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Investigating Students' Mathematical Needs and Successful Tutoring Strategies

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ABSTRACT

Quantitative learning centers (QLCs) have emerged on undergraduate around the globe in an attempt to provide necessary support to students enrolled in undergraduate courses that address quantitative literacy. QLCs often provide support through peer tutoring to students in mathematics or related courses. Since QLCs are prevalent on undergraduate campuses and have the potential to impact students from diverse backgrounds and disciplines, it is pertinent that we understand their effects on the learning experience. In the existing literature, QLCs are shown to have an overall positive impact on students both academically and affectively, however studies rarely investigate the needs of the students visiting or what is happening at the QLC that stimulate this positive impact. Thus, this dissertation seeks to address these two areas. Using a mixed methods research design that includes observations of tutoring sessions, interviews with tutors and students, and surveys of students, this study addresses the following three research questions. First, what are the mathematical needs of the students that visit the QLC in the tutors' and the students' perspectives? Second, what explanations or tutoring strategies help the students to understand the mathematical topics they are seeking help with in the tutors' and the students' per-

spectives? Third, how do the students' views about the first two questions compare to the views of students enrolled in mathematics courses who do not visit the QLC? The results of this study provide insights into how support can be enhanced not only within QLCs but also across undergraduate mathematics education more broadly.

Investigating Students' Mathematical Needs and Successful Tutoring Strategies

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Chapter 1

Introduction

With continued technological and scientific advancements comes the need for members of society with strong quantitative literacy (QL), "the ability to adequately use elementary mathematical tools to interpret and manipulate quantitative data and ideas that arise in an individual's private, civic, and work life" (Gillman, 2011). At many institutions of higher education, an emphasis has been placed on developing students' QL and as such, requirements are placed on students to take courses involving QL. However, for many students the mathematics involved in these courses causes trepidation, either because their mathematical background has not prepared them sufficiently or because they feel anxiety towards the subject. Even for those students who enjoy mathematics and have been well-prepared, often a shift in teaching style or expectations at the post-secondary level can cause challenges. Educators at the post-secondary level are then left with the question of how these students can be best supported and equipped towards success.

This dissertation seeks to investigate this question through the eyes of students and tutors at a quantitative learning center (QLCs) at an institution of higher education. Through this investigation, I hope to give insight into the mathematical needs of our students as well as ways in which we can continue implementing and build upon successful support strategies. In this chapter, I will give background and context for the current study, a statement of the problem that the study seeks to address, state the purpose and research questions for the study, and briefly describe the research approach. The chapter will conclude with definitions of key terminology that will be used in this study.

1.1 Background and Context

In response to the general public concern for QL, students at most undergraduate institutions are expected to fulfill a quantitative competency requirement in some form. While requirement descriptions at universities vary, the core idea is the same: quantitative literacy is considered a fundamental trait of a college graduate.

For students entering college mathematics in entry level courses, though, it can be a steep climb to achieve QL. Typical success rates in college algebra are only around 50 percent and very few of these students go on to enroll in Calculus I (Gordon, 2008). Thus, for many students these entry-level courses are the last mathematics courses they will take. Since these students may have weaker mathematical backgrounds leading to their placement in entry-level courses, additional support is crucial for their success.

Aside from the general concern for QL, there is also a need for strong mathematical skills in students hoping to pursue careers in STEM and related disciplines. Even those students with strong mathematical backgrounds may need support in their quantitative courses. There may be topics within their quantitative courses that they struggle with or they may be challenged by the transition to the post-secondary learning environment. Regardless, courses like calculus 1 and 2 are often considered barrier courses, particularly for engineering students (Suresh, 2006), and can cause students to rethink their desire to continue in their STEM discipline. In fact, Seymour (1995) reports that she and Hewitt found that low grades in a students' first two years of courses was a common reason for a student to lose confidence and switch to a non-STEM discipline. Since science and technology fields are only growing, this is a concerning result for students who otherwise were excited about their future careers.

To address the challenges their students are facing in quantitative courses, universities have experimented with various approaches to support their students in addition to traditional office hours offered by instructors. Schools have instituted placement exams in hopes of assigning students to the correct level course (Armstrong, 2000; Rueda & Sokolowski, 2004), offered supplemental instruction sessions, and enrolled students in co-requisite "just in time" courses that cover pre-requisite material at times chosen to coordinate with the main course's curriculum (Complete College America, 2016).

An additional response has been the creation of quantitative learning and support centers (QLCs). These centers are designed to provide support and necessary services to students in quantitative classes to help them succeed. QLCs are sometimes run through a mathematics department but are often run as a separate entity. A main feature of QLCs is that they provide a physical space for students to work together and with tutors or staff. Many centers use peer tutoring as a means of support for their students, hiring undergraduates who have successfully completed a quantitative course to tutor for that course. They may also hold review sessions with experienced tutors, graduate assistants, or faculty members (Grant, 2016). QLCs are available to all students enrolled in supported courses, and as such have the potential to reach students from diverse backgrounds and disciplines. These centers are found across the country and around the globe at institutions of higher education. As such, even with their varied structures, they provide a setting where students' mathematical needs can be explored.

1.2 Statement of the Problem

As mentioned above, students in undergraduate mathematics and quantitative courses often struggle to succeed, whether it is due to poor preparation or otherwise. For students enrolled in mathematics remediation courses, only 22% complete the course within two years (Complete College America, 2016). With the need for workers in STEM fields, this combined with an attrition rate of 48% of bachelor's degree and 69% of associate's degree students in the STEM fields (Chen & Soldner, 2013) is concerning, especially since there is evidence that receiving higher grades in their STEM related courses as compared to non-related courses can improve the probability that students will remain in the STEM disciplines (Griffith, 2010). Thus, support for students both in remedial-level and college-level mathematics courses is crucial. This raises two broad questions: (1) What are the needs of our students? and (2) What types of support can be provided or improved so that our students are equipped for success?

As already briefly discussed, one common support structure on a college campus is a QLC. Overwhelmingly, research has shown that these centers are having a positive impact on students. Studies have found that tutoring at QLCs has a significantly positive effect on final exam scores (Xu, Hartman, Uribe, & Mencke, 2001), that at-risk students who visit a QLC perform better than those that do not (Berry, Mac An Bhaird, & O'Shea, 2015), and that the mean scores of students who access learning centers can increase throughout the course of a semester whereas the mean scores of those who do not visit tend to remain relatively constant or decrease (Cai, Lewis, & Higdon, 2015). It is important to mention that the previously mentioned studies, and most of the existing literature in general, each focus on a single QLC; as such, the findings may not be generalizable to the broad range of QLCs that exist. However, it is noteworthy that across all studies attendance at the QLC never resulted in decreased grades or outcomes. Thus, altogether, the positive individual findings point to the importance of the impact QLCs have in the college learning experience and the value in studying them.

As in the above findings, studies often focus on the effectiveness of QLCs, however there is a lack of research pertaining to the specific mathematical needs present in students who visit QLCs. While it is important to understand the effectiveness of the centers and the behaviors of the students who visit them, by not focusing on the mathematical topics being supported within the centers we are missing out on an opportunity for growth in our educational practices as a whole. This dissertation will explore this from the perspectives of the students as well as the tutors, since each population may provide insights that the other does not have. In addition, I seek to explore the ways in which tutors successfully support students in these topics. While studies have addressed the effectiveness of QLCs in terms of certain measures, such as grades, retention, etc., they do not often explore what the tutors themselves do that leads to an effective QLC.

The results of this study will be of interest to QLC administrators, professors, tutors, and higher education administrators. It is my hope that through exploring the perceptions of students and tutors, new insights can be garnered about how we can better help our students to succeed. It is important that we find ways to transfer what we learn from studying QLCs to improving practice not only within the QLCs themselves but also in our teaching, office hours, and general interactions with and support of our students.

1.3 Statement of Purpose and Research Questions

The purpose of this dissertation was to investigate the mathematical needs of students enrolled in quantitative courses and the successful support strategies used by the tutors at the QLC. In particular, I investigated the perceptions of students enrolled in mathematics quantitative courses and of tutors at a QLC about these two topics. The study addresses the following research questions:

1. What are the mathematical needs of the students who visit the QLC

   in the tutors' view and

   in the students' view?

2. What explanations or tutor strategies help the students to understand the mathematical topics they are seeking help with

   in the tutors' view and

   in the students' view?

3. How do the students' views about questions 1b and 2b compare to the views of students enrolled in mathematics Q Courses who do not visit the Q Center?

1.4 Research Approach

The approach for this study was a mixed methods design, with both quantitative and qualitative methods used. Observations of tutoring sessions, semi-structured interviews with tutors and students, and students' open-ended survey responses provided the qualitative data. Closed-response questions on student surveys provided quantitative data. The mixed methods design was chosen because it would allow in-depth, rich details to emerge about the students' and tutors' perceptions of Research Questions 1 and 2 through the qualitative data, while the quantitative data could be used to address Research Question 3 and to design aspects of the qualitative data collection to address trends and anomalies seen in student responses on survey questions. The research design is described in detail in Chapter 3 of the dissertation.

1.5 Definitions of Key Terminology Used in this Study

Quantitative Literacy: "The ability to adequately use elementary mathematical tools to interpret and manipulate quantitative data and ideas that arise in an individual's private, civic, and work life" (Gillman, 2011).

Q course: A course at an institution of higher education that requires students to use quantitative literacy skills throughout. Typically the mathematics required is at or above the algebra level and the course requires students to draw conclusions from their mathematical or quantitative work. These courses are not always housed within mathematics departments.

Quantitative Learning Center (QLC): For the interests of this study, we will define a QLC as a support center on the campus of an institution of higher education that provides support and necessary services to students in quantitative classes.

Tutor: The tutors in this study are hired by a QLC to provide instruction and support to other undergraduate students who visit the QLC. Unless otherwise noted, these tutors are undergraduate students themselves.

Chapter 2

Literature Review

The purpose of this dissertation was to investigate the mathematical needs of students enrolled in quantitative courses and the successful support strategies used by the tutors at the QLC. In particular, I investigated the perceptions of students enrolled in mathematics quantitative courses and of tutors at a QLC about these two topics.

This chapter will present a review of relevant literature in three main areas of interest to this dissertation. Based on my interest in students' mathematical needs in undergraduate mathematics courses, the literature review will begin with relevant background on mathematical teaching and learning, with a focus on undergraduate mathematics education. Next will be a discussion of peer tutoring and finally, the chapter will end with a review of the literature on QLCs and a discussion of how the research discussed works together to inform my study.

2.1 Relevant Background on Active Learning

Given my interest on the needs of students and the strategies that can support them, this section discusses of the current literature on mathematical teaching and learning. Specifically, this section will focus on the literature regarding active learning pedagogies and their effects on student outcomes, since encouragement to provide environments within the classroom where active learning is promoted has become prominent in the literature. Additionally, my focus on active learning pedagogies is derived from the expectation that there will be a high use of student-centered, active learning techniques during tutoring at QLCs.

Schoenfeld, a notable figure in the mathematics education community for his work in problem solving, recommended that mathematics be taught in a way that would foster "an alert and questioning attitude in students, and that actively engages students in the process of doing mathematics" (p. 7, 1983). One technique that Schoenfeld argues for is small-group problem solving. This is intended both as an opportunity for the instructor to be involved with the students during their problem solving rather than after they have finished the problem, as well as to provide students with the opportunity to collaborate and think through possible solution strategies.

Active learning is generally understood to involve strategies that promote student engagement within the classroom beyond just listening to a lecture. The literature base documenting active learning in undergraduate mathematics courses continues to grow, with published work ranging from descriptions of and reflections on strategies implemented in the authors' courses to full-scale research studies attempting to assess the impact of a given pedagogy. The active learning pedagogies suggested include group work, flipped classrooms, inquiry based learning (IBL), and more. In the following paragraphs I will give a few examples of existing literature to survey the types of results that have been found.

An article by Rosenthal (1995) falls into the descriptive and reflective category. Rosenthal describes the active learning techniques that were used in an upper-level probability course. These strategies included small-group work as well as essay-writing and peer review. Rosenthal's reflections on the course concluded with the hope that instructors in mathematics and other technical disciplines would find ways to implement active learning in order to "make their classroom environments as exciting as the subjects they teach" (Rosenthal, 1995).

Research studies have also shown favorable results. Qualitative findings of Steen-Utheim and Foldnes (2018) revealed many affective gains for students in a flipped mathematics class, including being recognized, feeling safe, and developing a relationship with their instructor among others. McCallum, Schultz, Sellke, and Spartz (2015) also conducted a study involving 3 flipped classrooms in mathematics and business and found similar results, with students giving positive feedback pertaining to peer interactions and faculty interactions, as well as engagement with the course material.

Another interesting finding came from Retsek (2013). When comparing grades between his IBL course and his lecture-based class, Retsek found that there was an especially noticeable change in how many students failed or received a D in the course. His interpretation of this data is that the IBL methodology is especially helpful to those students at the bottom of the grade spectrum, who may struggle in a lecture-based classroom.

In mathematics courses, many instructors are hoping that beyond memorizing methods and definitions students will also gain understanding of the concepts behind the methods and definitions. Capaldi (2014) noted that in the abstract algebra course that she structured as an IBL class "there were significant differences in the level of understanding of both basic definitions and the ability to prove theorems" (p. 22) compared with the final exams from students who had taken her non-IBL class. Deep understanding of concepts is crucial not only for students who wish to pursue an undergraduate degree in mathematics, but also for those who will be continuing in other fields. Students who continue into higher level mathematics classes are often no longer doing computations but are instead asked to prove theorems and find examples of complicated structures. This is extremely difficult to do without fully understanding prerequisite concepts.

Ralph (2015) conducted a literature review on project-based learning in undergraduate STEM subjects. In project-based learning, instructors guide students as they work on projects that will result in some form of final product. This project is intended to engage the students with the content of the course in a way that will allow them to make meaning of the topics. Ralph (2015) found 14 studies that she then analyzed and found that overall, most students felt that they gained valuable skills for both future courses and their careers. One caveat was that there were negative reactions from some students concerning the teamwork aspect of the class, but most students from these 14 studies did find the teamwork and the skills they gained from participating to be valuable.

In a meta-analysis of 225 studies that compared undergraduate student outcomes under traditional lecturing and active learning in STEM courses, Freeman, et al. (2014) found that students were 1.5 times more likely to fail in a class that was taught with traditional lecturing rather than active learning. They also found that there was a 6% improvement in average exam scores of students in active learning sections. Since these findings were found to be consistent across class sizes and STEM disciplines, these results give credence to the call for more active learning pedagogies to be used in mathematics courses. In fact, the studies that were classified as active learning in the meta-analysis were considered active learning as long as some approach was used within the classroom that was not lecture, however lecture could still be used. For example, a class that used group work occasionally would be considered active learning. Thus, the impact of active learning was seen to exist even when the active learning was minimal.

These positive findings exemplify the results found in the current literature on the various forms of active-learning. The motivating factors to use these strategies is often that it allows students to engage with one another and with their instructor to construct their own understanding of topics. Similar ideas arise in QLCs as students are working together and with a tutor. Tutors are not typically lecturing, but rather working with the students in interactive ways that resemble many of the characteristics of the active learning approaches that have been shown to be successful overall.

2.2 Peer Tutoring

Often, drop-in tutoring centers rely on undergraduate students who have passed some form of application and interview process to provide tutoring for other students. A common rationale for why this works is that the tutors will be closely connected with the courses they are tutoring and able to answer questions pertaining to not only content but course expectations as well. Benefits to peer tutoring have been cited for both the students being tutored as well as for the tutors themselves. In this section, the literature involving peer tutoring at the undergraduate level will be discussed, primarily in the area of mathematics.

It is important to classify the type of peer-instruction that is discussed within this dissertation. Many support structures have been created using peer-instruction including supplemental instruction (SI), other peer assisted learning programs (PAL), and reciprocal peer teaching. In both SI and PAL programs, a knowledgeable peer, frequently a student who has taken the class already, leads a group of students in preparing for their course. Often this support involves more than just course content, but also development of study habits and problem solving skills (Hager, 2018). In reciprocal peer teaching, students typically teach each other content from a class they are enrolled in together, often as a class assignment. While these are all involving peer-instruction, they are not peer-tutoring in the sense that this dissertation discusses. One main difference between these and the peer tutoring I will discuss is that the sessions between tutor and student are typically not planned or structured. Rather, students arrive at their tutoring session with questions that their tutors do not know ahead of time.

