IS GAISE EVIDENT? COLLEGE STUDENTS' PERCEPTIONS OF STATISTICS CLASSES AS "ALMOST NOT MATH"

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ABSTRACT

The connection between mathematics and statistics is an important aspect in understanding college students' learning of statistics because studies have shown relationships among mathematics attitudes and performance and statistics attitudes. Statistics attitudes, in turn, are related to performance in statistics courses. Little research has been done on college students' perceptions of their mathematics and statistics experiences. To fill this gap, a phenomenographical study of 12 college students with self-identified negative attitudes about statistics was conducted to understand their perceptions of their previous mathematics and statistics classes. An integrated approach to data analysis was conducted in two phases. First, themes emerged from an inductive analysis. Second, the six recommendations from the Guidelines for Assessment and Instruction in Statistics Education (GAISE) College Report (2005) were used as a priori categories as an organizing framework for coding the data. Themes that emerged from the researchers' analysis of the data were changing attitudes about statistics, defining the nature of statistics, seeking help, and blaming the teacher. The GAISE recommendations did not appear to be realized in the statistics classes taken by these students in various programs of study. Implications of these findings are discussed and recommendations for further research are suggested. In understanding students' experiences from their perspectives, statistics educators can improve pedagogy and student learning.

Keywords: *Statistics education research; Student perceptions; GAISE; Phenomenography*

1. INTRODUCTION

Statistics classes seem universally disliked by college students (Hogg, 1991; Onwuegbuzie, 1994; Schau, Millar, & Petocz, 2012) and have become barriers to graduation for some students (Onwuegbuzie, 1997). A common complaint among students is that they do not like statistics because they do not like or are not good at mathematics (Dempster & McCorry, 2009; Griffith, Adams, Gu, Hart, & Nichols-Whitehead, 2012; Maier & Curtin, 2005; Pan & Tang, 2005). Numerous statistics education researchers (e.g., Cobb, 1992; Rossman, Chance, & Medina, 2006; Schaeffer, 2006) have repeatedly argued that statistics, although a mathematical science, is a

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separate discipline that requires "a different type of reasoning and different intellectual skills" (Rossman et al., p. 331). Although both statistics and mathematics use numbers, mathematics is "about proof...[and]...abstraction" (Schaeffer, p. 310), whereas "[s]tatistics is about trying to understand, measure, and describe real-world processes" (Schaeffer, p. 311). In his 1991 commentary to the statistics community, Robert Hogg made the call for change in the teaching of college-level introductory statistics courses and soon thereafter George Cobb headed a report with suggestions for change including less emphasis on mathematical theory used in statistics and more emphasis on "data and concepts" (p. 7). In the late 1990s, Garfield (as cited in Garfield, Hogg, Schau, & Whittinghill, 2002) surveyed statistics instructors from a wide variety of disciplines to determine how introductory college-level statistics was being taught. The study results suggested that "major changes" (A Survey of Introductory Statistics Instructors section, para. 7) were occurring, particularly in increased use of technology, but recently this optimism was tempered in terms of course content and pedagogy (Garfield, delMas, & Zieffler, 2012).

Over 20 years later, we are well into the college-level statistics reform movement and the introduction of the *Guidelines for Assessment and Instruction in Statistics Education (GAISE): College Report* (Aliaga et al., 2005) published by the American Statistical Association (ASA). It includes six recommendations for instructors of introductory statistics courses, followed by suggestions and examples to guide incorporation of the recommendations. The recommendations are:

1. Emphasize statistical literacy and develop statistical thinking
2. Use real data
3. Stress conceptual understanding, rather than mere knowledge of procedures
4. Foster active learning in the classroom
5. Use technology for developing conceptual understanding and analyzing data
6. Use assessments to improve and evaluate student learning

Yet college students' previous mathematics experiences persist in shaping their attitudes about statistics (Onwuegbuzie & Wilson, 2003). Thus although there may be a difference between the disciplines and although reform in teaching introductory statistics has begun, the connection between mathematics and statistics remains an important aspect in understanding college students' learning of statistics because college students' attitudes about and performance in mathematics continue to explain their attitudes about statistics (Gal, Ginsburg, & Schau, 1997; Nasser, 2004) that in turn influence statistics learning (Emmioglu & Capa-Aydin, 2012).

Ramsden (2003) stated that "we can only improve the quality of university education if we study its effects on students and look at the experience *through their eyes* [emphasis added]" (p. 20). The study reported here sheds new light on statistics students' attitudes and experiences "through their eyes" (Ramsden, p. 20) because the introduction of the *GAISE College Report* (Aliaga et al., 2005) has not explored in the extant literature. We argue that by understanding students' perceptions of their mathematics and statistics experiences and the connections between statistics and mathematics, statistics educators can better address the extent and effectiveness of their pedagogical practices to improve students' learning of statistics.

Specifically, this study was delimited to college students who self-identified as having statistics anxiety or negative attitudes about statistics and who had completed at least one college-level statistics course. The students were interviewed individually and asked to identify and describe their previous experiences in mathematics and statistics courses. Three research questions from the study are addressed in this article:

1. How do these students perceive their experiences in previous mathematics classes?
2. How do these students perceive their experiences in previous statistics classes in relation to the GAISE recommendations?
3. To what extent do students perceive similarities between their previous mathematics and statistics experiences?

As described in Lincoln and Guba (1985), rather than using the findings of this study to generalize to a larger population as is done in quantitative studies, we will provide a detailed description of the students and their responses so that the reader may determine the degree of transferability of the findings of this qualitative study to other contexts.

2. LITERATURE

2.1. MATHEMATICS

Research regarding affect in mathematics education has been a focus since the 1960s (Zan, Brown, Evans, & Hannula, 2006), including how students' experiences and attitudes impact their mathematics learning effectively. For instance, Malmivuori (2006) found "situation-specific factors condition the functioning of students' self-system processes [which include affect] and, hence, the quality of their mathematics learning experiences" (p. 151). Similarly, Crawford, Gordon, Nicholas, and Prosser (1998) posited a model that

> students enter a teaching and learning context with a range of prior experiences and understandings, and that these are in continuous interaction with their perceptions of the context and approaches while studying the subject, and with their post experiences and understandings (p. 456).

