational resources and accessibility of the instructor for support as well as thoughtful, specific feedback. Hannah described the materials from class as "a bible," while Bradley shared that the steps were clear and useful for applying the concepts to his problem and that they would be beneficial down the road. Samantha discussed the value of quick email replies, saying it "helps a lot." She went on to share that if she got to the point where she was having to reach out for help, she had already tried looking through her notes, book, and additional resources so the immediacy was invaluable. Furthermore, some of the students expressed the benefit of being pointed to a resource or asked probing questions instead of explicitly being told what to do. Rachel shared that this structure and availability helped students not "feel left out … like they were stranded on an island trying to figure this out on their own." This was also echoed by students in the panel discussion who said being guided in the right direction when they had questions or made mistakes helped them to successfully complete the projects. Another point multiple students brought up was the importance of a meaningful dataset. A consistent comment in the interviews and conference panel was that the General Social Survey dataset was difficult to work with. While some students like Samantha said they enjoyed working with it, others like Rachel and Hannah did not and wished they could have worked with an educational dataset instead.

6. DISCUSSION

The goal of this study was to explore students' experiences and attitudes toward learning and doing statistics after completing a doctoral level statistics course that used guided project-based learning. The results showed that students found completing projects as a learning and assessment tool—with proper balance of freedom and guidance/support from the instructor—to be a meaningful exercise that exposed them to the process and complex realities of quantitative inquiry, as well as one that built their confidence in reading and doing statistical analyses. Students were able to understand, grapple with, and successfully analyze real-world data using multiple analysis techniques. Taken together, these results show potential for guided project-based learning in statistics education generally, but especially at the graduate level.

Graduate students are typically adult learners, and the findings from this study supported many of Knowles's (1980, 1984) andragogical assumptions about this population. The students' appreciation for guided project-based learning over more traditional alternatives reinforced the idea that problem-centered learning is more effective for adult learners. Additionally, the students in this study spoke to their appreciation for being able to pick topics that were relevant to their interests for the projects. This supports the importance of relevance of the content. Self-directed learning is a primary assumption for andragogy, and the results showed that guided project-based learning afforded students the opportunity to assess what they knew and did not know, seek out resources to supplement their knowledge, and learn through application. This motivated them to succeed on the projects, to draw connections to their careers, and to continue using the skills and knowledge gained beyond the course.

The findings from this study also point to the role that guided project-based learning can play in building students' belief that they can successfully conduct research, that is, their research self-efficacy (Lambie et al., 2014). Proper implementation of this approach attends to all four areas of research self-efficacy: mastery experiences, vicarious experiences, verbal persuasion, and emotional states. Most importantly, successful completion of the project provides a mastery experience, which has the greatest impact on self-efficacy (Bandura, 1977). The other three areas are addressed through the social nature of guided project-based learning and the counsel of the instructor throughout the project. Taken together, the findings from this study suggest that guided project-based learning's impact on research self-efficacy, and the interconnection of this with the underlying assumptions of andragogy, can have positive effects not only on statistics education, but also on research methods education more broadly.

One of the key findings in this study was students' growth in their understanding of the full quantitative inquiry process, also called their statistical thinking. This is defined as "the complex thought processes involved in solving real-world problems using statistics" (Wild & Pfannkuch, 1999, p. 224). Students demonstrated growth in their statistical thinking in all four dimensions of the Wild and Pfannkuch framework. The nature of the projects developed their investigative skills as they identified problems, planned studies, pre-prepared and analyzed data, and drew conclusions (Dimension 1). Simultaneously, they had to think through concepts such as variation and measurement, and they had to integrate practical knowledge with statistical concepts (Dimension 2). The project required students to generate ideas and approaches to various problems, seek relevant information, interpret analyses, and reflect on the implications and limitations (Dimension 3). Finally, the qualitative data suggested that the projects improved the dispositions necessary for statistical thinking such as perseverance, seeking deeper meaning, and engagement (Dimension 4). This is an encouraging sign that guided project-based learning may be a fruitful approach to developing holistic statistical thinking.

While the results of this study are promising for guided project-based learning, the scope of their generalizability needs to be taken into consideration. This study was limited to a small sample of educational leadership doctoral students in a second-semester introductory statistics course at one institution. These students all worked full time in educational settings. Moreover, the research was conducted by the instructor of the class. While care was taken to focus the research design on the course projects, it cannot be said with certainty that the findings are not at least in part attributable to the instructor and/or learning statistics in general (though there was evidence in several accounts that the students preferred the guided project-based learning over typical examinations). The efficacy of the techniques used in this study should be explored at other institutions that serve students with differing backgrounds, professional experiences, and career goals. Additionally, future research should explore in more detail peer collaboration within guided project-based learning. Important insights can also be gleaned from replication of this study in true introductory and more advanced statistics courses, as well as examining how the outcomes examined in this study may differ across delivery methods (i.e., the effectiveness of guided project-based learning in online and hybrid statistics courses).

It was apparent from the results that students' responses to the SATS-36 were attributable in part to students' previous experiences with statistics, which gave them a false sense of what statistics (and quantitative research more broadly) is like in practice. All four students interviewed in this study described how their responses to the pre-survey SATS-36 administration were heavily (if not exclusively) informed by their experience in the prerequisite online asynchronous statistics course. This was consistent with findings from Chiesi and Primi (2010), who found significant relationships between previous experiences and knowledge in mathematics courses and attitudes toward statistics and achievement in statistics. Hannah is a prime example of a student who had a misconception of the true rigor involved with doing statistics because she excelled in the prerequisite class that did not address variable measurement/selection, assumptions, and other complex decisions inherent in the inquiry process. Similarly, some students who reported they struggled with the online format excelled in this course. Future research should continue to explore this important relationship and seek to understand not only how much prior experience had with statistics and their prior mathematical/statistical achievement, but also what that experience looked like.

This study contributes to the larger body of knowledge on statistics education and guided project-based learning because it examines it in the context of a graduate level statistics course. This, therefore, has useful implications for both research and practice for statistics instructors—especially those in social science fields. The study provides some evidence that supports the implementation of project-based learning in graduate level statistics courses. The qualitative findings showed that guided project-based learning improved students' general attitudes toward statistics and their confidence in using it. Students also demonstrated a clear appreciation of statistics' worth in educational research, though the projects gave some students the realization that they had not previously desired to use statistics in their own research. The results support this andragogical method to teaching statistics as an approach that promotes a lasting appreciation and increased research self-efficacy, and the feedback from students has the potential to be used for the development of core elements to structure other statistics courses.

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