The form of peer tutoring taking place at tutoring centers generally consists of a more knowledgeable peer acting as tutor to support the tutee in understanding content. In other forms of peer tutoring the two students may be on more level standing, but at tutoring centers the tutors are generally expected to act as the "experts" to aid the tutees. Topping (1996) conducted a literature review on peer tutoring in higher education across content areas and lists several benefits to this model as well as some drawbacks. Among the benefits for tutees were "immediate feedback, swift prompting, lowered anxiety with correspondingly higher self-disclosure" (Topping, 1996, pp.324-325), and others. Students may feel less pressure since their tutors are closer to their situation than their instructors. The major disadvantage cited was the organizational commitment involved with training tutors and matching tutors with tutees. Topping noted that at the time of his publication, the literature on peer tutoring at the undergraduate level was minimal. At the time of this dissertation, the research on peer tutoring and peer assisted learning at the undergraduate level has grown, however research on peer tutoring within mathematics specifically is still lacking.

The research that we were able to find shows positive effects from peer tutoring both for students and for tutors. For the students, both affective and academic gains were found. In a study across departments, Srivastava and Rashid (2018) focused on the effectiveness of peer tutoring on students' achievements as well as the social and emotional benefits of the tutoring. They found that students gained an assortment of affective benefits, including an improved attitude toward the subject, increased motivation to study the subject, and improved confidence. In another cross-subject area study, Rheinheimer, Grace-Odeleye, Francois, and Kusorgbor (2010) focused on a very specific population of at-risk students at one university and found correlations between being tutored and GPA, whether the students graduated, and the number of credits earned towards graduation. In all of these cases, tutoring seemed to have a positive correlation, most vividly towards graduating and number of credits earned. Young (2011) details the results of a study where onsite peer-tutoring was provided for three mathematics content courses for pre-service PK-8 teachers. While no direct outcomes were measured, survey results revealed that students felt that the tutoring was beneficial towards both their content knowledge and their confidence in their mathematical ability.

In addition to benefitting the students who are being tutored, peer tutoring is also seen to benefit the tutors. Through supporting other students, tutors are forced to revisit topics from previous courses and to think through difficult or even seemingly mundane topics to find new ways to explain them. In this way, the tutors come away with an even stronger understanding of the material. Evans, Flower, and Holton (2001) used a peer tutoring method in a teacher-preparation mathematics class with the hope that the students would find it to be a useful learning experience. In self-report data, the students involved felt that they learned the topic better because they were expected to teach it to others rather than just learning it from their instructor. In Young's (2011) study, tutors also found that their role helped them to improve their own understanding of topics because they needed to learn how to explain the topics in different ways.

While more studies have investigated peer tutoring in other disciplines, the aforementioned studies represent the types of results present in the current literature on peer tutoring of mathematics at the undergraduate level. Overwhelmingly, the results are positive, pointing to the validity of using this technique in QLCs. In fact, much of the research on peer tutoring in mathematics is set in QLCs at IHEs. The remainder of this literature review will focus on this branch of peer tutoring.

2.3 Quantitative Learning Centers

While much of the research on tutoring has been done in other disciplines and in scenarios outside of tutoring centers, the literature on tutoring mathematics and mathematics support centers is expanding. A large amount that is written is descriptive and explains what specific centers are doing, but research studies are being done more and more frequently about the support students receive at tutoring centers as well as about the students who visit. In particular, much of the research that exists surrounding QLCs focuses on the effectiveness of the QLC or the help-seeking behavior of the students who attend. This discussion will begin with a description of the different models of QLCs found in the literature followed by a look at the current state of the research on the effectiveness of QLCs. Finally, research pertaining to the help-seeking behavior of students at QLCs will be discussed.

2.3.1 Descriptions of Different Models

As noted above, much of the existing literature consists of descriptions of QLCs, including: the services offered, administrative organization (e.g. connections with departments on campus, director responsibilities, etc.), and staff training. Here I present representative descriptions to give a clearer image of the variety of QLCs that exist.

Services

One common aspect across many QLCs is drop-in tutoring. This will be the main form of service that this dissertation explores. The Symbolic and Quantitative Resource Center (SQRC) at Lewis & Clark College, for example, provides drop-in tutoring to undergraduate students in mathematics or related courses. The center tutors are undergraduate students who are able to tutor various mathematics subjects as well as some physics, chemistry, computer science, and related classes. SQRC is available to all students at the university and tutoring is not restricted to particular courses

(Black, 2016). Similarly, at the University of Connecticut's Quantitative Learning Center (Q Center) the main support involves drop-in tutoring by undergraduate peer tutors (Roby, 2016). Students sign in at the beginning of each visit and indicate why they have come to the Q Center and then are able to ask questions of tutors who roam the area. Unlike at Lewis & Clark College's SQRC, the Q Center only provides tutoring for specific courses. In addition to tutoring, review sessions are often held before exams by one of the Q Center graduate assistants (GAs) or by a course instructor.

In addition to drop-in peer tutoring, QLCs often offer a variety of other services. A slightly different model of QLC is seen at Simon Frazer University, where four math workshops were offered for the 2014 school year to support various courses in the mathematics department (Menz & Jungic, 2015). Each workshop supported multiple classes, grouped by topic: Algebra, Applied Calculus, Calculus, and Q Support. Similarly to the two centers mentioned above, the workshops provided drop-in tutoring with teaching assistants (TAs) assigned to that topic area. The TAs were primarily mathematics graduate students, but some graduate students from other departments and advanced undergraduate students were hired as well. The workshops were open daily Monday through Friday and each was held in its own room to keep the topic areas separated. An online discussion board was also available for each workshop. In addition to tutoring, homework was collected and returned within the workshop by the TAs. In this way, the workshops were not only focused on supporting students but also on supporting instructors by reducing their grading workload.

In some cases, quantitative support is offered at learning centers that also offer support in other subject areas. For instance, the William B. Law Learning Commons at Tallahassee Community College provides support for students in courses across all subject areas (Mayes, 2016). In this center, mathematics and related disciplines are housed on the first floor while other subjects such as English and writing are on the second. Thus, quantitative support is provided through the Learning Commons in addition to other supports. The center is intended to provide collaborative space for students to work together with staff support as needed. As such, the space has been designed so that white boards and other resources are easily accessible and furniture can be moved to accommodate groups. In addition to drop-in support, students can also sign up for one-on-one or group tutoring sessions in many lower level mathematics courses as well as in writing. The center also provides workshops on course topics and how to improve academic performance.

Organizational Infrastructure

There are a variety of ways a QLC may be situated in relationship to other departments on campus. At Simon Frazer, the workshops were organized through the mathematics department (Menz & Jungic, 2015). The SQRC at Lewis & Clark, on the other hand, is not formally attached to any department, but rather exists as its own entity with the director reporting directly to the Dean of the College (Black, 2016). However, it has a very close informal relationship with the mathematics department. The director of the center has an office in the mathematics department and attends departmental meetings. At the University of Connecticut, the Q Center is part of the Center for Excellence in Teaching and Learning (formerly ITL), which is not connected to any department on campus, but the director is also a faculty member in the mathematics department (Roby, 2016).

Responsibilities of administrators also vary. At Simon Frazer, one faculty member or a graduate student was assigned to coordinate each workshop. Each coordinator was responsible for supervising the TAs for the workshop, handling grades for students, answering student questions, and working with instructors. The TAs were evaluated by the coordinator at the end of each term. Student surveys were used throughout the semester to aid in evaluating TAs and the workshops in general (Menz & Jungic, 2015). At Lewis & Clark, the director is not only responsible for running the center, but also is expected to teach CS102, a remedial mathematics course intended to help students increase their quantitative reasoning skills. The director is also in charge of the school's Quantitative Reasoning Exam, which either places students in CS102 or allows them to skip it (Black, 2016).

Training

Training of staff and tutors is done in various ways, including the use of workshops, training sessions, or courses created specifically for tutor training. At Lewis & Clark, budget restrictions have limited training options. Training for tutors occurs at the beginning of each semester with a two-hour training program. A pilot course worth one credit was offered in the spring of 2014 with the intent to continue if successful (Black, 2016). At Bates College, the Math and Statistics Workshop (MSW) has a 4.5 hour long training session for tutors (Coulombe, 2016). The tutors are expected to read a training manual prior to the session and are given a quiz to ensure they have done so. They then participate in "activities and discussions focused on problem solving, learning styles, strategies for effective sessions, common tutoring scenarios, working one-on-one, working with small groups, and professional behavior" (Coulombe, p. 338, 2016). Tutors are also expected to attend various training courses in conjunction with other services on campus, such as a workshop on ethics that is offered for both MSW tutors and tutors from other services on campus.

Overview

These examples provide a representation of the different types of extant QLCs reported in the literature. As noted above, the most common service provided is drop-in tutoring, with review sessions being quite common as well. Evaluating the general effect of QLCs is made more complex by the variety of services offered, as it is possible that some services may be more effective than others. It is also notable that tutor training differs across campuses, which could result in differing levels of effectiveness of the services offered. Other interesting differences occur in the geographic placement of QLCs on campuses and in the relationships with other departments on campus. Both of these may affect which and how many students attend tutoring.

2.3.2 Effectiveness of a QLC

In addition to descriptive literature, many research studies have attempted to assess the effectiveness of QLCs, with the centers' effectiveness measured by factors such as student grades and retention. The effectiveness of a QLC is of high importance to students, faculty, and administrators. It is hoped that the funds and resources being used to run a QLC are not being wasted. In addition to monetary concern, there is the desire that a QLC fulfill its mission to support students and improve quantitative literacy. As such, most studies make an attempt to measure or assess the effectiveness of the program studied. Since this is a major portion of the research on QLCS but the focus of this dissertation is not focused on measuring the effectiveness of QLCs in this way, only a brief review of the research on QLC effectiveness is provided.

Overall, studies have shown a positive impact from QLCs. Longuevan and Shoemaker (1991) evaluated the effectiveness of a tutoring program at the University of California, Irvine using multiple regression to predict how tutored students would have performed without tutoring. While tutored students in general received lower scores than their non-tutored peers, when comparing their grades to the predicted outcomes from the multiple regression it was shown that their performance was better than predicted. A similar result was found by Rickard and Mills (2018), who found that the number of tutoring visits was a significant factor in predicting course grades, in addition to high school math GPA and ACT math sub-score. They were able to develop a regression model that displayed that tutoring visits had a higher effect on the final course grade of low-achieving students than high-achieving students.

A similar attempt to account for other factors was made by Xu, Hartman, Uribe, and Mencke (2001) when they analyzed final exam scores for students from a collegiate algebra class at the University of Arizona and sought to find relationships between these scores and peer-tutoring (as in the students' accessing the tutoring center on campus). Taking into account SAT scores, high school GPA and other factors, it was found that a positive correlation existed between attending tutoring and higher exam scores. However, this was predominantly seen for students with low SAT scores. It was also found that students with average high school GPA and SAT accessed tutoring most often while those with below and above average scores did not. These three studies point to the need for studies to take into account multiple factors in assessing a QLC's effectiveness since without them the statistics often disguise the impact that tutoring is having on those with lower mathematical performance.

As an example, Halcrow and Iiams (2011) attempted to assess the effect of a tutoring center in a mixed methods study. They conducted an experiment in which experimental sections of freshman level mathematics courses were required to attend a tutoring center while the control sections were not required to attend. In addition, interviews were conducted with 13 participants. The results of the quantitative data surprised Halcrow and Iiams, as they did not find a significant difference between final grades of students in experimental sections versus control sections. They did, however, find that time spent at the QLC directly correlated with final grades for students in the experimental sections; they did not find a similar result for the control group. The researchers suggest that there could have been some confounding factors involved that they had not accounted for. However, an additional positive result of the study was that interviews revealed that students perceived that their time in the QLC helped them to succeed in the course.

Positive results are seen across the literature. In addition to those already mentioned, Pell and Croft (2008) found that mathematics support improved the pass rate of a cohort of engineering students by approximately 3%. MacAnBhaird, Morgan, and O'Shea (2009) found that pass rates of students who visited their QLC were higher than for those who did not as well as that its effect is stronger for those with weaker mathematical backgrounds. Thus, the positive effects seen in the literature provide motivation for further study into what is happening at the QLCs and what these support centers are doing to achieve these results.

2.3.3 Help-Seeking Behavior within QLCs

While the effect of QLC attendance on struggling students' grades is promising, it can be difficult to encourage these students to seek help. This phenomena is documented in many studies related to help-seeking behavior. Help seeking behavior is a concept rooted in psychology and is often used in research on patients seeking medical help. In the context of research on university students, it refers to how students seek help academically and make use of the resources available to them. Help seeking behavior has been studied in many areas of research on higher education, including academic need (e.g., Karabenick & Knapp, 1988), gender (e.g., Kessels & Steinmayr, 2013), writing (e.g., Bodnar & Petrucelli, 2016), and discipline (e.g., Colvin, 2012), among others. In this section, I will review the literature on help-seeking behavior at QLCs.

Notably, in a study of 612 undergraduate psychology students, Karabenick and Knapp (1988) report that the students who were most likely to seek help had an expected grade between C+ and B. This left those with the highest and lowest expected grades as least likely to seek support. While we may be satisfied that those with an expected grade above B simply didn't feel the need for extra help, it is worrisome that the most struggling students may not be motivated to find the support they need. This same pattern was found by Xu, et al. (2001) in their finding that students with moderate SAT scores were most likely to attend tutoring but that tutoring had highest effect on students with below average previous math scores. Their first finding mirrors that by Karabenick and Knapp (1988) and their second points to the importance of reaching students who need the most help.

In Halcrow and Iiams (2011) interviews, students revealed that their use of the QLC was due to requirements placed on them by their instructor and that without those requirements they may not have accessed the center. These responses came primarily from students in lower level mathematics courses, again suggesting that students with lower mathematical ability may be hesitant to attend a learning center. This, tied with both the findings of Cai, Lewis, and Higdon (2015) and those of Xu, et al. (2001), emphasizes a need to encourage low-achieving students to visit learning centers.

Cai, Lewis, and Higdon (2015) used an early alert warning system to notify students who needed additional support that they should consider visiting the tutoring center at their institution. The system alerts GAs when students fail an assessment, and this prompts the GAs to send personalized messages to those students encouraging them to visit the learning center. They found that students who received alerts were more likely to attend the learning center, however it cannot be ensured that this was due to the alerts rather than their academic need. This early alert system and others like it require that there be close communication between the course faculty and staff and the tutoring center. Tutoring centers generally do not have access to students' grades and thus are unable to provide early alerts themselves. Both this and the results of Halcrow and Iiams (2011) suggest that students' may benefit from encouragement to attend.

When comparing at-risk and not at-risk students, Berry, Mac An Bhaird, and O'Shea (2015) found that at-risk students were more likely to visit the QLC than those not at-risk at the National University of Ireland Maynooth. Since students were categorized only as at-risk and not at-risk in this study, we cannot directly compare these results to the results of Karabenick and Knapp (1988) or Xu, et al. (2001). However, this does imply that in the setting of their study the QLC was reaching their target population, since the QLC had initially been designed to specifically support at-risk students. Notably, the at-risk students tended to stay longer per visit to the QLC and at-risk students who attended the MSC did better on average than those who did not.

Beyond categorizing students based on academic need, the research community has also explored the relationship between other categorizations of students and their help-seeking behavior. For example, in a study by Bannier (2007) it was found that students who had graduated from high school more than five years prior were more likely to take advantage of the resources offered at the learning center. She also found that experiences and outcomes in prior mathematics courses had a greater effect on students visiting the learning center than did their current mathematics courses. This suggests that it may be worthwhile for learning centers to find ways to encourage younger students to access the centers.