Another model showed that adult beliefs were related to middle school students' attitudes about mathematics and science, such as "self-perceived importance, competence, scholastic behavior, and [course] performance" (Bouchey & Harter, 2005, p. 673).

Jansen (2012) used a case study to categorize mathematics dispositions of middle school mathematics students and found that more productive mathematics dispositions are associated with classrooms where teachers "transferred responsibility to students, solicited multiple solution strategies, provided process scaffolding, and pressed for conceptual understanding" (p. 37). Howard and Whitaker (2011) conducted a phenomenological study to describe "newly successful" (p. 2) developmental mathematics students' experiences, attitudes, and strategies. Themes that emerged from their study were a "turning point" (p. 4), motivation, and strategies.

Studies of attitudes about mathematics extend beyond the mathematics classroom. Rotgans and Schmidt (2014), in the quantitative portion of their mixed-methods study, found that undergraduate polytechnic students in Singapore thought that the mathematics courses in their programs of study were the least interesting of all. In fact, a program's mathematics requirement(s) was correlated to a "significant decrease in perceived interest" (p. 31) for that program of study. The qualitative portion of the mixed-methods study provided Rotgans and Schmidt with an explanation for these attitudes. They found, using content analysis of open-ended survey questions, students felt that it was not the subject of mathematics that was less interesting but instead it was the way in which mathematics courses were taught. Students desired "more adequate learning resources and structure" (p. 31). Flegg, Mallett, and Lupton (2012) found similar results among Australian engineering students. A majority of students did not think that mathematics courses were successful in "teaching students how to formulate and solve problems directly related to engineering" (p. 723), although they did think that mathematics was relevant to their career.

2.2. STATISTICS AND MATHEMATICS

The relationship between college students' attitudes about statistics and their previous mathematics experiences has been extensively studied using quantitative methodologies. In recent quantitative studies using the Survey of Students' Attitudes Toward Statistics (SATS-28 or SATS-36), researchers found that statistics students thought statistics was difficult and would require much effort, regardless of their previous mathematics experiences (Carmona, Martinez, & Sanchez, 2005; Chiesi & Primi, 2010; Dempster & McCorry, 2009; Finney & Schraw, 2003; Hannigan, Gill, & Leavy, 2013; Nasser, 2004). The statistics students who had taken higher level mathematics courses generally had more positive attitudes about statistics compared to the others who did not (Carmona et al.; Hannigan et al.). Statistics students' grades on a test of mathematics knowledge were shown to have a positive effect on statistics attitudes (Chiesi & Primi; Nasser). Also positively affecting statistics attitudes were higher numbers of previous mathematics courses taken (Nasser) and better grades in previous mathematics courses (Chiesi & Primi). In addition to mathematics performance, quantitative studies have shown better statistics attitudes were correlated with better perceptions of mathematics abilities (Dempster & McCorry; Finney & Schraw; Nasser).

In terms of statistics anxiety, researchers using the Statistics Anxiety Rating Scale (STARS) or the Statistic Anxiety Scale (SAS) found that higher statistics anxiety was significantly related to statistics students' numbers of previous mathematics courses (Pan & Tang, 2004), grades in previous mathematics courses, mathematics knowledge (Chiesi & Primi, 2010), and mathematics self-efficacy (Finney & Schraw, 2003). However, one quantitative study (Bui & Alfaro, 2011) did not find the relationship between statistics anxiety and the level or time of the last mathematics course taken to be statistically significant.

Thus connections between mathematics and statistics have been well established using quantitative methods. Qualitative studies published since the early 2000s that have explored students' attitudes about statistics have varied in terms of research questions, methodologies, and the populations studied. Themes that emerged from these studies included references to students' attitudes and/or anxiety about mathematics. Leavy, Hannigan, and Fitzmaurice (2013) studied undergraduate statistics students who were enrolled in a mathematics education program in Ireland that accepted students who scored in the top 10% of the mathematics portion of a national university entrance exam. In the quantitative portion of their mixed-methods study, the students indicated that they thought statistics was difficult. To understand why the students thought statistics was difficult, Leavy et al. conducted personal interviews in the qualitative portion of the study. Themes that emerged indicated students' perceptions of difficulty arose from differences between "statistical thinking and reasoning as compared to mathematics [and] the use of context and language in statistics" (Results section, para. 2). Griffith et al. (2012) also studied undergraduate statistics students but the students' programs of study were different—business, criminal justice, and psychology. The qualitative portion of their mixed-methods study used results from a written survey to explore students' attitudes about statistics and the reasons for their attitudes. Themes that emerged from students with negative attitudes about statistics were "*difficulty, nonuse in future career, dislike math, not part of the major*, and *professor*" (italics in original, p. 51). Themes that emerged from students with positive attitudes about statistics were "*use in future career,* *necessary for graduate school, professor, like math*, and *challenging course*" (italics in original, p. 49).

Maier and Curtin (2005) studied negative attitudes about statistics among journalism students enrolled in a quantitative research methods course. For the qualitative analysis portion of this study they collected data through surveys, interviews, and observations to understand students' mathematics attitudes and previous experiences. The themes that emerged were perceived lack of mathematics aptitude, anxiety, and confusion about statistical terminology. Pan and Tang (2005) also studied students in a quantitative research methods course. They conducted a focus group interview of seven graduate students to understand factors that contributed to their statistics anxiety. The themes that emerged were "[m]ath phobia, [l]ack of connection to daily life, [p]ace of instruction, [and] [i]nstructor's attitude" (p. 209).