Related to Bannier's (2007) finding that prior mathematics courses have an effect on students visiting the QLC, Knowles and Paglia (2004) hypothesize that "poor functioning in mathematics might be related to past experiences that have led to conflicting and counterproductive conscious and unconscious patterns of thought and behavior regarding mathematics" (p. 31). Thus, they introduce the K-P Model of collaborative mathematics support in which faculty members, learning center personnel, a mathematics relational counselor and a class-linked tutor work together to provide support to students. In this collaborative approach, students are not only aided in their mathematical content knowledge but are also counseled through any negative attitudes or anxiety they may have towards mathematics. This is an involved method of support and is rare at QLCs.

The idea that previously held mathematical beliefs or anxiety will influence a student's success is mirrored in a study by Daugherty, Rusinko, and Griggs (2013). This study involved 351 students in an introductory college math course and found that in addition to Math SAT scores, Perceived Susceptibility to Failure and Perceived Benefits of Action were predictors for student outcome. If students felt susceptible to failure, they were more likely to fail the course. If students saw benefits from seeking help then they were more likely to pass the course. Both Knowles and Paglia (2004) and Daugherty, Rusinko, and Griggs (2013) suggest that the previous experiences and beliefs that students bring into their math courses in an IHE will affect their success. Thus, QLC faculty and staff should be prepared to aid students while being conscious of what each student may be bringing with them from previous schooling.

In addition to exploring and attempting to categorize the students who seek help at QLCs, many studies also seek to investigate the motivations behind the students' help-seeking behavior. In particular, multiple studies refer to students' experiences moving from high school to IHEs and the influence that QLCs have in this transition. This experience often involves a change in expectations from instructors, a change in living situation, and an entirely new set of people to interact with. In this period, it is crucial that students adapt and form good study habits. QLCs can be a resource where students do so. Solomon, Croft, and Lawson (2010) found that almost half the participants in their study believed that mathematics teaching at the university level was not as good as at the high school level. Interviews revealed that becoming independent learners was a struggle for participants but that the learning center provided a space where they could learn to do so.

While there has been an increase in research on QLCs in the past few years, there are still multiple unanswered questions in the currently published literature. The effectiveness of QLCs is often the focus of research studies, however few studies have tried to explore what is occurring at the centers and how this effects the students both in terms of academic outcomes as well as in affective outcomes. Additionally, studies on QLCs also did not typically focus on the tutors' or the students' perceptions of their needs. In this dissertation, I seek to contribute to these areas by exploring the students' and tutors' perceptions of both the students' needs and the strategies they believe to be successful.

In addition, studies that have the ability to compare students' and tutors' perceptions are also rare. A notable exception to this is Perkin, Pell, and Croft (2007) who conducted a study in which they compared their mathematics learning staffs' perspectives with that of the students. However, the staff were not necessarily peer tutors, which makes the contributions of this dissertation unique. While the main focus of this dissertation is to investigate each perspective separately, the design of the study also allows for comparisons to be made.

Chapter 3

Methodology

The purpose of this study was to investigate the mathematical needs of students enrolled in mathematics courses, in particular those who visited the QLC, as well as to explore the successful tutoring strategies used by the tutors at the QLC. I believe that investigating these areas will lead to a greater understanding of our students, how students can be better supported towards success in their quantitative classes and towards greater quantitative literacy, and how we can use what is done in the QLC to improve both practices at the centers as well as practices more generally in undergraduate mathematics education. The research questions addressed by the study were threefold: (1) What are the mathematical needs of the students who visit the QLC (a) in the tutors' view and (b) in the students' view? (2) What explanations or tutor strategies help the students to understand the mathematical topics they are seeking help with (a) in the tutors' view and (b) in the students' view? (3) How do the students' views about questions 1b and 2b compare to the views of students enrolled in mathematics courses who do not visit the Q Center?

This chapter will describe the study's research methodology, beginning with the rationale for the study's design, a description of the research setting, and an overview of the research design. It will then describe the sample, discuss the methods of data collection and analysis and end with discussions of the ethical considerations, trustworthiness, and limitations of the study.

3.1 Research Design

An embedded mixed methods research design was used to address the research questions. The purpose of this study was to explore deeply the perceptions held by tutors and students about students' mathematical needs and the tutoring strategies that were successful in helping them. I also wanted to be able to compare the perceptions of students who visited the QLC and those who did not. For this reason, the collection of both qualitative and quantitative data was deemed to be important. The qualitative data allows for in-depth understanding of the perceptions of tutors and students, and the quantitative data allows for statistical comparisons.

The design chosen for this study was convergent. In this type of mixed methods design the data collection and analysis of both forms of data happen concurrently. The design was also interactive, meaning that throughout the study the ongoing data collection and analysis affected changes in the procedures for data collection. In an embedded mixed methods design specifically, one form of data is chosen as the major data form, with the secondary data form acting to support the major data (Creswell, 2012). Embedding in this design occurred both through connecting, which means that the qualitative and quantitative data is linked through the sample, and through building, where the data from one procedure influences the data collection in another procedure (Fetters, Curry, & Creswell, 2013). The major form of data in this study was qualitative, since the main purpose of this study is to explore deeply the perspectives of the tutors and students. The secondary form of data is the quantitative data, which was used to support the qualitative data, to design portions of the qualitative data collection, and to answer Research Question 3. Qualitative data was collected through the use of interviews, observations, and open-ended questions on surveys, while quantitative data was collected through closed-response questions on surveys.

3.2 Research Setting

The study took place at the main campus of a large, state research university in the Northeast United States. The university has approximately 19,000 undergraduate students on its main campus, with a student to faculty ratio of approximately 16:1 over all campuses. In 2017-2018, just over half of classes offered had between two and 19 students, while 16% had more than 50 students. The student body is approximately 49% male and 51% female.

At this university, students must complete a quantitative competency requirement before graduating. The requirement is fulfilled by passing two quantitative courses, designated as such by the general oversight committee. For the purposes of this dissertation, we will call these Q courses. Q courses exist in many departments, but students must take at least one Q course in mathematics or statistics.

3.2.1 Highly Enrolled Mathematics Q Courses

In this study, surveys were sent to students at the university who were enrolled in one of four mathematics Q courses. These courses were chosen because they are high enrollment courses in the mathematics department and because they are courses for which many students visit the QLC. Brief descriptions of each of these four courses is provided below.

Math for Business and Economics (MB&E)

This is a standard mathematics course for students in business and economics. Students learn topics such as linear equations and inequalities, exponents and logarithms, matrices and determinants, linear programming, and probability. There are no required prerequisites for students to enroll in the course. In the Spring of 2018 the course was offered in a large lecture format with each lecture meeting twice a week for 75 minutes with approximately 180 students per lecture. In addition to lecture, students met in discussion sections of approximately 19 students once a week for fifty minutes. In the Fall of 2018, this course became an entirely online course with no in-person option.

Calculus for Business and Economics (CB&E)

As a standard business calculus course, students learn derivatives and integrals of algebraic, exponential and logarithmic functions with a focus on applications to business and economics. Students are able to enroll in the course with no required prerequisites. The course is offered in classes of approximately 32 students and each meets three times per week for fifty minutes.

Calculus 1

Most students who are required to take calculus will enroll in this course. Exceptions occur when students have credits that are transferred from another institution. Students learn the standard topics of differential calculus, including limits, continuity, and differentiation, as well as the beginning of integral calculus, including antidifferentiation, the definite and indefinite integrals, and solids of rotation. Applications in the course focus primarily on applications to the physical sciences and engineering sciences. Students must have a qualifying score on a math placement assessment (similar to the ALEKs online placement exam) to enter the course. The class was offered in-person for Spring 2018 and in two formats in Fall 2018, both in-person and online. The in-person format meets in large lectures of between 150-250 students twice a week for 75 minutes, and in discussion sections of approximately 22 students twice a week for fifty minutes.

Calculus 2

This is a continuation of Calculus 1. The course picks up where Calculus 1 leaves off, beginning with methods of formal integration, and including polar coordinates and infinite sequences and series, with applications to the physical sciences and engineering. Students must have a qualifying score on the math placement assessment and credit for Calculus 1 to enter the course. In the Spring and Fall of 2018, the class was offered only in an in-person format. The in-person format meets in large lectures of between 150 and 250 students twice a week for 75 minutes, and in discussion sections of approximately 22 students twice a week for fifty minutes.

3.2.2 The QLC

The QLC at the institution where this study took place offers drop-in peer tutoring to students in several highly-enrolled Q courses from mathematics, statistics, physics, and chemistry. The staff for the center is made up of 10 graduate assistants who act as supervisors at the QLC, 10 receptionists, and approximately 70 peer-tutors.

The QLC is set up with a section for each discipline. Chemistry, physics, and statistics each have one group of tables and students from various courses within a discipline are all seated together with the tutors in these sections. Since the mathematics section has high attendance, this section contains four groups of tables. Each group is assigned one of four courses, MB&E, CB&E, Calculus 1, or Calculus 2. Students are seated with others from the same course and tutors will typically stay at one table their entire shift but are able to move from table to table as needed. Students who are taking mathematics courses outside of these four courses are seated at one of the four tables where there is a tutor who is able to help them with that course.

Hiring of Tutors

Tutors are largely undergraduate students who have applied online through the QLC website. Occasionally, tutors will remain at the institution for graduate school and in this case they may be allowed to continue on as tutors past their undergraduate degree. At the time of this study, approximately 3-5 of the tutors were graduate students each semester. Before hire, tutoring candidates go through a three step interview process. The first step is a content exam in the area they wish to tutor. The exam is typically made up of multiple-choice or true/false questions and is untimed and administered by the program coordinator. The exam answers are graded by the program coordinator and if the score is high enough then the exam is then looked over by a graduate assistant in that discipline to check justifications and explanations. Based on these, graduate assistants give a recommendation to bring the student in for the second step of the interview process, to ask the student to review material and then test again, or to reject the candidate.

The second step in the process is an interview with a graduate assistant in the discipline. During this interview, graduate assistants are looking for a candidate's ability to explain how to do a mathematics problem clearly as well as to gauge whether the candidate is personable and able to work with others. The graduate assistant chooses questions based on what they see in the candidate's content exam. If there were any areas of concern then this is another chance for the graduate assistant to gauge their knowledge and see if they truly understand the concept. Based on this interview, graduate assistants make a recommendation to the program coordinator regarding hiring the candidate.

The third and final step in the process is an interview with the program coordinator. Primarily this interview is to gauge the candidates' interpersonal skills as well as to ask questions pertaining to their strategies for handling difficult tutoring situations. Questions asked cover topics such as the background of the candidate, their ideas on how to handle frustrated students, and their understanding of different learning styles.

Tutors are initially hired for tutoring in one primary discipline. Tutors can choose to list other disciplines as secondary disciplines which means that they have not taken the test to tutor in those courses but feel comfortable helping students if needed. Tutors can also choose to test for other disciplines as well and in this case they would have multiple primary disciplines.

Tutor Training

Each semester the QLC holds a mandatory kick-off meeting for all tutors, receptionists, and graduate assistants. In the fall, this typically consists of two sessions, each of which is two hours long. In the spring, the two sessions are each one hour. In the first session each semester, the director and program coordinator discuss tutoring strategies and general information about the QLC with the tutors. This includes expectations for tutors' interactions with students, how tutors should respond to students' questions, and the logistics of working in the QLC.

During the second session of the kick-off meetings, tutors are divided by primary discipline to meet with graduate assistants and take part in a content workshop. If a tutor has multiple primary disciplines they are able to choose which discipline to attend. For this workshop, the graduate assistants typically compile various questions that cover a variety of topics and courses in their discipline. The tutors work on these in groups and present solutions to the larger group.

In addition to the kick-off workshop, tutors must attend at least one additional content workshop per semester. If a tutor misses the kick-off meeting for extenuating circumstances, then they must attend two content workshops during the semester. These workshops are held throughout the semester by the graduate assistants and each workshop focuses on a topic that is coming up in the curriculum for one of the courses that is tutored at the QLC. Graduate assistants choose these topics based on their experience teaching the courses or based on comments from tutors about topics they would like to review. Tutors are allowed to attend as many content workshops as they would like but are only required to attend two, typically the kick-off and one other.

3.3 Overview of Research Design

Here we list the main steps of the study, each of which will be discussed in more detail in the following sections.

1. IRB approval was obtained prior to beginning the study to ensure that participants' confidentiality and rights were protected.

2. All mathematics tutors at the QLC were emailed to invite them to participate in the study.

3. Non-participatory observations of tutoring shifts were conducted with seven tutors. No data about the students visiting the QLC aside from the course they were seeking help with was collected. Following the observations, students who were present were invited to participate in the study. Those interested were given an information sheet detailing their involvement.

4. Observation data was analyzed to design questions for follow-up semi-structured interviews with the seven observed tutors and one interested student.

5. Surveys were sent to both QLC users and students enrolled in MB&E, CB&E, Calculus 1, and Calculus 2 in the spring and fall of 2018. Within the surveys in Fall 2018, students were invited to participate in a follow-up interview with the researcher.

6. Semi-structured interviews were conducted with the three students who agreed to participate.

7. Analysis of all data was conducted on an ongoing basis, to ensure that there was breadth and depth to the information gathered.

3.4 IRB Approval

Before beginning the study, the researchers submitted a proposal to the university's Institutional Review Board and received permission to conduct the study. The proposal outlined the main purpose of the study, the research questions, a brief literature review, and all procedures for data collection and analysis that would be followed to ensure participant confidentiality.

3.5 Participants

Given the focus of the research questions, the sample for this study was chosen from two main population groups: tutors and students. For the qualitative portions of the study, seven tutors were observed and interviewed and four students were interviewed. In addition to these observations and interviews, qualitative data was also collected through open-response questions on surveys sent to students enrolled in MB&E, CB&E, Calculus 1, and Calculus 2, and all students who had visited the QLC for support in their mathematics courses. In qualitative methods, the focus is on an in-depth understanding of the research topic and rich descriptions. As such, sample sizes are small compared to quantitative studies to allow for thorough data collection and so that the researcher can rigorously analyze the data. The sample of seven tutors was chosen because it provided data rich in details and insights into the tutors' point of view. The number of student interviews was four based on the design of our data collection process. Since the student interviews were intended to dig deeper into the survey data and observations through the perspective of students, a sample of four was sufficient to provide the additional depth of their perspective.

For the quantitative data, the sample of students was taken from all students who attended the QLC for mathematics support in the 2017-2018 academic year or Fall 2018 semester and all students who were enrolled in MB&E, CB&E, Calculus 1, or Calculus 2 in the Spring or Fall semesters of 2018.

3.5.1 Tutors

All mathematics tutors in the 2017-2018 academic year or the Fall 2018 semester were invited to participate in an observation and follow up interview. An email was sent to all tutors with the consent form attached. Out of the 54 tutors invited in Fall 2017, three responded that they were interested in participating. Out of the 46 tutors invited in the Spring of 2018, three more were interested in participating. Finally, in the Fall of 2018, 44 tutors were invited and one tutor was interested in participating. The number of tutors invited for each semester includes tutors that had already been invited in previous semesters but had not chosen to participate previously. The seven tutors are described in Table 3.5.1, including their academic year, disciplines that they tutor, experience teaching at the QLC, and courses they frequently tutor within the mathematics discipline.

3.5.2 Student Survey Participants

Emails were sent to all students enrolled in MB&E, CB&E, Calculus 1, and Calculus 2 during the Spring and Fall semesters of 2018 inviting them to participate in a survey. Out of the 2071 students emailed in the spring, 148 responded. Out of the 2546 students emailed in the fall there were 230 respondents.

Pseudonym	Academic Year	QLC Experience	Frequent Courses
Trace	Senior	3 semesters	Calculus 1, 2, 3, MB&E, CB&E, Differential Equations, Linear Algebra
Shaniya	Senior (fifth year)	8 semesters	Calculus 1, 2, 3, MB&E, CB&E, Differential Equations, Linear Algebra
Wayne	Second year PhD	12 semesters	Calculus 1, 2, 3, Differential Equations, Linear Algebra, Some statistics
Seth	Senior	6 semesters	Calc 1, 2, MB&E, CB&E, Statistics 1, 2
Elias	Sophomore	2 semesters	Precalculus, Calculus 1, 2, 3, Differential Equations
Drake	Junior	1 semesters	Calculus 1, 2, 3, MB&E, CB&E, Linear Algebra, Differential Equations
Lucas	Junior	<1 semester	Calculus 1, 2, 3, Differential Equations, MB&E, CB&E

Table 3.5.1: Study Tutor Participants

Emails were also sent to all students who had visited the QLC for mathematics support during the 2017-2018 academic year or the Fall 2018 semester. Out of the 1713 students emailed at the end of the 2017-2018 year, 82 consented to participate. Out of the 1075 students emailed at the end of the Fall 2018 semester, 81 consented to participate.

The demographic information on those who chose to participate is shown in Table 3.5.2, along with the demographic information of all students who visited the QLC for mathematics support in Fall of 2018, for comparison.

		Surveys		QLC Visitor Data
	Response	Courses (N = 349)	QLC (N = 136)	Fall 2018 (N = 1141)
Gender	Male	37	35	49
	Female	62	65	50
	Decline to Answer	<1	0	-
	Other	-	-	1
Hispanic, Latino, or Spanish Origin	No	86	84	82
	Yes	10	11	14
	Unknown	1	1	0
	Decline to Answer	2	6	4
Race	American Indian or Alaska Native	0	1	<1
	Asian	16	13	13
	Black or African American	6	14	19
	Native Hawaiian or Other Pacific Islander	0	0	<1
	White	71	63	56
	Some other race	3	3	4
	Unknown	<1	0	0
	Decline to answer	2	7	7

Table 3.5.2: Survey Participants Demographic Information and QLC Visitor Data for Fall 2018 (%)

3.5.3 Student Interview Participants

There were two methods for recruiting students for interviews. In the first method, the researcher invited students who were present during one of the tutor observations to participate in the study. Students were given an information sheet and encouraged to contact the researcher if they had questions or wanted to participate. From this recruitment strategy, one student, Mackenzie, agreed to participate.

The second method of recruitment garnered three additional student participants.

In a survey sent to all students enrolled in four mathematics courses in the Fall of 2018 and another sent to all students who had used the QLC for mathematics support, students were asked to include their email address if they were willing to be contacted to discuss their answers further. Twenty-five students left their email addresses, and upon follow-up from the research team three students agreed to participate in an interview. Upon reviewing these three students' survey responses, it was found that each would contribute to our understanding of the survey responses more generally.

In Table 3.5.3, the student participants are described, including their academic year at the time of the interview, major, Q courses they had taken, and either that they were a student at an observation or a list of a few areas of interest found in their survey answers.

3.6 Data Collection

This study was conducted using a mixed methods approach. As such, data collected included both qualitative and quantitative data. The qualitative data was chosen to explore first two research questions with particular attention to thoroughly investigating the students' and tutors' views. The quantitative data was used to address the first and third research questions, allowing for comparisons of the perspectives of students who attend the QLC and those who do not. Non-participatory observations, semi-structured interviews, and surveys made up the data corpus. Observations and interviews were used to address Research Questions 1 and 2, and surveys were used to address all three research questions. Each of the types of data is described in detail below.

TABLE 3.5.3: Student Interview Participants

Pseudonym	**Academic Year**	**Major**	**Math Q Courses**	**Areas of Interest for Interview**
Mackenzie	Freshman	Psychology and Speech Language Hearing Science	Calculus 1	Tutor Observation
Hannah	Freshman	Civil Engineering	Calculus 2, 3	Preferred Resource was course notes, Main difficulty was applying the topic
Whitney	Freshman	Chemical Engineering and French	Honors Calculus 2, 3	QLC is preferred resource, Visited office hours
Angela	Freshman	Secondary Education - Math Teaching Track	Calculus 1, 2, Geometry	Mentioned wanting to figure out problems on her own, Main difficulty was clarity of key ideas, Optimization

3.6.1 Student Surveys

Since this study seeks to explore the perspectives of students who visit the QLC, a survey was distributed to all students who had visited the QLC for mathematics support. This survey was intended to allow the researchers to gather data from a larger number of students than would be possible in a purely qualitative study so that the data collected could inform the design of the interview questions asked to students. In addition to this survey, a survey was also sent to all students enrolled in MB&E, CB&E, Calculus 1, and Calculus 2, so that the perspectives of QLC users could be compared with the perspectives of non-QLC users in Research Question 3. However, the information gathered from the surveys was primarily intended to give initial insights into the students' perspective that could then be delved into within interviews.

The surveys were used to collect quantitative and qualitative data from students who had used the QLC for support in mathematics courses as well as from students enrolled in four mathematics courses, specifically MB&E, CB&E, Calculus 1, and Calculus 2. These surveys were used to address all three research questions. Students were able to skip any questions they preferred not to answer and could also close the survey before completing it. As such, some surveys were unfinished so we will report sample sizes for questions in our findings.

Surveys for QLC Users

The QLC user survey is included as Appendix A. The survey consisted of three parts. The first part asked for demographic information that matches the information which is asked of students at their first visit to the QLC. The second section of the survey asked for responses to closed-response questions about their general experiences at the QLC and in their Q courses. For example, students were asked:

In the third part of the survey, students were asked to choose a specific instance where they had sought help at the QLC and to answer a mixture of closed- and open-response questions about that situation. An example of an open-response question is:

An example of a closed-response question relating to their described situation is:

Surveys for Q Courses

For students enrolled in the four Q courses mentioned above, the survey was very similar to the survey sent to QLC users. The survey questions are included as Appendix B. The main difference was that in second part of the survey with questions about experiences at the QLC was omitted because we could not assume the students had attended the QLC. Instead, closed-response questions were included about their experiences in the Q course they were enrolled in, such as: .

The third part of the survey remained, but instead of focusing on scenarios in which students had visited the QLC, students were allowed to describe any situation in which they had sought help. Thus, the open-response question given above was altered to read:

3.6.2 Tutor Observations

By conducting observations, the researcher was able to see what occurs during a tutor's regular shift and to observe behaviors and activities that the tutors and students may not pick up on themselves (Patton, 2002). As a non-participatory observer, the researcher did not interact with the students or the tutor in any way. Rather, the researcher sat nearby and followed the observation protocol (Appendix C), which focused on tutor strategies and explanations, reactions of students, and the questions brought up by students. The protocol allowed flexibility for the researcher to make notes of what occurred during the session with special attention to when a tutor decided to switch an explanation or strategy, as well as to take additional notes and memos as needed. This non-participatory approach was chosen because it would cause the least infringement on both the tutor's ability to perform their duties and the students' abilities to receive support.

Observations of tutoring sessions took place during a tutor's regular tutoring shift in the QLC. Tutors were able to choose which shift would be observed. The observations focused on the tutor strategies used by the tutors, the tutor-student interactions, and the mathematical topics and explanations discussed. The observations were not recorded. The data from the observations helped to address Research Question 2. Additionally, the researcher used what was observed to design questions that were asked in interviews with the tutor.

In total, seven observations were conducted. In all but one case the shift observed lasted for two hours. The exception to this was the observation of Wayne's shift, which was restricted to one hour. Six of the tutors were working in the mathematics section during their observations, but during Seth's observation he was asked to move to the statistics section to help students in that topic. This observation was still included since Seth used techniques that he would have used in the mathematics courses as well, and the interview with Seth focused on those aspects that related to his mathematics tutoring as well.

3.6.3 Interviews

Since the purpose of this study is to explore the perspectives of students and tutors, semi-structured interviews were conducted with each of the seven tutors and with four students. These semi-structured interviews allowed the researcher to ask follow-up questions to elicit more information from interviewees rather than conforming to a strict script. This allowed for richer data (Merriam, 2009) and allowed the researcher to dig deeply into what the students and tutors said about their experiences at the

QLC.

Tutors

These interviews were designed to address Research Questions 1a and 2a, by asking questions intending to illicit responses about the tutors' perceptions of their activities and experiences in the QLC. The interview explored the tutor's experiences tutoring in general as well as questions specific to the observation. Questions focused on the tutor's thoughts on students' mathematical needs, their own tutoring strategies and techniques, and their views on what is successful and unsuccessful in building students' understanding of mathematical topics.

Specifically, the interview followed the protocol in Appendix D, with the researcher asking follow-up and additional questions as needed. The interviews consisted of three main parts. First, tutors were asked about their mathematical and academic background and their tutoring experience. Second, tutors were asked general questions about their experiences as a tutor at the QLC. These first two sections of the interview were the same for all seven tutors. The final section was tailored to each tutor with questions specific to their own observation. Tutors were asked to answer questions to the best of their ability, but if they could not remember a specific situation the researcher reminded them of what happened. This final section of questions were created based on the notes from the observation protocol, again paying particular attention to the specific strategies the tutors used as well as when they decided to switch explanations or strategies.

All seven tutors participated in the interview. The interviews were audio-recorded on password-protected computer and mobile device to ensure that any technological issues would not result in lost data. The recordings were transcribed by the researcher and all names were changed to pseudonyms. The interviews generally occurred 2-7 days after an observation, at a time that was convenient for the tutor. The interviews ranged from 24 to 51 minutes and were held at a time and location convenient to the participant, such as various study rooms on campus in a campus cafe.

Students

These interviews helped to address Research Questions 1b and 2b, by asking questions intending to illicit responses about the students' perceptions of their activities and experiences in the QLC and in their Q courses.

Specifically, the interviews followed the protocol in Appendix E, with the researcher asking follow-up and additional questions as needed. The interviews consisted of three main parts. First, students were asked about their mathematical and academic background. Second, students were asked general questions about their experiences as a student attending the QLC for mathematics help. These first two sections of the interview were the same for all four students. The last section was tailored to each student with questions specific to the observation they had been participated in or the survey responses they gave, depending on their case. Students were asked to answer questions to the best of their ability, but if they could not remember a specific situation the researcher reminded them of what happened or what they had said in the survey. For the one student recruited through an observation, the final section of questions were created based on the notes from the observation protocol, similarly to how the tutor interview questions were created. For the three students recruited through the surveys, the questions in the final part of the interview were selected based on what the students had answered in response to both the open- and closed-response questions on the survey.

Four students participated in these interviews. Interviews were held at a time and place convenient to the student. The interviews ranged from 17 to 26 minutes. The interviews were audio-recorded and transcribed by the researcher with all names changed to pseudonyms.

3.7 Methods for Data Analysis and Synthesis

Since our data collection included both quantitative and qualitative elements, data analysis included both quantitative and qualitative methods. These methods are described below.

3.7.1 Quantitative Data from Surveys

The quantitative data from the surveys provided insights about student perceptions of their own mathematical needs. The students' responses were primarily analyzed using descriptive statistics since this study is not intended to measure outcomes or claim causation of any help-seeking behaviors. Specifically, the data collected were categorical in nature so frequencies were reported to describe the results of the data. Analyzing the response frequency within each question allowed us to pinpoint those areas that students consider of greater need as compared to others.

In response to Research Question 3, responses from the Q course survey were used. I compared the responses of students who reported visiting the QLC to those who did not. Since the data collected was categorical, a Chi Square analysis was used to test for any relationships between different variables. In some cases, the expected values for cells in the contingency table were too low to satisfy the assumptions for Chi Square, in which case a Fisher's Exact Test was used instead. For each Chi Square and Fisher's Exact analysis, QLC use was the independent variable and responses from students on various questions were chosen as the dependent variable. If a statistically significant relationship was found between QLC use and another variable, a post hoc analysis using a standardized residual method with adjusted Bernoulli alpha level was used (Beasley & Schumacker, 1995). This post hoc analysis revealed which responses from students within a variable were significantly related to QLC use.

3.7.2 Tutor Observations

Since the protocols and memos from the observations were collected to inform and guide follow-up interviews with respect to tutor strategies and student needs, these were analyzed using process coding. This form of coding involves analyzing data with particular attention to action in the data (Saldana, 2009). In this study, this analysis allowed us to identify tutor strategies and a tutor transitioning to a new strategy. These moments and the tutors' techniques were used to focus the questions that were posed in the interviews that followed the observations.

Consider the following example of how observation data was used to structure a tutor interview. In an observation with Elias, I observed that while working with a student he had her think about the graphs of the functions as a strategy that seemed to be intended for helping the student to make sense of the problem. The resulting question in the interview was:

> I also noticed that before she had finished the problem you had her think

about the graphs of e^t and e^{-t}.

a. Can you explain why you did this (or why you might use this technique if they don't remember the exact situation)?

b. How did you feel that the student responded to this?

c. Are there other occasions in which you would use/have used this approach? (which ones, why?)

3.7.3 Interviews and Open Responses from Surveys

The interview transcripts and open responses from the surveys provided data that was then analyzed with particular attention to Research Questions 1 and 2. Inductive thematic analysis was used so that themes and categories emerged naturally from the data rather than the researcher imposing their pre-supposed themes and categories onto it (Patton, 2002). Themes that emerge in thematic analysis may be identified from previous literature or from the context the data provides. This allows the data to speak for itself (Grbich, 2013).

In this study, each interview transcript was initially read through by the researcher to gain familiarity with what was discussed. Following the initial read throughs, each transcript was read through a second time, this time with more focus placed on highlighting and underlining key ideas found in each transcript. A third read-through was conducted, with the highlighted and underlined sections carefully considered to find key concepts that related to Research Questions 1 and 2, similarities in ideas across transcripts, and topics that seemed of particular importance to the participants.

Through this analysis, those ideas and concepts that stood out were coded, using phrases that fit the idea related to the research questions. As new data was collected and new transcripts were analyzed, codes were rephrased or changed in order to reflect the data that was present (Miles & Huberman, 1994). Throughout this process, I had my advisor also code the interview transcripts. Once she had done this, we discussed our results together to ensure reliability of the codes, their definitions, and the processes followed. Once a set of codes was finalized based on analysis of all the interview transcripts, the codes were reviewed to find themes. Themes that emerged stretched across codes and speak to the broader ideas in the data, addressing specifically the needs of students and effective tutoring strategies through the perspectives of tutors and students.

3.8 Trustworthiness

To ensure that the findings from this study are credible - that they appropriately match the perceptions of my participants - methods triangulation and peer review of the analysis was used. In methods triangulation, various methods are used to verify that the results from different methods match up. In this study, the observations of tutoring sessions were used to ensure that the findings from the tutor and student interviews matched what was seen in practice, as well as to help in interpreting the tutor's statements in interviews.

Peer debriefing was used with my advisor in that I asked my advisor to read portions of my data, in particular interview transcripts and a sample of the open responses from the surveys, and we discussed the data. This peer debriefing helped to clarify my thoughts and assumptions about what I was finding and to ensure that I focused on interpreting what the data was saying independent of my own biases.

To ensure that the findings were dependable, inter-rater reliability was used during coding of the tutor interviews. To do this, my advisor and I each separately coded one of the transcripts to ensure that no major ideas were missed.

To ensure confirmability, I provide my own subjectivity statement in this chapter. The qualitative portions of this study involved interpretation, and as such there is the possibility of bias within the findings. By providing my subjectivity statement I hope to both make the reader aware of any potential biases as well as provide the measures that were taken to ensure they would not play a role.

In order to maximize transferability, an in-depth description of the research setting and specifically the QLC is provided. While the findings of this study may not be widely generalizable, by understanding the form of QLC and institution at which the study takes place, readers can determine its transferability to their own situation. In addition, findings and discussion are supported by excerpts with thick descriptions from the qualitative data to support potential transferability of the results.

3.9 Limitations of the Study

One of the limitations of this study lies in its sample. While purposive sampling was used to invite participants who would be able to speak to the topics of interest, a sample bias may still be present because those who chose to participate may have a greater interest in the topic than the general population. It is also possible that those who chose to participate may have a strong opinion about the QLC or the Q courses at their institution and thought of this as an opportunity to share these opinions, whereas students and tutors with neutral opinions may be less inclined to participate.