Reid and Petocz (2002) did not explore students' attitudes or anxiety, rather they conducted a phenomenographical study of undergraduate students enrolled in a mathematics program to describe the group's understanding of the phenomenon of "the notion of statistics" (The Method of Phenomenography section, para. 5). Students' perceptions included connections between mathematics and statistics. Through interviews, they found that students whose descriptions of statistics were more "inclusive and holistic" (Abstract section) were able to focus "on 'higher-order' statistical thinking" (Abstract section) compared to students whose descriptions of statistics were "limited and fragmented" (Section 3, para. 2), who described statistics as "a sort of mathematics which involves using 'boring calculations,' 'numbers,' or 'probability'" (Section 3, para. 2). Similarly Bond, Perkins, and Ramirez (2012) described the undergraduate statistics students' "depths of understanding and conceptualization of statistics" (p. 6) that emerged from open-ended survey data in the qualitative analysis portion of their mixed-methods study. They reported that their data codes "overlapped completely" (p. 13) with Reid and Petocz's conception categories.

Thus qualitative studies of statistics students have shown a connection between students' attitudes and/or anxiety about statistics and aspects of their previous experiences in mathematics. We note that with the exception of the Leavy et al. (2013) study, the aforementioned qualitative studies found that many students equated statistics classes with mathematics classes and assumed their negative mathematics experiences would carry over to statistics class. We further note that none of the aforementioned qualitative studies of statistics students intended to explore the students' perceived relationship between statistics and mathematics.

Because mathematics experiences and attitudes influence statistics attitudes that in turn influence statistics learning, we undertook this study to understand better students' perceptions of their previous mathematics and statistics experiences. A better understanding of these perceptions has the potential to provide guidance to statistics instructors about their practices. Furthermore, it can offer direction for further research in regards to statistics students' attitudes and how these attitudes influence learning. In the following sections, we describe the framework and procedures we used in the study to represent students' perceptions. After presenting the findings from our analysis, in which we used an integrated approach to coding the data, we discuss their implications.

3. THEORETICAL FRAMEWORK

We approached the research questions through the lens of symbolic interactionism, a framework developed by George Mead and refined by Herbert Blumer. Blumer (as cited in Denzin, 1992) stated the three principles of this framework as (1) people respond to things based on meanings they create, (2) people create these meanings as a result of social interaction, and (3) “meanings are modified through an interpretive process which involves self-reflective individuals symbolically interacting with one another” (p. xiv). Thus, we aimed to understand the students’ meanings from their descriptions of their past experiences in their statistics and mathematics classes.

4. PROCEDURES

Phenomenography, a qualitative methodology that “is grounded in empirical research in education” (Limberg, 2008, p. 612) was used in this study. Phenomenography focuses on how people experience a phenomenon rather than on describing a phenomenon itself, which is the aim of phenomenology. Phenomenography explores the “variation of human experiences of phenomena” (p. 612) rather than the commonality of human experiences that is explored in phenomenology. Thus for this study, we attempted to capture variation in students’ experiences of the phenomena of learning mathematics and statistics.

4.1. PARTICIPANTS

Participants for this study were students recruited from a large Midwestern university. Four were recruited through word of mouth and eight were recruited through use of a research subjects pool maintained in the School of Education. The research subjects pool contained names and contact information for students from various programs of study who were taking courses in human development and educational psychology. Students in these courses were required to participate in a research study as part of their coursework. An online database of research studies was available to these students that included study descriptions. Students were provided the following description for this study: “Participation in this study involves a personal interview with Professor Hedges where you will be asked questions about your previous experiences in mathematics-related classes and some demographic information. The interview may require up to one hour of your time. After the interview has been completed, you may be contacted by Professor Hedges to verify and/or clarify your responses.” Students were also provided with eligibility criteria and available participation times. Over a time period of two semesters, nine students registered through the research subjects pool and eight met the eligibility requirements for the study. Students who had completed a college-level (graduate or undergraduate) statistics course within the past three years, who self-reported a negative attitude or anxiety about statistics classes, and who were not currently students of the principal investigator/interviewer were eligible to participate in the study. After approval by the Institutional Review Board and before interviews began, students signed a consent form that described the study and that confirmed eligibility.

Almost half of the participants (five out of 12) were young (late teens to early 20s) female undergraduates enrolled in the Communication Sciences and Disorders program. Three participants were enrolled in education programs, two were enrolled in health education and promotion programs, one was enrolled in a nursing program, and one was enrolled in neuroscience and biology. Three participants were male. Table 1 shows a summary of the demographic information taken from the participants during the interviews.

Table 1
Participants' Demographic Information

Participant	Age	Sex	Program of Study	Level of Study	Interview Date
Marvin	23	M[a]	Health Education	Masters	Sept. 10, 2013
Finn	43	M	Educational Studies	Doctoral	June 25, 2013
Nanette	19	F	Pre-Nursing	Bachelors	Oct. 7, 2014
Nora	21	F	CSD[b]	Bachelors	Sept. 11, 2014
Nicole	22	F	CSD, Deaf Studies Certificate	Bachelors	Oct. 2, 2014
Theresa	40s	F	Health Education	Masters	Aug. 30, 2013
Danielle	20	F	Secondary Education	Bachelors	Mar. 6, 2014
Fiona	24	F	Curriculum and Instruction	Masters	Oct. 16, 2013
Michael	22	M	Neuroscience, Biology	Bachelors	Oct. 21, 2014
Brittany	20	F	CSD	Bachelors	Oct. 16, 2014
Beth	22	F	CSD, Arabic	Bachelors	Oct. 23, 2014
Laura	19	F	CSD	Bachelors	Feb. 18, 2014

Note. [a] M = male, F = female, [b] CSD = Communication Sciences and Disorders

4.2. DATA COLLECTION

Semi-structured interviews were conducted by the first author with 12 eligible students over a period of about 17 months. In following phenomenographic data collection methods, the interviews were guided by the research questions and allowed the students to express their own views and were followed by probing questions to extract rich descriptions (Limberg, 2008). The interview guide may be found in Appendix A. Interviews were audio-recorded and later transcribed.