Additionally, as a graduate assistant at a QLC I am in a role that supervises tutors. As such, the tutors may be hesitant to participate in observations or share some aspects of their experiences with me in interviews because of the hierarchy in play and out of worry that I may share what they say or do in observations with their supervisors. In an attempt to alleviate this power imbalance, tutors were assured that while observing their tutoring shifts or speaking to them in interviews I would be acting purely as a researcher and that anything that I observed or that they shared with me would not be used for assessment purposes or reported to the QLC for evaluation. This was reiterated throughout the process, both at the time of signing the consent form and before each of the observations and interviews.

For the survey and student participants, I did not have access to their grades in either the mathematics course they were currently enrolled in or their previous courses. This would have been helpful in describing the participants in the study and could give insight into the sample and their responses.

A final limitation of the study is that for three out of the four student interview participants I had not observed the tutoring session that they had attended nor had I seen the other situations of help-seeking that they discussed in their surveys. Because of this, if they did not remember the situation clearly then I was unable to refresh their memories. Also, unlike in the tutor interviews, I was unable to observe if there were any actions during the tutoring session that they may not have picked up on.

3.10 Subjectivity Statement

The qualitative aspects of this study involved a large amount of interpretation of the responses from tutors and students involved with the QLC. Because of this, in qualitative work it is important to acknowledge the background and biases that could be present in the researcher. As a graduate assistant at a QLC, my own experiences there and my role with respect to the tutors need to be acknowledged. Here I will discuss these aspects as well as the efforts that were made to alleviate their effects.

My role as a graduate assistant and its possible affect on the tutors' and students' willingness to be open has been discussed in the Limitations of the study. In addition to this aspect, there is also the possibility that my prior knowledge of tutors and QLCs as well as my experience as a mathematician and instructor may color my interpretations of their methods or ideas. In my data collection and analysis I made a concerted effort to be open to what the tutors would say and without bias in my interpretations of their ideas. This was an additional reason that peer review of my analysis was important to me in ensuring the reliability of my findings. On the other hand, my familiarity with QLCs and with tutors was also helpful in conducting the study. Some tutors may have been more willing to participate and talk to me because they had the comfort of knowing that the person they would be observed by and talking to had prior experience with tutoring and working at a QLC. I also had knowledge about the procedures and details specific to the QLC, which gave me an understanding of what the tutors and students were speaking about and referring to during interviews.

3.11 Chapter Summary

This chapter has discussed the methodology that was used in conducting this study. The rationale and a description for the use of an embedded mixed methods design is described followed by a description of the research setting and sample. Then an overview of the research design is given, followed with detailed descriptions of the data collection and analysis. Qualitative data included open-responses on student surveys, observations of tutoring sessions, and interviews with tutors and students. Quantitative data included closed-answer responses on the student surveys. Analysis of the qualitative data included thematic analysis of the interviews and open-responses to the surveys, with themes emerging from the initial codes found. Quantitative analysis of the survey responses included descriptive statistics and comparisons between the responses of those who visited the QLC and those that did not. Finally, the chapter discusses the trustworthiness of the findings and the subjectivity statement of the researcher.

Chapter 4

Findings

This study sought to address the following research questions:

1. What are the mathematical needs of the students who visit the QLC

    in the QLC tutors' view and

    in the students' view?

2. What explanations or tutor strategies help students who visit the QLC to understand the mathematical topics they are seeking help with

    in the tutors' view and

    in the students' view?

3. How do the views about questions 1b and 2b of students who visit the QLC compare to the views of students enrolled in mathematics Q courses who do not visit the QLC?

In this chapter, the findings of the study will be reported in order of the research questions. The analysis of data that led to these findings is outlined in Chapter 3.

4.1 Research Question 1: Students' Mathematical Needs

To investigate the mathematical needs of students who visit the QLC, data from observations, interviews with tutors and students, and surveys were analyzed. In this section, the findings relating to the tutors' perspective will be presented first, followed by the findings relating to the students' perspective as displayed in the surveys, and finally the findings relating to the students' perspective from the analysis of student interviews will be discussed. The two perspectives will be further discussed in Chapter 5.

4.1.1 Tutors' Perspective

Exploring the students' mathematical needs through the tutors' perspective was accomplished through data from non-participatory observations of tutoring sessions as well as follow-up semi-structured interviews with the tutors. Process coding was used to analyze the observation data and these results informed the design of the interview questions. After the interviews were transcribed, thematic coding was performed and four main themes emerged. It was found that the tutor's believed that students had four main needs: current material, pre-requisite material, moving from content to problem solving, and learning from class.

Area	**Specific Topics within Area**	Difficult Aspect
Limits	General Concept Precise Definition	Conceptual Conceptual & procedural
Integration	U-substitution Partial fraction decomposition	Procedural Conceptual & procedural
Series and Sequences	Convergence of series Error and Remainders Taylor and Maclaurin Series Power series	Conceptual & procedural Procedural
Applications	Optimization Related rates	Procedural Conceptual & procedural

Table 4.1.1: Topics Mentioned by Tutors

Current material

The theme of current material emerged through the interviews with the tutors. Through our conversations and the experiences and situations that the tutors described, some specific general topic areas were revealed as particularly difficult for students. In particular, the ideas surrounding limits, integration, series, and applications of topics were often present in our conversations. Within these topics, students struggle with various aspects of the problems. For some, the difficulty is conceptually understanding the topic, for others it is procedural, and for still others it is applying the topics to various problems. Table 4.1.1 displays some of the general topic areas that emerged along with specific topics within those areas from conversations with the tutors as well as the aspect of the topic that tutors described as difficult for students.

As can be seen in the table, the responses were varied with only a few topics repeated by multiple tutors. This is not necessarily surprising since each of the tutors can only speak to the courses and the students that they frequently work with. For example, Shaniya mentioned that during her shifts she primarily works with Calculus

2 students. As such, she does not have as much experience working with students from the other courses and did not often speak to their needs. In describing the difficulties associated with these topics, tutors elaborated on why these topics might be challenging, which included pre-requisite material, students' difficulties learning from lecture, and their difficulty understanding how to use these concepts to problem solve, which form the remaining three themes, described below.

Pre-requisite Material

Analysis of the interview transcripts revealed that tutors believe that students struggle with prerequisite material. In particular, tutors felt that students had difficulty with algebraically manipulating expressions, understanding the concept of a function, and trigonometry. The tutors expressed that these were topics that students need to have a strong grasp of, but that they see lacking in many students. In my conversation with Drake, he made the distinction between what he takes to be the basics and what the students bring with them as prior knowledge:

> I notice especially with you know, some of the business majors, a lot of the times they have trouble just moving stuff around in the integral. Like, okay, I'm going to be at the board again. They will have a hard time recognizing $\frac{2du}{u}$, that they can move these ingredients around in the integral to produce $2 \times \frac{1}{u} \times du$. You know. That's not calculus, that's just algebra at that point, or you know using the distributive property, properties of fractions, you know the exponent rule, a^{m+n} is equal to $a^m \times a^n$. These are the tricks that they really - they're in calculus now that they need to have like this, and you know they just don't have them

> like this sometimes. And the things that I take to be so axiomatic they need explained to them. So there's definitely a level of disconnect that I have to put more time into getting over. (Drake, p. 7)

In this case, Drake was speaking specifically about the business majors who take the MB&E or CB&E classes. However, in the interviews with the tutors this idea was repeated several times about students from various mathematics classes. Elias was particularly elaborative about students who had trouble with the concept of a function and trigonometry, even in higher-level mathematics classes. He made the point that "functions and trigonometry, they like trickle their way down or trickle their way up to like, calc, and like multi and stuff like that, diff. eq. So it's obviously really really important. There's even students in like calc one through diff. eq. that whole sequence, that they just struggle with the trigonometry and functions" (Elias, p. 3). He specifically mentioned improper integration as an area that students struggle with if they have difficulty with the concept of a function. He gave the specific example that when students are asked to integrate the function $\frac{1}{x}$ on the interval $[-2, 2]$ they don't recognize the issue in the domain of the function.

In addition to not recognizing the domains of functions, Shaniya and Trace both provide descriptions of students who struggle with working with functions in the general sense of understanding how to plug values into functions and what that means in the context of a problem. Shaniya was a large proponent of providing students with visuals to aid in their understanding, which will be discussed in more detail in the findings from Research Question 2. However, even in describing one of these visualization techniques, she points to the idea that students do not understand how to "plug in" to a function. She says,

> I like using boxes just because it's so easy to understand what's happening because I feel like, when we talk about variables especially x, because x is usually the variable that we use, people get stuck on okay, it has to be x, like it's just x, it's the variable x, and they forget what that variable represents. So that's why I say like, 'Oh, whenever you have a variable it's actually a box that you put the same thing in wherever that variable is'. And then people are like, 'Oh right, so you plug things into that, it's not just its own existence'. (Shaniya, p. 8)

In addition to this example, Trace also mentions that students often think that $\frac{\sin(x)}{x}$ is just sin. This is a misunderstanding of trigonometric functions specifically, and shows that for students that Trace has worked with, there seems to be a disconnect between their understanding of the sine function and the fact that it is actually a function and needs an input. In Trace's interview, he was actually connecting this with other common fraction mistakes that students make, such as splitting up a fraction by splitting up the denominator: $\frac{a}{a+b} \neq 1 + \frac{a}{b}$.

These examples portray the beliefs of the tutors that some of the challenges their students face in their mathematics courses are due to misunderstanding of prerequisite material. However, it is interesting to note that for at least Trace, these prerequisite topics are not the reason that students are coming to the QLC. He says, "So those are some prerequisite things that people have difficulty with, but it's usually not the problem that they're having with the question" (Trace, p. 17). This contrast will be discussed further in the discussion of findings from Research Question 2.

From Concepts to Problem Solving

This theme speaks about students' difficulty actually applying the concepts that they are learning to specific problems or applications. The idea behind this code is a bit less tangible than those previously mentioned, in that this is not speaking specifically about any one topic or aspect of the course. Rather, when tutors spoke about the students they worked with, they often spoke about the students' ability to take the concepts and formulas that they had learned and identify how to use these concepts to solve a problem. The following excerpt from Wayne's interview exemplifies this theme's meaning. In discussing exercises that are difficult for students, Wayne said,

> I guess what I said before, the kind of word problems ... where you need to go back and actually formulate the, rather than just do the calculation, you need to formulate the equation and then solve it. I think a lot of people have problems ... formulating the mathematics, which to me, which obviously I could be wrong because I've never done any research in it, to me kind of shows less fundamental understanding of what the topic is and why it's useful. (Wayne, p. 3)

Wayne goes on later in his interview to talk more about students' challenges with word problems where they need to "formulate the equation and then solve it" (Wayne, p. 3) as opposed to a problem where you are just doing a calculation. He speaks of the specific example of related rates, where students need to find the relationship between rates and to find the equation that they are going to differentiate, rather than being given the formula. From Wayne's perspective, applying the topic when the procedure is not laid out is an obstacle for the students he works with and that in these problems there are "a couple of steps there and a couple layers of abstraction

[he] thinks people have a problem overcoming" (Wayne, p. 3).

For Trace and Lucas, there is an added component to their views on this code. Both would agree with Wayne that students have trouble formulating the mathematics, but in their explanations they add in comments about their lectures, that there is a disconnect between what the students understand in class and their ability to identify what the questions require. For example, Lucas says that students "want someone else to show them how to get to the problem solving. So a lot of times they come in with notes on what they took in lecture but they don't know how to actually do the problem when they have the formulas or whatever they're doing and so they need help to get from a to b, in that respect" (Lucas, p. 1). For Trace, this disconnect occurs partially because of the amount of rules and formulas that the students learn in class. Speaking about the students learning about series, he says,

> When you're looking at the problems you've just gone through two or three classes at most where they threw like, 30 rules at you. Most people don't read the textbook so they're getting these just from class and it's, you know, difficult to know which ones to apply to because they're an entirely new space for a lot of people to work in. (Trace, p. 3)

The tutors also mentioned that students might also have trouble interpreting what the questions are asking of them, regardless of their understanding of the content. Shaniya says that "they just need help kind of conceptualizing what the questions are asking because they've never seen that wording before or that like, format of what was being asked" (Shaniya, p. 1).

Learning from Class

As was mentioned within the previous theme, the interviews illuminated the tutors' perspective that some students struggle to learn from their class. One explanation that was described was that students have trouble focusing. Wayne mentions that "a lot of students have difficulty paying attention or learning in a traditional classroom environment" (Wayne, p. 1). This, he believes, is one of the reasons that they visit the QLC. They need the added support and the ability to review with the tutors. By attending the QLC, they are able to work one-on-one with tutors in a less traditional environment. Lucas often worked with a student at the QLC who had trouble focusing even within the QLC setting. However, since Lucas works with only a few students at a time, he feels that he is able to call this student back into focus whereas that may not happen during a regular class period.

Lucas also elaborates that students attend the QLC "because they didn't understand [a topic] in lecture and so they want someone else to show them how to get to the problem solving" (Lucas, p. 1). Tutors are able to re-explain a concept to a student and showcase their own problem-solving strategies as they do so. This provides added time for students to grasp a concept and opportunities to practice the ideas with someone who can show them how to move from concept to problem.

Shaniya posits that some of this struggle comes from the size of the lectures. She says, "And I know the lectures have gotten to a pretty large size and there isn't a lot of one on one time with your professor so I think they come looking for that at first and then stay because it becomes an environment that's conducive to doing work" (Shaniya, p. 2). Often within my conversation with Shaniya she would describe the environment of the QLC as one where students could come and work and feel comfortable with the tutors and each other. In her view, the large class size prevents students from getting the time they need with their professor and the QLC provides much needed interaction.

In each of these comments, the tutors are sharing that they believe that students may struggle simply due to a difficulty with the classroom setting, whether that is due to difficulty paying attention, a need for more practice than is available in the standard classroom, or the size of the class.

4.1.2 Students' Perspective: The Surveys

The students' perspective was gained in part through the surveys sent to all students who had used the QLC. The survey is shown as Appendix A. Through the analysis of responses to questions 10 through 12 and 15 through 19, insights into the students' views of their own needs were gained. The results of this analysis is presented below, beginning with the results from questions 10 through 12 sequentially, followed by the results from analyzing the open response questions and questions 17 and 18.

Overall Main Difficulty in Challenging Topics

Students who responded to the QLC user survey were asked "What would you say is the main thing you find difficult about the topics for which you have visited the Q Center?" and given seven options to choose from. The options and the frequencies of student responses are shown in Table 4.1.2.

Half of the students responded that their main difficulty was applying the topic to specific problems or examples. From this response we gather that these students felt

	QLC ($N = 122$)	
Response	Frequency	%
Applying the topic to specific problems or examples	61	50
Clarity of key ideas related to the topic	26	21
Understanding when a problem requires that topic	14	11
Following procedures	8	7
Understanding prerequisite material	7	6
Other	4	3
I have not had difficulty with any topics	2	2

Table 4.1.2: Overall Main Difficulty in Challenging Topics

that they had clarity about the topic but when it came time to use it on a specific homework problem or example, they struggled to know how to do so. Related to this, we see that 11% believed they struggled with identifying problems that would use a specific topic. However, we also see that just over 20% of the students felt that it was actually the key ideas that they struggled with. In this case, struggling with the key ideas would most likely have a domino effect and cause some difficulty in the other areas as well. Only six percent of students believed that prerequisite material was their main difficulty. The four (three percent) who chose other explained that their difficulties came either from use of software in a statistics class or from the structure of the class rather than from specific topics.

Reason for Seeking Help

In order to investigate students' main reasons for seeking help at the QLC, students were also asked for their most frequent reason for visiting and given the options of (1) an approaching exam, (2) completing the homework, (3) understanding concepts, ideas and/or procedures, and (4) other. There were 122 students who responded to the QLC user survey and a majority of the students chose completing the homework as their main reason for attending the QLC, with 69 (57%) students choosing this option. There were 26 (21%) students who chose approaching exams and 27 (22%) who chose understanding concepts. There were no students who chose other.

Areas of Difficulty in Solving Math Problems

The survey also asked "When you are seeking help with doing math problems, what is usually the main area you are having difficulty with?" Students were allowed to choose all answers that they felt applied, with six specified options, an additional option for a write-in answer, and the option that they do not seek help with doing problems. The results from the QLC survey responses to this question are shown in Table 4.1.3.

	QLC ($N = 122$)	
Response	**Frequency**	**%**
Setting up the problem so I can solve it using math techniques	71	58
Understanding the steps I need to take to solve the problem	62	51
Understanding what is being asked	41	34
Understanding the requirements of the problem	37	30
Understanding the problem's topic that we recently covered	37	30
Recalling prior knowledge	30	25
Other	2	2
I don't seek help with doing problems	2	2

Table 4.1.3: Areas of Difficulty in Solving Math Problems

Notably, the results show that more than half the students found setting up the problem so that it can be solved using mathematics was one of their main areas of difficulty. The survey also had a high proportion of students who felt that understanding the steps to take caused them difficulty, with 51% of those who took the QLC survey choosing this response. The two students in the QLC survey who chose other explained that it was due to an online class format that they had difficulty.

Specific Help-seeking Situations at the QLC

The final section of the survey included a mix of open- and closed-response questions. Students were first asked to "List three topics that you went to the Q Center for help with this semester" in their mathematics Q courses. These are displayed in Table 4.1.4 in the same form as for those mentioned by tutors. However, since there were no elaborations by students on these topics I will not be able to give the aspect of the topic that they found difficult.

Students were then asked to describe a situation when they sought support for one of those topics. Students did not typically explain what needs they had pertaining to the topic, but did go into detail about what the resource did to successfully support them. This will be discussed in Section 4.2 under the Students' Perspective: The Surveys.

I conclude this section's discussion of the surveys by presenting the results to two questions the students were asked about the situations they described in their open responses. These questions mirror those asked earlier in the survey about the students' main difficulties in challenging topics and main area of difficulty in solving mathematics problems but now focus specifically on the situation they chose to write about.

Main difficulty in the student's specific situation. Students were asked to choose the main thing they found difficult about the topic they described in their

Area	**Specific Topics within Area**
Trigonometry	General topic, Trig Identities
Limits	General topic, Precise definition
Differentiation	General topic, Riemann sums, Curve sketching, Implicit differentiation, Logarithmic differentiation Chain rule
Integration	General topic, Fundamental theorem, Integration by parts, Partial Fractions, Trig substitution, Substitution, Indefinite integrals, Area between curves, Volumes of rotation
Series and Sequences	General topic, Testing for convergence, Alternating series, Taylor and Maclaurin series
Applications	Optimization, Related rates, Exponential growth and decay, Arc length, Modeling with differential equations
Probability	General topic, Conditional probability, Permutations, Combinations
Multivariable calculus	Planes, Triple integrals, Line integrals, Sketching 3D shapes, Green's theorem, Partial derivatives
Linear Algebra	General topic, Matrices, Eigenvectors & Eigenvalues, Diagonolization, Determinants
Other precalculus topics	Parabolas, Logs, Polynomials
Other	Proofs, Vector math, Coordinate systems, Fourier Series, Linearization, Sets, Linear independence, Bernoulli's equation, Linear programming, Cost functions, Markov chains, Standard deviation

Table 4.1.4: Topics Mentioned by Tutors

open response. The responses from the QLC surveys are presented in Table 4.1.5. The responses show that 37% of the participants responded that the key ideas of the topic were unclear to them and 34% reported difficulties with taking their knowledge of the topic and then using it on specific problems of rexamples. Notably, only 4% responded that understanding prerequisite material was their main difficulty.

Area of difficulty in solving their specific problem. Students were also asked to select all options that they felt answered the question, "If it was a problem

	QLC (N=73)	
Response	**Frequency**	**%**
Clarity of key ideas related to the topic	27	37
Applying the topic to specific problems or examples	25	34
Following procedures	8	11
Understanding when a problem requires that topic	4	5
Understanding prerequisite material	3	4
Other	6	8

Table 4.1.5: Main Difficulty in Students' Specific Situation of Seeking Help

that you sought help with, what do you think it was about that problem that made it challenging?" The responses and frequencies are presented in Table 4.1.6.

	QLC (N=73)	
Response	**Frequency**	**%**
Setting up the problem so I can solve it using math techniques	40	55
Lack of practice solving similar problems	29	40
Understanding what was being asked	22	30
Understanding the requirements of the problem	22	30
Understanding the steps I needed to take to solve the problem	21	29
Understanding the problem's topic that we recently covered	18	25
Recalling prior knowledge	13	18
Other	3	4
I didn't seek help with doing a problem	0	0

Table 4.1.6: Students' Difficulties Solving their Specific Mathematics Problem

Here, we see that over half the students felt that setting up the problem so that they could solve it was a difficulty for their specific situations. We also have 40% of students saying that they needed more practice solving similar problems and 30% reported understanding what was being asked and understanding the requirements of the problem to be a difficulty. For those who chose other, one of the students was speaking about a software he had trouble using, one student couldn't recall a specific situation, and a third said that they could not understand what had been explained in class.

4.1.3 Students' Perspective: The Interviews

Through the four interviews with students, we were able to look more deeply at the needs of the students who responded to the survey as well as gain insight about tutoring experiences. Aspects of Mackenzie's interview were designed based on the observation that was done with a tutor while she was visiting the QLC and Whitney, Hannah, and Angela's interviews were following up on the information they gave in the surveys as well as some of the general data that had been collected from the surveys. To analyze the interviews, thematic analysis was performed to code the interviews in relation to the students' needs. Here, I will elaborate on the specific topics mentioned by each student they they believe were the most difficult topics in their mathematics Q courses, then describe the three themes describing the students' needs that emerged from the thematic analysis: (1) tangible needs, (2) intangible difficulties, and (3) content.

Topics

During the interviews, students focused on new topics as those that they struggled with as opposed to prerequisite material. We hear from Whitney,

> For me I think it's mostly new stuff, just because, I felt like I had really good teachers in high school, as far as math goes, so I felt really prepared coming in. It's more just like, a different set up and like, not liking my teacher as much as I had in high school, like I didn't feel comfortable asking

> him questions as much as I did in high school, that type of thing, made it more difficult. Not necessarily like, me not being prepared. (Whitney, p. 10)

Thus, I provide Table 4.1.7 showing the topics that were specifically mentioned by the four students as particularly difficult in their courses.

Area	**Specific Topics within Area**
Limits	General topic Horizontal asymptotes
Integration	Volumes of rotation (disks and shells)
Series	Testing for convergence Errors Fourier series
Applications	Related rates Optimization Mixing problems with differential equations
Other	Lines and planes

Table 4.1.7: Topics Mentioned in Student Interviews as Challenging Topics

Intangible Difficulties

The first theme that emerged from the analysis of student interview transcripts was intangible difficulties. Intangible difficulties refers to the challenges that students face in their mathematics Q courses that do not necessarily directly relate to the content of the course. The intangible difficulties are needs that may not be only related to the students' mathematics courses, but may also affect them in other courses or in their lives more generally. The two codes included in this theme are the transition from high school to post-secondary education and a disconnect between the student and the professor.

Transition. The conversations with the students illuminated that they had had some difficulty adjusting to the structure of their college mathematics courses, either because of the level of difficulty in the content or because of a different style of teaching from their instructor. Whitney was in her second semester of her freshman year when she was interviewed, and reflected that she had difficulty adjusting to the teaching style of her professor in her first semester, whereas she felt more comfortable with the professor of her multivariable class because he was "similar to teachers that [she'd] had in high school" (Whitney, p. 8). For Mackenzie, calculus had been difficult in her first semester but attending the QLC had helped her to look back on her high school experience and actually realize that she should have asked her teachers for more help even then.

Angela, who is intending to be a high school teacher when she finishes her degree, was a bit tougher on college professors when she reflected on the transition. She seemed particularly frustrated that in her opinion many mathematics professors have no formal training in education. She says,

> So I think that's a big thing for me, it's just like, I wish the professors had some type - like a lot of professors don't have that education degree which I feel like kind of affects the students more negatively just because in high school you go from teachers that have to have an education degree, like primarily it's about education, and you go to college where like, most 75% of professors - don't quote me on that statistic - don't have that education background. (Angela, 11)

For Angela, the transition was difficult not only because she had to adjust to the different styles and, in her opinion, quality of teaching, but also because what she was learning from these professors was something that she may need to teach to her own students in the future.

Disconnect with professor. This code speaks directly to a need that motivates students to visit the QLC in particular. Angela explains that there is “a disconnect sometimes within college professors and students so coming here allows me to get that student learning” (Angela, p. 3). She elaborated that the student learning was beneficial to her because the students could explain the pieces of the process along the way, whereas a professor might skip over steps that they do not realize she has missed. While a student may feel that they cannot relate to their professor or that there is some barrier between them, the QLC provides an environment with peer tutors that provides relatable instruction that connects with the student’s experiences. This relates closely to *insights*, a code in the findings from Research Question 2b, which will be discussed in detail in that section.

Tangible Needs

Tangible needs emerged from the interviews as a theme and represents those aspects of the mathematics Q courses that the four students discussed needing support with that directly result in a grade for the students. The two codes within this theme are homework help and studying. All four students said that they had visited the QLC for homework help, and Hannah added that she had also attended the QLC to study for a quiz.

Angela discussed that she came in for Calculus 1 due to homework questions that she wanted to make sure she had answered correctly. She said, “Last semester, I visited it, definitely quite often I would say once every week, week and a half - more for like quick homework questions that I didn't understand. Not really overall content, just like my homework was based on how well I did something so I wanted to make sure and get the reassurance that the answer would be correct" (Angela, p. 2). For Angela, it wasn't so much the concepts in the class as it was making sure that she could answer questions correctly on her homework. Similarly, Whitney said that she came in once or twice a week after trying the homework on her own and not getting very far.

Content

Aside from the specific topics already discussed, the interviews with the students brought up difficulties that they had understanding the content in their courses. Two codes were subsumed into this theme, including understanding the question and applying the topic.

Understanding the question. Here, students revealed that one of the difficulties they had was actually understanding what the questions were asking them to do on homework and other assignments. For Hannah, this was partially due to the variety of ways that questions were asked, so deciphering what a question was asking required her to recognize the concept within questions that were phrased differently than she had previously seen. Angela agreed, saying, "the part that students have the most difficulty is just understanding what [the questions are] trying to say" (Angela, 4). While the students may feel that they understand the content they are learning in class, they still have difficulty understanding the phrasing or deciphering the context within a question.

Applying the topic. In this code, students struggled with completing problems because they had not practiced enough examples yet. Whitney explained that if she had only seen one example in class that she would "have the idea of what the concept was but then trying to do anything else just from one example just didn't really work well for [her]" (Whitney, 5). Whitney's class relied heavily on group work in class so she felt that they did not see as many examples in class as they would in a more traditional lecture setting. Similarly, Hannah gave the example of learning about planes in multivariable. She described that she understood what they were doing in the class and all the concepts and equations, but without any practice it was difficult for her to know how to start the problem.

4.2 Research Question 2: Successful Strategies

To explore the support strategies and explanations that tutors and students believe to be successful, data from observations, interviews with tutors and students, and surveys were analyzed. The organization of this section will mirror that of the previous section covering Research Question 1. The findings relating to the tutors' perspective will be presented first, followed by the findings relating to the students' perspective as displayed in the surveys, and finally the findings relating to the students' perspective from the analysis of student interviews will be discussed.

4.2.1 Tutors' Perspective

Again, the tutors' perspective was gained through interviews with tutors that followed an observation of a tutor's tutoring shift. Through the analysis of the interview transcripts, five main themes emerged that influenced how tutors chose to work with students and that they believed factored into their success: understanding students' predetermined goals, knowing the students' challenges, the tutors' views on the nature of mathematics, their tutor identity, and finally, the actual tutoring strategies that they employ. I will now discuss these themes and how they contribute to our understanding of successful tutoring strategies.

Students' Predetermined Goals

This theme references the goals that tutors perceive that students have for the tutoring session. There were two codes that were subsumed into this theme, students need support on homework and students who just want the grade. All seven tutors expressed that students are visiting the QLC primarily for homework support. Within these responses, distinctions became apparent between students who the tutors felt were genuinely seeking help and wanted to understand the content and those who tutors believed visited just to earn a grade on their homework and who just wanted to get the answer. These two codes will now be discussed in detail.

Students need homework support. When asked what he thought was the most common reason that students came to the QLC, Elias said, "I would say to, to complete homework, whether it be webassign or worksheets" (Elias, p. 1). This was echoed by all tutors except Drake, who instead said that students were visiting because they were not strong in mathematics. Within his interview, however, he did reference that students were often there for their online homework.

Wayne, who had 12 semesters of tutoring experience at the time of the interview, explained his perception of the effect of online homework on student attendance at the QLC. After saying that historically he did not remember having many students for Calculus 3 or differential equations, he continued that

> Over the past four years I've seen a continuous increase in people coming in for specifically calculus three and differential equations and linear algebra as those courses have moved towards more online homeworks. For instance, I know that diff. eqs. actually this year starting to use WebAssign and stuff like that and multivariable has moved into that and so as that has become the norm for these classes I've seen it more. (Wayne, p. 2)

Seth goes so far as to say that "sometimes you get people who are there to study for their exams for that class but nine times out of ten it seems like on the math side it's either a worksheet or online homework" (Seth, p. 1). Thus, the homework that the students are assigned is playing a large role in what the tutors are doing during their sessions. If the students are hoping to finish a homework assignment, then that will influence how a tutor structures their session. This forms some difficulties for tutors as they try to add in information that they think is important but that students may not care to learn. Seth goes on to say, "There are a lot of times where I tend to go on tangents if I'm like, 'oh this is something else I know about this topic that might be helpful or interesting,' and nine times out of ten it seems like the people aren't interested in the extra thing" (Seth, p. 1).

To connect this code to the next, I'll include a statement from Lucas. He says, "Most of the time it's just, 'make sure that I'm doing this correctly,' and so ... if they have a worksheet they don't want to have done the whole worksheet and then hand it in and get it wrong, they want to make sure they know what they're doing. So I'll help them to check their work" (Lucas, p. 2). This statement could be interpreted in a couple of ways. Perhaps Lucas is saying that students want to have the conceptual understanding to "know what they're doing". However, he is also pointing out the impetus for wanting this understanding is to not "get it wrong" after handing it in. Through statements from the other tutors as well as more statements from Lucas, we will see that the majority of these tutors believe that students just want the grade and don't necessarily value the understanding.

Students just want the grade. In each of my interviews, the idea of students just wanting the correct answer came up. In every instance except with Drake, the tutors were clear that they believed many students were coming to the QLC just to get the correct answer to their homework questions or just to get a good grade on an assignment, regardless of their own understanding of the process. Drake, on the other hand, was very clear that he does not think this, saying, "I do not think any of them want me to just give them the answer" (Drake, p. 1). However, since six out of the seven tutors spoke about this, it is an important finding and has an effect on how these six tutors work with their students.

In each interview, this idea emerged without prompting from the interviewer. In Lucas' interview, when asked if there was anything else he thought I should know, he responded with, "Something I think you should know is a lot of time people come in and just want me to do their homework for them without saying it. Like they'll be like, write it down for me. And I'll just be like, it's for you to do not for me" (Lucas, p. 9). Shaniya also shared that "it can be really hard for [her] to tutor a student if they come in and just kind of expect [her] to do all of the work for them and give them the answers" (Shaniya, p. 10). She then went on to explain in detail a situation that had happened recently in which a student had come to the QLC and expected Shaniya to work through every problem without having to show her own work at all.

Elias also mentioned his frustration with students he believed to have this mindset multiple times throughout the interview. At one point he said,

> A lot of times students usually just come in to get a homework grade ... I do get frustrated when I notice the students just come in for their homework, for just, just to get a mark on their homework. Because a tutor's not going to be there to navigate them through an exam. I notice way too many students coming in and they focus on that 10 or 15 percent of their homework grade but they're not focusing on that 30 percent of their one exam grade. (Elias, p. 6)

Not only is it frustrating for the tutors because they know that they are not allowed to give answers, but Elias clearly feels that this mindset is also not beneficial for the students and desires for them to want more from their session.