4.3. DATA ANALYSIS

The aim of our analysis using a phenomenographic approach through a lens of symbolic interactionism is to focus on students' meanings from the interview transcripts. Thus phenomenographic analysis is interpretivist and emergent (Reid & Petocz, 2002). After transcribing the interviews, we individually read the transcripts as a whole and made notes in memos related to the first research question. Using an inductive process to coding, we then individually coded phrases in the transcripts that related to the first research question and from the codes we developed themes within each transcript and between transcripts by aggregating similar codes based on our interpretations while analyzing and reflecting on the data. Next, we met, made comparisons, and came to a consensus on themes. The same process was used for the second and third research questions, respectively. In analyzing the second research question, it became apparent that participants' reflections on their experiences in statistics classes suggested alignment with the GAISE recommendations and thus an additional iteration of analysis of the transcripts was performed using the six GAISE recommendations as a priori categories as an organizing framework for coding. Thus we used an integrated approach to data analysis.

5. FINDINGS

5.1. SUMMARY OF EXPERIENCES

During the interviews, participants self-reported the mathematics and statistics courses they had taken prior to the study. Most participants had completed mathematics courses through precalculus in high school and most had only taken one undergraduate statistics course. The undergraduate statistics courses experienced by these participants varied greatly in size from 15 to 100. Table 2 shows a summary of participants' previous mathematics and statistics experiences.

Table 2
Participants' Previous Mathematics and Statistics Courses

Participant	Highest Level High School Math Course	College Math Course	Statistics Courses		
			Level	Number of Courses	Class Size
Marvin	Algebra	"review of high school"	undergraduate	1[a]	18
Finn	Trigonometry	Calculus	undergraduate	2[b, c]	100
			graduate	2	15, 10
Nanette	Precalculus (honors)	none	undergraduate	1	50 - 75
Nora	Precalculus	College Algebra	undergraduate	1	100
Nicole	Precalculus	College Algebra	undergraduate	1[c]	60; 15 - 20
Theresa	Geometry	Remedial Algebra	undergraduate	3[b]	20 – 30[d]
			graduate	1	28
Danielle	Precalculus	none	high school	1	unknown
			undergraduate	1	20 - 25
Fiona	Precalculus	Calculus	undergraduate	1[e]	unknown
Michael	Precalculus	Applied Calculus I, II	undergraduate	1	70
Brittany	Precalculus	Algebra II	undergraduate	1	20 - 25
Beth	Precalculus	College Algebra	high school	1	unknown
	Trigonometry	Trigonometry	undergraduate	1	15
Laura	Precalculus College Algebra	none	undergraduate	1	20 - 30

Note. [a] student was beginning second course at time of interview, [b] courses taken on quarter-system, [c] course (or equivalent) retaken, second time to replace grade, [d] size for each course, [e] research methods for psychology course

5.2. PREVIOUS MATHEMATICS EXPERIENCES

The first research question asks how these students perceived their experiences in previous mathematics classes. All study participants were selected because of their self-identified negative attitudes or anxieties about statistics classes but their attitudes about their experiences in previous mathematics classes varied.

Five participants made positive assertions, such as “I love math,” or that mathematics “came naturally” to them, and six said that mathematics “clicked” for them. In describing details of their positive experiences, a common theme emerged: the procedural aspects of mathematics. Beth was confident “when it came to the formulas and actually solving math” and liked “step-by-step” solutions and “solving problems...especially trig and algebra” as did Nanette who enjoyed all of the equations in precalculus and “loved algebra.”

Although these students liked the procedural aspects often found in algebra, four expressed negative opinions about geometry. Beth said algebra was “really easy” but struggled with geometry because “I don’t think visually.” Danielle did not describe herself as someone who liked mathematics but she “liked doing the equations better” than visualizing geometric figures and said, “I really didn’t like geometry, like all the angles and...triangles and stuff. I really didn’t like that so I did a lot better in algebra...than geometry.” Similarly, Nicole said she was “not a fan” of geometry, adding

> I think my first bad [mathematics] experience was high school with that geometry class. Yeah, so, ‘cause I’m pretty good at algebra? Like plugging and chugging stuff I can do but if it’s like figuring out angles and, you know, what’s the angle of this triangle and stuff, it’s not—(chuckles). I just, I don’t even know where to start.

Fiona liked algebra because it was “a puzzle. I have the pieces. I put them together. I get an answer” but “hate[s] geometry with a burning passion.” She specifically did not like the proofs and found them “nit-picky...and very dry and boring.”

In addition to negative recollections of geometry, almost half of the students expressed an aversion to mathematics courses in general. Theresa, who placed into a remedial mathematics course in college “just felt like there was such a block, almost like a piece of my brain was missing that knew how to do math.” In contrast, Laura earned college credit for the mathematics course she took her senior year of high school but similar to Theresa, she also felt that she did not “have the right kind of [mathematics] brain” and said, “I just don’t like any kind of math classes...I find them difficult and, um, I have a hard time learning the material.” Brittany, placed in advanced mathematics courses starting in eighth grade, was frustrated like Laura by the difficulty she had learning mathematical concepts but felt she was “decent at algebra” although she had a rough transition between Introduction to Algebra I and II and she thought geometry was difficult. Nora, who like Brittany, was also placed in honors mathematics courses starting in eighth grade said, “I’ve always struggled with math. I hate math.”

5.3. PREVIOUS STATISTICS EXPERIENCES

The second research question asks how these students perceived their experiences in previous statistics classes. First we first present findings categorized around the *Guidelines for Assessment and Instruction in Statistics Education (GAISE) College Report* (Aliaga et al., 2005) recommendations and second we present a finding that emerged from the researchers’ analyses of the data.

GAISE recommendations Students’ statistics experiences are described using each of the six GAISE recommendations.