It became clear within the interviews that not only did the tutors believe that this mindset was not beneficial but that it also causes the tutors frustration and challenges in trying to decide how to deal with the situation.

Challenges

The second theme that emerged relates to the challenges of students as perceived by tutors. These challenges are those mathematical needs discussed in Section 4.1.1. Specifically, tutors believe that students' have challenges with pre-requisite material, assorted topics from the course students were visiting for, applying the concept to specific problems, and learning from class. These challenges are a factor in how tutors work with the students, and by knowing the students' challenges, tutors feel that they can provide more beneficial support. However, when the challenges that tutors' see the students facing are in opposition with the students' predetermined goals for the session, tutors must make use of their various strategies to ensure the session is beneficial for all involved.

Nature of Mathematics

The third theme speaks about the tutors' beliefs about the nature of mathematics. In their interviews, it became apparent that the way that the tutors thought about mathematics informed how they chose to work with students. Their beliefs about mathematics also inform which tutoring strategies they believe are beneficial. This theme encompasses two codes, mathematics is creative and mathematics requires intuition.

Mathematics is creative. The tutors believe that mathematics requires some creativity and ability to use the concepts that are learned in creative problem solving. For Trace, he believes that certain aspects of mathematics are difficult primarily for this reason. He says that "integrals get tough because that's where things become creative rather than just following steps" (Trace, p. 2). For Seth, these comments come about more out of sadness for students who have been made to believe differently, saying,

> I've heard horror stories of ... 'when I was at home ... I learned that this technique that I learned in this other class could be used here to do what we're doing faster.' I've heard horror stories of people showing that they've done that on their own time to their math teachers and their math teachers getting mad and being like 'I told you to do it this way, not doing it that way'. And like, nothing stifles a kid's creativity with math and in

> general like being scolded for being creative and going outside the lines. (Seth, p. 10)

Seth goes on to talk about how he is not going to school to be a middle- or high-school teacher because of this. He does not believe he could "stand to see like, thirty like sixth or sixth through eighth graders everyday treating math as a chore no matter how much I try to get them not to" (Seth, p. 10). This belief that math is creative plays a heavy role in how both Trace and Seth feel about doing mathematics themselves and also how they want to portray mathematics to the students they work with.

Mathematics requires intuition. The second code describing how tutors view the nature of mathematics is that mathematics requires intuition. Tutors believe that in order to be successful in mathematics, students need to gain an intuition about the different aspects and topics they have learned, including being able to connect the different ideas together. Seth calls it a "math puzzle" and when discussing students' difficulties with logarithms and exponentials, he says that they are "at the point in math that you should be able to like use them together and ... if they don't make intuitive sense ... maybe they'll be able to use them on the exam when they realize, oh this is a log problem but they wouldn't naturally see to use them in doing other math" (Seth, p. 3). There is an interconnectedness between topics that Seth is speaking about that he wants to portray to the students he works with.

Wayne also agrees with the idea that mathematics requires intuition and that familiarity with the topics and the reasons behind why things work will benefit students. Referring to learning about differential equations, he says, "You've kind of done the drill repeating these problems over and over again, but what makes you really remember it is kind of the logical process, why these things make sense" (Wayne, 4). Here, Wayne distinguishes between just repeating procedures over and over and actually understanding how the procedures work. Since he believes this understanding is important, in his tutoring session he had asked the student what made her differential equation special and different than algebraic functions. He was trying to "make sure that they were able to identify that kind of problem so that what I was about to teach them they would know when to use it" (Wayne, p. 4). By gaining intuition about the types of equations the student would encounter, Wayne hoped that the student would be able to identify problems that required differentiation more easily.

We see Drake's agreement with this in his statement referring to the students' knowledge of exponent rules, which was already mentioned as a mathematical need in Section 4.1.1. He says,

> These are the tricks that they really - they're in calculus now that they need to have like this, and you know they just don't have them like this sometimes. And the things that I take to be so axiomatic they need explained to them. So there's definitely a level of disconnect that I have to put more time into getting over. (Drake, p. 7)

The idea that Drake takes these facts to be essentially "axiomatic" and that he believes the students he is working with should as well points to his belief that there does need to be a level of intuition within mathematics.

Tutor Identity

The fourth theme is the tutor identity. This theme refers to how the tutors see themselves and what they believe their role as a tutor is. This factors into how each tutor will respond and interact with students, which in turn impacts the types of strategies the tutors use. Within this theme, there are three codes: the power dynamic between tutor and student, the tutor's desire to be relatable, and that the tutor avoids giving the answer. These codes will be described in turn below.

Power dynamics. In interactions between instructors and students, there is a clear power dynamic at play since the instructor has control over the students' grades and work. In the interview with Elias, he mentions this dynamic in relation to his own interaction with students.

> They do want help because instead of going to a professor, they are going to a peer because they feel more comfortable with a peer, and they feel more comfortable with a peer than they do with a professor or TA ... and I also understand that it takes courage to even, to go to a professor, to go to a TA, or to go to a tutoring center. (Elias, p. 5)

Here, we see that Elias recognizes that he is a peer tutor and that this helps students to feel more comfortable coming to the QLC to ask questions. However, he does still realize that there is still some level of power dynamic at play since the students still need to come to the tutoring center to ask for help.

Shaniya also recognizes this dynamic as a peer tutor. She spoke about her role in relation to the students quite often throughout her interview and this seemed to be important to her in how she interacts with students. At one point she says, "I think it makes it less of a scary environment ... I try to make it like as friendly as possible too, because I don't want to be condescending or teacher so I feel like [having them look over their work and ask me any questions they have is] just another way of like making it - putting us on the same level almost" (Shaniya, p. 7). As a peer tutor, Shaniya believes her role is to almost be a friend to the students that come in, saying she wants the students to feel like they are "going to hang out with Shaniya and do some math homework" (Shaniya, p. 7).

While the tutors seem to agree that they are not instructors and that they prefer to be viewed as fellow students by their tutees, there is still the slight power imbalance in that the tutors are the holders of the knowledge that the students are seeking. Wayne refers to himself as "the person who knows the topic" (Wayne, 11), and that it is his responsibility to figure out what the student is struggling with. Likewise, Drake recognizes this imbalance and shares that he tries to teach students from the insights he has gained about their courses. He says about these insights, "This is something that I realized on my own and I found to be very effective. And this is why I bestow this knowledge on the people that I help" (Drake, 6). So we see that while these are peer tutors who are students providing help to other students, the tutors are still aware of a power imbalance.

Be relatable. Since the tutors recognize themselves as peers to the students that they work with, the tutors also try to be relatable to the students. As was mentioned in discussing the power dynamic, Shaniya in particular sought to be relatable and friendly with her students. She says,

> And I think it makes it again, a little bit more approachable because it makes it less of 'Oh I need to go get tutored, I'm going to the tutoring center', it's more like, 'Oh yeah I'm going to go hang out with Shaniya and do some math homework' and it makes it less daunting, and a little more enjoyable. And also it makes my job more fun too, like I enjoy it better if I kind of know the person a little bit and it's more of a friendly environment rather than a work place environment. (Shaniya, p. 7)

Shaniya clearly emphasized throughout her interview that she believes part of her success as a tutor is because of this aspect of her tutoring. However, she does make a distinction that different students will prefer different tutors, so her regulars may appreciate her style of tutoring while other students might not.

Trace also felt that relating to students benefited the tutoring experience. In his case, he specifically felt that commiserating with students about difficult topics could be useful. He says that when students come in for probability questions he will agree with them that the problems are tough but encourage them in that, "We can work through this together" and he believes that it "makes you like, relatable, like oh wow, someone else also hates this but has gotten through it, I guess maybe I can too" (Trace, p. 8). He does emphasize afterwards that there is a line between being commiserating and being pessimistic, but that he feels that relating on this level with the students can be useful.

Wayne reiterates that he wants to relate to his students and that it is important to him that the students that he helps remember that they are two people working together. He says, "I'm not Wolframalpha doing your homework for you either. We're both people and so if I can somehow relate this - you know math can be a dry, conceptual thing - to us as like, to our everyday lives as people I think that it, I think that the overall process of teaching goes better" (Wayne, p. 12). Whereas in the previous examples the tutors were relating to the students primarily to make the students comfortable in the environment, Wayne implies that by relating to them as people he is also trying to make the mathematics less dry and conceptual and to ground it in their lives.

Avoid giving the answer. The third code within the theme of tutor identity is that the tutors feel that they must avoid just giving the answer to students. In a fairly straight-forward way, Trace does not want to help the students cheat. In explaining why he had students work through most of the problems themselves during the observation by the researcher, he says, "I think this was a worksheet and I didn't want to do too much of the work, and so I felt that if I showed her how to get the form that that - I wouldn't be crossing any lines there. Like no professor could come in here and say, 'You helped my student cheat for 1/100th of a percent of their grade'" (Trace, p. 7). This is something that is reiterated by him further on, saying that these are things they are taught about in training.

Based on what the tutors said in relation to the students' predetermined goals of just getting the answer, we can tell that tutors grow frustrated when students just want the answers. This also causes the tutors concern with how to deal with these students and how to work with them. A statement we've briefly discussed from Lucas speaks to this point:

> Something I think you should know is a lot of time people come in and just want me to do their homework for them without saying it. Like they'll be like, write it down for me. And I'll just be like, it's for you to do not for me. And so you have to work with those people to make them do it without just giving in and telling them everything they need to do" (Lucas, p. 9).

Thus, the tutors belief that they should not be giving out the answers to students is a factor in the strategies they use and also causes some challenges for the tutors in how to maneuver through the opposing desires of their tutees.

Tutoring Strategies

The final theme that emerged from the tutors' interviews and observations was the tutoring strategies that the tutors employed and that they thought were useful. This theme speaks directly to the research question. There are seven tutoring strategies that will be elaborated on. The strategies are that tutors make interpersonal connections, make connections to what the students know, engage the students, write things down and create visuals, avoid overloading the students, check the understanding of the students throughout the session, and train the students in good study habits.

Make interpersonal connections. The tutors often spoke about the connections they had with the students they worked with. This is tightly connected to the code *be relatable* from the previous theme, *tutor identity*. However, I add a short discussion to explain the difference between the two codes. In be relatable, the tutors were primarily speaking about relating to their students on a personal level, being friendly and sometimes commiserating over difficult assignments. In this code, the tutors extend this relationship to also connect with the students to improve their ability to choose strategies that will work for them. A key example of this code is a statement by Lucas where he says, "that's because I've worked with him like 5, 6, times now. And so I've noticed that he needs like a constant reminder of what to do or he'll forget it and I'll have to explain it again. So if I just write it down for him then he'll just remember it" (Lucas, p. 4). Lucas had worked with this particular student many times and had developed a friendly relationship with him. He used this relationship and what he learned about the student to choose what strategy to use to support him.

Make connections to what the students know. The second code refers to how the tutors use their knowledge about the students to connect the mathematics to what the students already know. In practice, this includes both the tutors finding an appropriate starting point for the students by asking them questions about what they know and giving examples related to a student's interests or disciplines. For Lucas, it is important to him to find out what the students are bringing with them to the session in terms of their prior knowledge. He says that he asks the students questions about the topics "Because some people come in with a high knowledge and some people come in not knowing at all. And so if they don't know at all, I'll teach them how to do it out front and then try to see if they can put the pieces together for another problem" (Lucas, p. 5). By knowing his students' starting points, he can format the session so that the students gain the most benefit. Often, the tutors also discussed giving examples in terms that the students will understand. Shaniya described why she explained the radius of convergence of a series as the radius of a circle, saying,

> I think that it usually helps the concept click a little bit. Especially because for the most part they know what a circle is. They know that a circle has a radius, they know that it is what's included in a circle, so using terms or concepts that they already know to then explain a new concept is kind of like, 'oh okay, now I can understand because you are speaking in words I know, or like you're speaking in the same language as me' basically. (Shaniya, p. 5)

Not only do the tutors mention using language the students will understand, but they also comment that giving examples of how the mathematics relates to the students' interests can give the students more motivation and clarity. Trace, in discussing students' difficulties understanding functions, speaks about how if he is working with a computer science or engineering student he will often relate the mathematical idea of functions to the functions that computer programmers create. Wayne also speaks about relating the mathematics to his students' interests, saying that "when you make it tangible for somebody it becomes more graspable" (Wayne, p. 10).

Engage students. A third strategy is to make sure that students are fully engaged throughout the tutoring session. Elias speaks about this in terms of building a student's confidence. By keeping the students engaged, he says their confidence can be built by showing them that they can do pieces of the problem, even if they couldn't initially complete it on their own. He says that he encourages students to engage

> In short, it really helps the student feel good about themselves when they can see that when they talk to someone out loud - I think speaking helps, I think you work with other people and collaborate, that helps - and I do notice that the students are nervous sometimes, like they don't want to say the wrong answer, and I just tell them, 'listen ... if we're wrong we'll fix it. There's no reason to be nervous about trying to answer a question because if it is wrong then we're going to understand why it was wrong and we'll get to the bottom of it.' (Elias, p. 6)

For Elias, there is motivation to get his students talking and engaged in the session because it will build their confidence and help them to be able to speak about the problems to find their mistakes and to fix them.

In Trace's interview, he gave some examples of how you can engage students in the session. He says, "Something important is to not do too much of a problem for them.

Even if it's something really simple ... Say you're showing them how to do partial fraction decomposition and there's a simple arithmetic step, even asking something like that that's not integral to the problem, can hook them back into it" (Trace, p. 8). This process was reflected in each of the observations of tutors. In some way, each of the tutors would engage students in the problems they were working on, either by asking them questions about simple steps in the process as suggested by Trace, or in more complex procedures as the tutor took a less involved approach.

Write things down and create visuals. In four out of the seven tutor interviews, writing things down and creating visuals for the students was mentioned explicitly by the tutors as a strategy they use, and in fact I observed this strategy used in all seven observations in some form. As we discuss this code, we are defining writing things down as more than simply writing the mathematics down on paper as scrap work, but as an intentional method used by the tutors to clarify the content being discussed. For example, Shaniya describes it as

> Writing things down, really clearly writing down step one this, and then maybe doing the step underneath that and then writing step two is this, and then doing the step under that. So usually just having like almost like a textbook for math of what I'm writing down, rather than, like I'll have a separate piece of paper if I'm just doing like scrap work or something, or if someone needs some help with algebra or some simple thing I have papers for that, but then I almost always give a student a piece of paper where we do a problem out and then I'll say hang onto this, when you have another question I'll add onto this piece of paper so everything is in one place and that usually helps a lot. Having something to take away

> and also having something to actively look at while we're talking about it. Um, so that's probably my go to strategy. (Shaniya, p. 8)

This may or may not include creating visuals for the students by drawing pictures of examples to clarify concepts. For Shaniya, visuals were very important to her tutoring because she recognizes herself as a visual learner and feels that visuals help students because "one, they can see what's going on and two, so they have something to focus on, because also the Q Center can be kind of distracting, there are a lot of people talking about different things, so if I'm just talking at you but someone else is talking next to me it's easy to kind of like, get spacey" (Shaniya, p.4).

Seth and Elias both gave specific examples of visuals that they use often in the classes they tutor. Seth creates a number line to explain to his statistics students how to use a function on their calculators and understand the inputs they should be using. Elias describes how he likes to refer to the graph of a function when doing problems in the classes he tutors, because he feels it helps students to visualize what will make sense as answers to their problems. Specifically he speaks of how an exponential function e^x can never be negative. In both these examples, the visual is used to help the students see what makes sense in the problems they are working on.

Lucas also elaborated on his own method for tutoring, in which he is the main writer during the session as opposed to having the students write anything down. He describes that it "helps a lot because they can focus on doing the problem and they don't have to focus on writing it down. If they just tell me what to write and I'll write it. And I didn't think it was that big of a deal, but the results are crazy good" (Lucas, p. 5). These strategies match with what I observed during the tutoring sessions.