Statistical literacy and thinking. The first *GAISE College Report* (Aliaga et al., 2005) recommendation advised college instructors to “emphasize statistical literacy and develop statistical thinking” (p. 4) and later defined statistical literacy as “understanding the basic language of statistics...and fundamental ideas of statistics” (p. 14) and described statistical thinking as “understanding the need for data, the importance of data production, and the omnipresence of variability, and quantification and explanation of variability” (p. 14). The only comment related to this recommendation that we gleaned from student comments was from Finn, who had taken five statistics classes (two at the graduate level) at the time of the interview and who said, “How many people really do use statistics above and beyond central tendency?”

Use of real data. The second *GAISE College Report* (Aliaga et al., 2005) recommendation called for the use of “real data” (p. 4) and “summaries based on real data” (p. 16). Eight students made references to using real data in their statistics classes. Finn did not get the opportunity to collect his own data. He described making up data for a quiz and using problems from the textbook to put data into SPSS. Although Danielle’s primary memory of statistics class was formulas, she also described the use of business applications but unfortunately, “It wasn’t interesting. Like, I real—I didn’t care, I guess....Yeah. Like, if I cared more it woulda been a little better (laughs).” This is in stark contrast to her high school statistics class, “the only math class that [she] didn’t absolutely hate” in which the teacher “related it a lot to things we were interested in. Like [sports] and things that made us want to, like, figure it out.” Fiona was uninterested in the context—psychological research—and therefore the statistical tools that were used. Nora found that any applications provided in her statistics class were contrived and gave this example,

> A kid’s riding a school bus and there’s, like, 30 kids on the the bus. Like wha-what are the odds that they’ll go over a bump and five kids hit their heads and those are girls because they’re lighter and they, you know, just stuff like, and I’m like what? Like, no one even cares! Like, what does that mean?

Michael was excited at first to learn statistics when he was introduced to it in high school science class and later in college he appreciated it when the instructor applied the content to business and health care but it was not enough, saying, “That was really nice but I, at the time, I was, like, ‘You know what? I’m just, like, know it for the exam.’”

Others had more positive recollections of the use of applications and/or data in their statistics classes. Theresa appreciated the “realistic way...not out of context” material was presented in her graduate-level statistics class. Brittany also appreciated the “real life examples.” Marvin valued the “relatable situations...to understand the material” and “hands-on” activities using candies to create data in his undergraduate introductory statistics class.

Conceptual understanding or merely procedures. The third *GAISE College Report* (Aliaga et al., 2005) recommendation advised college instructors to “stress conceptual understanding, rather than mere knowledge of procedures” (p. 4). Students who described their enjoyment of formulas and the procedural aspects of algebra did not likewise find this enjoyment in statistics class. To be sure, though, these students experienced formulas. It was the primary memory of Danielle’s college statistics experience:

> I feel, like, with statistics you have to learn a lot more formulas than other math classes. Like, there’s tons of formulas and I’m not really good with formulas and he didn’t give us all the formulas on a formula sheet so we’d have to memorize a lot of the formulas. And that—not—I felt like he shoulda, he probably just shoulda given them to us ‘cause it’s, it’s more, I think it’s more about, like, knowing if you can use the formulas than memorizing the formulas. That’s just how I feel about it but, yeah, it wasn’t a very good experience in that class.

Nora described statistics as a class where “you have to follow formulas and tables and you’re not using a calculator. There’s not much you can write. Um, it’s weird, there’s—it never made sense to me. It didn’t click.” Beth remembered getting a “stats paper” (formula sheet) and finding it challenging to learn how “to use what equation for that problem.” Finn also remembered formulas being a large part of his introductory statistics class. Nicole liked it when her statistics instructor used "very very simple steps" to explain how to use the *t*-table.

We get merely hints of aspects of statistics class other than formulas from Nanette's description of confusing "wordings" in her statistics class and Nicole's description of her experience: "Statistics, certain parts were easier for me 'cause a lot of it's, like, plug and chug but some other stuff was not." Michael said,

> When I first heard the concept of statistics I was, like, that sounds cool. That's an interesting thing and what it's being applied for, like in medicine or science. I thought that sounds cool. Um, but then in high school when you're forced to actually start doin' it yourself....It was jus' like plug and chug or this is what you, um, would use this for. But then also, there was time you had to like, think, outside the box and think which test would you use and I think that's where I started to go, oh alright. Now there's work involved.

Brittany experienced by-hand calculations in her introductory statistics class and found the connection tedious between the techniques she learned there and in the research methods class she was taking at the time of the interview, "Uh, we're doing, like, *t*-tests and stuff and it's not really so much, like, calculating and getting the answer. It's more of like [interpreting] the data... which confuses me." When asked if they made interpretations after the calculations in her introductory statistics class, she replied, "kind of."

Concepts were occasionally mentioned by the students but their muddled descriptions illustrated their confusion. Finn briefly mentioned regression and stated, "I'll have to go back to my notes to even determine if that's what I need to use to analyze my data." Nora remembered learning about the mean, median, and mode before her statistics class but she insisted, "Nothing stuck in my head from the entire course. I forgot everything, even now." When prompted by the interviewer naming several concepts, Laura remembered that regression was "the line with data" but she was confused about confidence intervals, "I didn't see, like, how could you be more confident but there would be more error?" Nanette had vague recollections of correlation and probability among concepts that were mentioned to her. Danielle remembered probability as the most difficult concept in her statistics classes. Fiona stated that the only concept she remembered from her undergraduate research methods class, other than negative feelings about ANOVA, was the correlation coefficient. She then correctly described it. Nicole said that the introduction to the *t* and *z* scores in her statistics class increased her understanding when reading research articles for her research methods class. Theresa also said that concepts she learned in her graduate-level statistics class helped her understand research articles better.

Active learning. The fourth *GAISE College Report* (Aliaga et al., 2005) recommendation advised college instructors to "[f]oster active learning in the classroom" (p. 4). Although lectures dominated the students' recollections, there were occurrences of active learning. Brittany and Nicole mentioned group activities but did not describe them. Laura recalled group quizzes. Among the five statistics courses Finn had taken in his undergraduate and graduate study, he recalled two instances of active learning in his graduate statistics courses. He created a video to teach others about *t*-tests for independent samples and did a group presentation on regression. Danielle, Nanette, and Michael remembered that there was no group work in their statistics classes, although Danielle and Michael remembered active learning in which they had to complete individual projects. Danielle was required to use Excel.

Use of technology. Beth was overwhelmed with her college statistics class, in part, because "most of the work [was] on Excel, and we did a lot of work, like, programming that you had to do, like, through websites and different programs online in order for you to do the homework on Excel." Obviously, Beth's experience with technology in her statistics class fell short of the fifth *GAISE College Report* (Aliaga et al., 2005) recommendation to "use technology for developing conceptual understanding and analyzing data." Eight students, including Beth, mentioned using at least one form of technology in their statistics classes—four Excel, three calculators, and two, both graduate students, SPSS. The descriptions of uses of technology were sometimes fraught with anxiety or frustration. Danielle said,

> We had a project where we had to make, um, tons of different graphs on, uh, Microsoft Excel but we just did that on our own time. We had to do it on our own time. He didn't really show us. That was actually really hard, too, 'cause he didn't show how to make the graphs on Excel and I'm not very familiar with Excel. I've never really used it before so it was really hard for me to figure out how to make the graphs on, on that, so it was, that was pretty hard.

Using Excel was optional in Michael's statistics class. Marvin and Finn struggled with accessibility issues with SPSS.

Use of assessments. The sixth and final *GAISE College Report* (Aliaga et al., 2005) recommendation advised college instructors to "[u]se assessments to improve and evaluate student learning" (p. 4) and provided a list of types of assessments that includes "homework, quizzes and exams, projects, activities, oral presentations, written reports, minute papers, [and] article critiques" (p. 21). Tests, quizzes, and homework dominated the descriptions of the types of assessments that students experienced. All students, except for Fiona who made no mention of any types of assessments, experienced tests. Four mentioned quizzes (including Laura's experience of group quizzes), three mentioned homework, and four mentioned group activities and projects, and only one (Finn) described presentations.

By students' descriptions, tests appeared to have been ineffective in promoting statistical thinking and conceptual understanding and instead fostered anxiety and encouraged surface learning of concepts. Marvin remembered the anxiety provoked by the heavy weight that tests counted toward his course grade. Five others also recalled being nervous or anxious about exams. Michael described "memorize...and forget" as a strategy he used in his college statistics class. Brittany also said she "knew it for the test but...[did not] retain the information."

Assessments other than the traditional homework, quizzes, and tests were valued by the students. Finn recalled,

> We were required to create a video of ourselves presenting one idea so I did a *t*-test for independent means ....It was a different way to go about learning stats to show your understanding than sitting down and looking at a test and...selecting the correct answer....I would say while it was inconvenient just from a time standpoint, it was very much appreciated because it was something that that I was more comfortable doing and it was constructive.... [Whereas for tests] I ultimately studied to know the information I need to know or that I thought would be on the test to answer it and get through the test but by doing that that video, I mean, I probably know that method much more so than I know anything else so that worked for me whereas a traditional test does not.

Emergent theme Not all themes related to students' previous statistics experiences came from the *GAISE College Report* (Aliaga et al., 2005) recommendations.

Changing attitudes. One theme that emerged from the researchers' analysis of the data was relevant to the second research question and arose from the fact that six of the 12 students had taken multiple statistics courses. Five of the six students changed their attitudes about statistics after their first statistics course. The change was positive for only three. Marvin and Theresa, who took introductory statistics courses as undergraduates, gained better understanding and appreciation of the worth of statistics after taking graduate-level statistics courses. Nicole gained confidence about her knowledge of statistics after retaking an undergraduate statistics course. On the other hand, Brittany and Danielle, who recalled relatively positive experiences in high school statistics courses, felt negatively about their undergraduate statistics courses because they felt they were overwhelming and covered too many topics. Finally, Finn, who took two graduate-level statistics classes after having taken multiple statistics courses as an undergraduate, remained unchanged in his negativity about statistics. He still found it confusing and did not plan to use it in his future research.

5.4. SIMILARITIES AND DIFFERENCES BETWEEN MATHEMATICS AND STATISTIC EXPERIENCES

The third and final research question asks to what extent do students perceive similarities between their previous mathematics and statistics experiences. Three themes emerged from the researchers' analysis of the data: the nature of statistics, seeking help, and the teacher is to blame.

The nature of statistics Students were divided in describing statistics classes, falling into three areas: (1) statistics is mathematics, (2) statistics is like geometry, and (3) statistics is almost not mathematics.

Statistics is mathematics. Two students made no differentiation between statistics and mathematics. When Theresa was asked if she had any negative feelings or anxiety about statistics, she responded, "Yes, math in general." Laura's response to the question was the same, "I just don't like any kind of math classes."

A possible explanation for the lack of differentiation between the disciplines of mathematics and statistics could be the similarities they perceived in their classroom experiences. One reason Laura gave for disliking mathematics classes (including statistics) was that she did not like the classroom routine of "notes on the board and then copy the notes and then learn it and do the homework and then come back and take a test." Nanette echoed this routine of lecture, notes, homework, quizzes, and test. Fiona described a similar routine in her undergraduate research methods class, "He had a PowerPoint. He went through it and, you know, we followed along and took notes." Beth felt positively about this classroom routine in her mathematics classes and the high school statistics course that she took. She felt it was the proper and "regular" way to teach mathematics and statistics, saying, "I feel like math needs to be done in the classroom with students with the teacher, like, on the board. Not necessarily on the board, demonstrations in other ways."

As previously discussed, six students, including Beth, described specific software used in their statistics classes but no students described technology other than a calculator in their previous mathematics classes.

Statistics is like geometry. An unexpected subtheme that emerged from the interviews was a connection between statistics and geometry. Fiona compared statistics to geometry in that they were both "nit-picky." Brittany said that statistics and geometry were both "different type[s] of math." Nora commented that statistics, like geometry, involves many formulas and further described statistics as "almost not math. It's more, well, I guess it's math. There's numbers included but it's very (pauses). It's different."

Statistics is almost not mathematics. Nora's description of statistics was echoed by others. Michael made comparisons between statistics and mathematics courses and verbally expressed his internal conflict about the nature of statistics.

> Even though statistics would be math. It's just the, um, the math that I took jus' came more naturally. In stats I had to think about it. I had to, um, constantly keep thinking about it so it jus', it didn't come natural. It didn't come easily (chuckles).

Nanette described mathematics as a discipline in which there is a "right or wrong and then for statistics, of course, it's still right or wrong but I feel like you could also, like, persuade it a little more." She elected to take an introductory statistics class because she expected it to be like a mathematics class but she was disappointed to find that "with statistics, it wasn't so much math as it was, like, I don't know how to describe it. I just feel like it wasn't so much calculations as, like, wordings." Beyond disappointment, Nora expressed fear when describing the use of language in statistics class. She said "Oh God, there's words and numbers."

Seeking help A common theme among students was the one-on-one help students sought out and received from mathematics and statistics teachers—both helpful and unhelpful. Nora sought out help from her teachers in multiple mathematics classes. For algebra, she would stay after school and the teacher would "sit with me through every single problem." Her afternoon help sessions with her precalculus teacher were similar,

> You were able to sit down and have [the teacher] do the entire homework assignment with you and then you got rewarded for coming and asking for help....knowing my homework was done and it was correct, 'cause I did it with [the teacher], I had—I felt good turning it in.

Nicole also consistently sought out one-on-one help from her mathematics teachers, saying the extra practice helped build her confidence. "I had always kinda struggled with math but I would go in either before school or after school." Theresa did not have positive one-on-one experiences with her mathematics teachers, "I tried so hard. I mean, I'd stay after class....and [the teacher] knew how hard I would try." Similar to Theresa, Brittany found her teacher willing but unhelpful, "It was really hard for him to, like, make sense, I think, to the students. Like, explain in a way that we could understand."

Similarly, students sought out one-on-help from their statistics teachers with mixed results. Marvin gained confidence by asking for help from his undergraduate statistics teacher and upon registering for his master's level statistic course, he "planned the first week [to] reach out for help, like...not even gonna get behind." Finn felt that one of his graduate-level statistics instructors did not communicate well so he sought out a tutor. Nicole had a small class of about 15 students the second time she took the undergraduate statistics class, which provided more one-on-one opportunities with the instructor who she found approachable.

The teacher is to blame Another common theme for both mathematics and statistics experiences was the perceived poor quality of the teacher, often given as the primary reason for the negative experiences. This sentiment was illustrated succinctly by Brittany who said "a lot of my struggling [in mathematics] was due to, like, my teachers" even saying that her Algebra II teacher "didn't teach." Laura did not like how her middle school mathematics teacher and student teacher taught and thought this was the reason it was hard for her to learn. The "bad experience in that class...just carried on....Like I had good teachers in high school but I just still didn't like math." Similarly, Theresa thought that the "bad teaching" she experienced in high school prevented her from learning "those underpinnings of math" and caused her mathematics anxiety, which negatively affected her career choices because she "didn't have the math skills." Fiona also felt the teacher affected her feelings about mathematics but she was able to recover from experiences with bad teachers. She said,

> I did not like math at all up until sixth grade and then I had a really good math teacher in sixth grade and she helped me like it a little bit more. Seventh grade, she sucked, started hating math again. Eighth grade we started algebra....I had Mr. T. and Mr. T. was awesome so he helped me to uh like algebra and math...

Beth believed that her sixth grade teacher's inability to "click it with the students" resulted in poor learning. Beth also felt that her college statistics teacher was to blame for her confusion because—unlike her high school statistics teacher—he was unclear in class, did not demonstrate enough problems, and did not return exams in a timely manner. She cited an attrition of between 40% and 50% of students as evidence of bad teaching. Nora said that her undergraduate statistics teacher lectured the entire class and was not engaging. Three other students also felt their statistics teachers contributed to their lack of understanding.

6. DISCUSSION

We posited that by understanding students' perceptions of their mathematics and statistics experiences and students' perceptions of the connections between statistics and mathematics, statistics educators can better address the extent and effectiveness of their pedagogical practices to improve students' learning of statistics. In analyzing the students' retrospective perceptions, we captured variation in students' experiences of the phenomena of learning mathematics and statistics. Although all students in the study were selected for their common disdain for statistics, reasons for their negative attitudes varied as well as their conceptions of the nature of statistics. Their responses about their previous mathematics experiences also differed. Several themes provided insight into areas of potential improvement for statistics instructors and future focused study in statistics education. The detailed description of the students' backgrounds and their responses provide the reader with information necessary to determine the degree of transferability of the findings of this qualitative study to other contexts.

First, the *GAISE College Report* (Aliaga et al., 2005) recommendations did not appear to be realized in the statistics classes taken by these students in various programs—no more than and sometimes less than Garfield's findings of the late 1990s, prior to the report. This finding supports that of Garfield et al. (2012) who stated that "[d]espite repeated calls for change and attempts to change the content and pedagogy of the introductory statistics course at the tertiary level, there is little to no evidence that substantial changes have taken place..." (p. 883). As of this writing, a revised GAISE College Report has been sent to the American Statistical Association for approval. Included in the revision are two additions to the first recommendation about statistical thinking that involve "an investigative process of problem-solving and decision-making" and "multivariable thinking" (Carver et al., 2016, p. 3). As there were very few student responses in this study regarding statistical thinking, we do not think this change in the guidelines impacts our analysis. Students recalled experiencing applications of concepts in their statistics classes but sometimes found them contrived and often personally uninteresting. When statistics was taught as part of a discipline-specific research methods course or during graduate studies, the applications were often perceived to be more valuable. Students also recalled experiences of focusing on procedures rather than concepts in their statistics courses, which they also experienced in previous mathematics courses. Interestingly, though, students who enjoyed mathematics courses due to this emphasis on procedures did not likewise enjoy statistics for that reason. The use of technology and active learning in statistics classes, as students described them, seemed merely add-ons to the traditional pedagogical practices of lecture, assign homework, and test.

These traditional practices in statistics courses mirrored what students experienced in previous mathematics classes and thus it was not surprising that students viewed statistics class as another mathematics class. This idiom seems to capture what students indicated by their responses: if it looks like a duck, swims like a duck, and quacks like a duck, then it probably is a duck ("duck test," n.d.). Their previous mathematics experiences echoed those described by Crawford, Gordon, Nicholas, and Prosser (1994) over 20 years ago where a "majority of students [view] mathematics as a necessary set of rules and procedures to be learned by rote" (p. 331) and they echoed Perry's (1970) description over 40 years ago of freshman college students' "dualistic conception of knowledge...[learning] between true and false, between right and wrong" (as cited by Dahlgren, 1984, p. 21). Even if students recognized that statistics was not quite mathematics, they could not clearly articulate how. This finding is similar to that found by researchers Bond et al. (2012) and Reid and Petocz (2002) who described students with "limited and fragmented" (Section 3, para. 2) conceptions of statistics. Like the mathematics education students in the Leavy et al. (2013) study, the students in the current study found statistics difficult, in part, because of the differences between statistical and mathematical reasoning and because of the heavy use of language in statistics. Other findings similar to previous studies were teacher blame and mathematics anxiety, as found in Pan and Tang (2005) and Maier and Curtin (2005).

Finally, as previously described, one particular similarity between students' mathematics and statistics experiences was a heavy reliance on testing. Testing, in the form students recalled experiencing, reinforced the idea of the "dualistic conception of knowledge" (Perry, 1970 as cited by Dahlgren, 1984, p. 21) and did not promote conceptual understanding or statistical thinking. In addition, several students described anxiety associated with test taking. Several students described how they appreciated well-designed alternative forms of assessment such as group activities and presentations. This finding related to statistics anxiety is aligned with that of Pan and Tang (2004) who found that incorporating the "application-oriented teaching methods" (p. 152) of writing essays and critiquing journal articles significantly reduced statistics anxiety among graduate social sciences students.

Although the current study has provided insight into student perceptions of their previous mathematics and statistics experiences, it is not without limitations. The study relied exclusively on retrospective interviews in which the interviewer attempted to "get a respondent to recall and then reconstruct from memory something that has happened in the past" (Fraenkel & Wallen, 2000, p. 510) and which, compared to other types of interviews, have the lowest chance to result in accurate data. Yet student perceptions and memories after the fact were important to the aims of the study. Effective pedagogical practices are of lesser value if they are not recalled by students. Also, student recall of statistics classes were by in large from experiences that had occurred within the past three years, thus we felt we could trust that their memories were fairly accurate representations of their perceptions. Another limitation was that five of the 12 students were in the same program of study, Communication Sciences and Disorders, and thus these students potentially could have had the same statistics experiences by having the same statistics course required in their program and possibly the same statistics instructor, which may overrepresent one particular experience. However, we reviewed the interview transcripts and found that this potential limitation was not realized as evidenced by the students' descriptions of class sizes, campuses where and semesters when the classes were taken.

Finally it is important to note that because students were selected because of their negative attitudes or anxiety about statistics, perceptions from students with neutral or positive attitudes may be very different.

7. IMPLICATIONS AND CONCLUSIONS

The study findings not only provided a glimpse into student perceptions of the current state of the college statistics classroom from a variety of departments and colleges in a Midwestern area and how students related it to their previous mathematics experiences, but also pointed to areas for pedagogical improvement and further study. A call for change in the college statistics classroom has been repeatedly made for over 20 years but sweeping reform has still not occurred in the eyes of the students in this study who had negative statistics experiences. Why is this so? Crawford et al. (1994) cites past research of teachers of introductory physical science courses that found that many believed "reproductive learning" (p. 344) was appropriate at that level. The current study suggests that this may be true of some introductory statistics teachers as well. The practice of primarily using lectures and tests to promote student learning suggests a subscription to behaviorist learning theory rather than the more current and accepted view of constructivist learning theory in which students learn through constructing their own knowledge through experimentation and/or social interaction with a "more knowledgeable person" (Brahier, 2013, p. 49). To what extent do statistics teachers (as well as the high school and college mathematics teachers) consider the learner as well as the discipline? Further research of introductory statistics teachers' conceptions of and approaches to teaching and learning and their reasons for selecting specific assessments and technologies could provide insight into barriers to implementing reform measures.

The finding of some students' comparing statistics to geometry also warrants further study that may provide insight into student understanding. Statistics education researchers will be well-served to find connections and incorporate the voluminous research in related areas such as mathematics and physics to improve statistics students' learning in addition to learning from the statistics learner.

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APPENDIX A

INTERVIEW GUIDE

[State student's name, date, and time.]

1. Tell me a little about yourself.

Probes: How old are you?, What year are you (e.g. freshman)?, What is your current program of study?, Have you earned any other degrees?

2. Do you currently have negative feelings or anxiety about statistics or statistics classes? Can you describe how you feel?

Probe: Is it just negative feelings, just anxiety, or both?

3a. Let's go from the most recent statistics and math classes and go backwards as far as you can remember and describe your experiences for each class. [Determine most recent class, then for each class:] Describe what the class was like.

Probes: [For college-level statistics classes:] What did you do in the class? How many students were in the class? How were you assessed? Did you have tests or group projects? Did you use any technology? (If so, what kind(s)?)

3b. How did you feel about it?

3c. What was the instructor like?

3d. Are there any specific experiences or incidents that you remember?

Probe: What was your first negative experience in math or statistics?

4. Is there anything else you would like to add?

[Thank participant. State the time at end of interview.]