Avoid overload. The fifth code, avoid overload, refers to the tutors' attention to not introduce too many new topics at once. During the observation of Wayne's tutoring session, a student was working through a problem and in the middle of her work Wayne realized there may be an issue in the domain if she continued on in the way she was working. Wayne stopped her there, and began explaining the domain issue. However, in his interview he revealed that he regretted doing so.

> I also think that because they were in the middle of solving a problem and I all of a sudden started introducing another concept to them in the middle of them processing and working out another one it may have - the detriment there it may have been that (a) in the best case scenario they just completely did not understand the kind of domain thing I was talking about the thing I interjected, worst case scenario I confused them on everything prior as well because I - you - the brain was processing one thing and then all of a sudden tried to do two things at once and then messed up the first thing. (Wayne, p. 7)

Here, he recognized mid-explanation that he may have been confusing the student more by interjecting at that point. He goes on to explain that sometimes it is best to let them finish and correct them after, allowing their mind to process each piece individually.

We also see in Trace's interview that he believes that for many students he works with there is an overwhelming amount of information introduced in class, particularly for series. We've seen this quote earlier in our findings, "When you're looking at the problems you've just gone through two or three classes at most where they threw like, 30 rules at you" (Trace, p. 3). While this is not specifically speaking to Trace's tutoring strategies, there is an implication that he should not just throw those 30 rules at the students again, but rather that he would slow down and help them to process them. In Shaniya's interview, she also references slowing down in the explanation, saying, "In the beginning I feel like because a lot of the concepts are new and a little intimidating they just need someone to break it down a little slower" (Shaniya, p. 2).

Check understanding. As discussed earlier, the tutors are not concerned only with whether or not the students get the correct answer to a problem, but also with the level of understanding of the topics that students leave the QLC with. As such, the tutors have methods that they use to check for this understanding. For the tutors, the first stage is simply asking the students if they understand. For Drake, he is looking for "enthusiastic affirmative approval". If he receives a less than enthusiastic response, he will try to explain it again. However, he will not push the issue if the students are not receptive to a second explanation. For Drake, "some students may pretend to understand something just so they can, you know, sleep on it, maybe understand it later, but you know they have more stuff to come to. Meanwhile they can quasi-understand it for now. It'll help them get through the rest of the assignment" (Drake, p. 7). So while Drake does check for understanding, he leaves responsibility to the student to either accept or reject further explanation.

For Wayne, asking the students for their understanding occurs throughout the entire process. In this way, he hopes to be able to pinpoint where students might be struggling. If a student does not understand a certain part, then he can try to explain it again or ask them another conceptual question to try to "target the specific part of the concept that they don't get" (Wayne, p. 10). Elias mentions a similar procedure for checking understanding at the end of a session. Rather than asking a question specific to one part of the problem, if they have made it to the end of a problem then he will ask them to do a similar example problem to see if they can now complete it on their own. In both these methods, an example problem is created by the tutors and designed to target either the topic or a specific piece of the topic.

One other method used by the tutors was to summarize what they had just done in a problem or to have the student explain it back to them. For example, Shaniya likes to explain what they had just worked through and then give the student "a chance to see that flow ... and to ask any questions that may come up as [they] learn the next piece of information" (Shaniya, p. 6). In her motivation for this method, she explained that she remembered reading a study that said that you remember much more of what you teach to others than what is just explained to you. In this way, she is hoping to not only wrap up what they had been working on, but also provide the student with another level of understanding.

Train in good study habits. The final code is that tutors try to train the students in good study habits. This was seen especially in the interviews with Lucas, Trace, and Elias. In all three observations, the tutors asked students if they have notes or a textbook. When asked about this in their interviews, not only did the tutors say it was to refresh their own memories but also to show the students what resources they have and how to properly use them. Lucas points out that it "helps [him] too, and it also helps [the students] to know that they can, kind of remember it in their mind. Like they can put together this page in their notes with this type of problem" (Lucas, p. 8). This will help the students when studying or working on problems later on when they are not with a tutor.

For Elias, he wanted his student to realize how many resources she had in addition to the QLC. He believed that students sometimes don't even realize all the resources that they have, including the textbook, notes, their professors, and Youtube. Elias even mentioned that sometimes he will look up videos on the internet with his students to show them where to find useful content. Similarly, Trace spoke of trying to demonstrate how to use the textbook with his students. When he has a manageable number of students he will use the textbook and show the students how he finds the material he is looking for and how he finds example problems. In this way, he is hoping to instill in the students an appreciation for the textbook, which he calls a "source of truth".

4.2.2 Students' Perspective: The Surveys

The students' perspective was gained in part through the surveys sent to all students who had used the QLC for support in mathematics courses. The survey is shown as Appendix A. Through the analysis of the open responses to questions 17 and 20, the students' views on successful support strategies were explored.

QLC Survey

For the QLC Survey, the two open response questions asked the students to respond to the following prompts:

- Choose one of the topics from the previous question. Describe a specific situation when you went to the QLC and when the support you received was successful in helping you to understand that topic. Please include the type of problem, why you sought help, and any other details that will be useful to understand the challenge involved.
- What did the tutor do or say to help you to understand the topic? Be as specific as possible.

From the analysis of the 55 responses, 15 responses were found to not give useful information either because the student had written that they could not remember, the student was speaking about a non-mathematics course, or the student did not explain what the tutor did. Out of the remaining 40 responses to these two questions, four main strategies emerged that the students thought aided in a successful tutoring experience.

Step-by-step. It was evident from the student responses that they appreciated that the tutors would walk them through problems and examples with all steps explained. Seventeen students reported that their tutor talked them through a problem step-by-step and that this was successful in helping them to understand the concept. The students described this as a main feature of the support that was useful and something that they did not necessarily receive in class.

More examples. Additionally, students' explanations of their situations revealed that being able to see more examples was particularly helpful. Twelve students mentioned that the tutors were frequently having them work through more examples beyond what was done for them in class or on their homework. One student in linear algebra mentioned that they were working on a problem involving eigenvectors and that the tutor was able to show them another example so that they could clearly understand the one that they needed to complete.

Why. Four students mentioned that tutors supplied the logic behind the steps they needed to take to solve a problem and that this helped them to understand the process. One student who was working with Maclaurin series said that their "tutor helped to describe the steps that must be gone through giving a logical way to think through it about what each step achieves." The students wanted to understand the steps so that they could remember them on future problems.

Visual. Finally, four students also mentioned that their tutor was able to successfully support them by providing visuals, whether they were drawings, tables, or using a piece of paper to represent a 3D surface for multivariable. While the students in the surveys did not elaborate much beyond saying that a visual was helpful for them, the student interviews were able to elaborate on this a bit further. This will be discussed in the next section.

Other notable strategies. While the four strategies already mentioned were most frequently seen, other strategies also emerged in the students' responses. Two students mentioned each of the following strategies:

- the tutor used language that they could understand rather than mathematical terms,
- the tutor related the topic to other topics that the student was more familiar with,
- the tutor allowed the student to figure parts of the problem out on their own,
- the tutor reminded them of background knowledge that could help them to better understand the current material, and
- the tutor showed the students where they could find useful resources when they were working on their own.

4.2.3 Students' Perspective: The Interviews

From the thematic analysis of the student interviews, three themes emerged regarding the successful support that tutors provided. These themes describe aspects of support that the students mention as beneficial as well as the specific strategies used by tutors that the students mentioned. The three themes are logistics, support identity, and strategies.

Logistics

The theme of logistics refers to logistical aspects of a support structure that are desired by the students. The analysis of the student interview transcripts revealed that for these students, the ability to interact with the tutor and the convenience of the QLCs location and schedule were major factors in why they felt they were able to be supported there.

Interaction with tutor. Even among the four students, different opinions on what types of interactions were helpful emerged. However, overall they were able to have the interactions that they needed. For example, Mackenzie would often sit and work on her homework and ask questions if she had them. The QLC provided a location where she felt productive and supported. Hannah also usually came to the QLC alone, but she preferred to come to the QLC with specific questions to ask rather than working on her homework while she was there. She believes that "talking one-on-one with a professor or just someone ... helps a lot, because you can ask a lot of little questions which you might be thinking when you're taking a test and you don't know the answer because you're asking it" (Hannah, p. 7). Unfortunately Hannah sometimes struggled to receive this support at the QLC because the tutors were busy or did not understand the content she was learning in her multivariable class. In contrast to Mackenzie and Hannah's tendency to attend alone, Whitney appreciated the ability to go to the QLC with a group of students and work together with a tutor. She appreciated that she and a friend could work together with a tutor so that there could be more back and forth between the three of them.

Convenience. Another logistical aspect of the QLC that students appreciated was its convenience, both in location and schedule. For Angela, this was a main benefit. She could not attend office hours because of other classes and she also felt that her questions were not necessarily big enough to go to office hours for. Instead, she preferred to bring them to the QLC when her schedule allowed. However, she says, "it's just more out of convenience, it's not as much out of like, I think one's better than the other" (Angela, p. 10). Thus, the convenience of the QLC made it preferable as a resource but it was not necessarily due to a lack of support from her professor.

Support Identity

In discussing the students' thoughts about the QLC and the tutors there, student thoughts surfaced about the tutor's identities as peers who had insights about the mathematics Q courses. This identity encompassed three codes, students felt comfortable with the tutors, the tutors understand what they need, and the tutors have insights about the course and the mathematics material.

Comfortable. When discussing why she was willing to go to office hours for one class over another, Whitney expressed that she feels more comfortable with one professor than another. For Whitney, this came up multiple times throughout the interview, that she based where she sought support off of her comfort level with that resource. Mackenzie explicitly linked this to why she visits the QLC, saying that "the way [her teaching assistant] explained it was not as clear and he sort of intimidated [her], but then the tutors helped to make the concepts and questions clear" (Mackenzie, p. 5). Mackenzie was able to feel comfortable asking the tutors questions as opposed to her teaching assistant who she was intimidated by.

Understand what they need. In addition to feeling more comfortable with tutors, students also refer to the tutors' ability to figure out what they need and to start from that point. Whitney felt that other resources would try to teach her topics from the beginning, whereas the tutors would help her get the answers she wanted, starting from what she already understood. Angela also felt that tutors could figure out what she needed help with. Comparing to what she had learned in a proof-based class, she said, "When I come here they're helping me understand, okay, you have this information, how are you putting it into words. It's more of like, instead of going from 0 to 10, they're giving you the blocks that are helping you to succeed in that specific topic" (Angela, p. 3). Whereas she feels comfortable with the content knowledge from class, she feels like she hasn't been given the support in writing proofs. The tutor recognizes that and focuses on that aspect.

Insights. The final code under the support identity is insights. For Whitney, part of these insights was the tutor showing her some tricks to make simplification in a problem easier. For Angela, these insights also include insights into the course since the tutors had already "somehow got past that specific class and somehow were able to learn from it and think about, 'Okay, how do I do this, from what my professor taught me how do I do this?'" (Angela, p. 11). Since the tutors had already found a way to make it through the class, Angela felt that they had insights that they could give her of how she could think about the concepts and pass the class as well.

Strategies

The final theme includes codes related to the strategies mentioned in the student interviews. These codes include visuals, don't give the answer, more examples, let me explain, and check my understanding. Each is described below.

Visuals. Hannah, Whitney, and Angela all spoke about specific situations when tutors used visuals to help them understand a concept or problem. In Whitney's situation, her tutor showed her a graph and she believes that that helped her to understand the concept a lot more. In Hannah's situation, she was working on a mixing problem using differential equations in calculus 2 and her tutor drew her a large image showing where the rates were entering the tank and leaving the tank. This helped Hannah to see that she could solve the problem by recognizing where the values were coming from. This gave Hannah a way to relate the mathematical formulas to the actual situation that they were describing.

In Angela's case, she had already been taught optimization in high school but had never fully understood it. She was having difficulty understanding the problems and what they were asking, so her tutor showed her how to draw a picture to decipher what they were trying to figure out. Similarly to Hannah's situation, this allowed Angela to relate the problem statement and the situation to the mathematical formulas and methods that she needed to use. In all of these cases, the students gave an overwhelming positive review of the technique.

Don't give the answer. It emerged that the students appreciated the tutors who did not just give them the answers to their homework. For these four students, they wanted to be able to figure out the problem themselves or work through the problem with the tutor so that they understood the process. As Mackenzie puts it, “I mean if they give me the answer that’s nice, but that’s not giving me any benefit if I just get the answer, right” (p. 3)? This reflects the feelings of each of the students. Hannah adds that she even tries “not to use the internet too much because it just gives you the answers and so that’s not really helpful” (p. 7).

More examples. The students also mention that they appreciate when tutors can give more examples in addition to the problems they might see on homework or in their notes. In Whitney’s honors calculus course, she was given worksheets that the instructor created rather than problems from the textbook. Finding examples of similar difficulty was sometimes difficult, but the tutors at the QLC gave her good explanations and she was able to try other examples while there. Mackenzie and Hannah also look for tutors that will provide more examples. When discussing what she thinks makes a good tutor, one of her traits was that they give more examples or bring out examples from the text book.

Let me explain. Students also discussed that being asked to explain their ideas helps them to process and learn. Hannah mentions that working with other people allows her to explain things to the other students and that if she doesn’t understand then they can explain it to her. Angela appreciates the environment at the QLC because the tutors ask her what she thinks the next step is and let her think about how she would proceed, rather than just telling her how to do everything. This is in part due to her desire to be able to put it into words, both for her future teaching and for the proofs in her geometry class.

Check my understanding. Finally, it was revealed that students appreciate when tutors check that they understand what they are working on together. Mackenzie discusses that she likes when tutors check her understanding as they are working through problems. Her ideal tutor is “someone who explains it and then makes sure that I'm following with them and if I'm not quite understanding then they'll ask me what I'm having problems understanding, or like go through it" (Mackenzie, p. 7). She prefers when a tutor takes their time and works through the problem with her, specifically checking to make sure she understands each piece of the process. If she does not understand, she appreciates that the tutor will go through that piece again to clarify and find where her confusion is coming from.

4.3 Research Question 3

To compare the perspectives of students who attend the QLC with those who do not, statistical analyses using the chi-square test and Fisher's Exact test were performed on survey responses to various questions on the Q course survey. The Q course survey is attached as Appendix B. An alpha level of .05 was used to determine significance in each test. Since there were slight differences in the questions posed in the Q course and the QLC surveys, these could not be directly compared in this way. Instead, the responses of students in the Q Course survey who reported visiting the QLC were compared with the responses of students in the Q Course survey who did not report visiting the QLC.

In this section, I will begin by reporting the findings of the statistical comparisons of closed-response questions relating to the students' needs for students who visit the QLC and those who do not. The section will then conclude with a presentation of the findings from the qualitative analysis of the open response questions on the Q course survey.

4.3.1 Students' Needs

As discussed in Section 4.1.2, the responses for closed-response questions nine through 11 and 15-16 correspond to the needs of the students. The results of the analyses of the responses are presented here.

Main Difficulties

Students who responded to the Q course survey were asked "What would you say is the main thing you find difficult about the topics that you have sought help with in this course?" The results are presented in Table 4.3.1.

	Q Courses (N=321)	
Response	**Frequency**	**%**
Applying the topic to specific problems or examples	136	42
Clarity of key ideas related to the topic	72	22
Understanding when a problem requires that topic	30	9
Following procedures	13	4
Understanding prerequisite material	13	4
Other	26	8
I have not had difficulty with any topics	31	10

Table 4.3.1: Overall Main Difficulty in Challenging Topics

A chi-square test of independence was used to examine the relationship between QLC use and students' main difficulties in challenging topics. A statistically significant relationship was found with $\chi^2(6, N = 321) = 16.256$, $p = 0.012$. The contingency table (Table 4.3.2) shows the count, expected values, row percents, and adjusted residuals for each cell. Post hoc analysis using a standardized residual method with adjusted Bernoulli alpha level of .0036 (.05/12) revealed the count of students reporting they had not had any difficulty with any topics was significantly higher than

			Difficulties with Challenging Topics							
			Clarity of key ideas	Following Procedures	Applying the topic	Prerequisite Material	Understanding when a problem needs that topic	Other	None	Total
QLC Use	No QLC	Count	47	6	92	7	22	14	29	217
		Expected Count	48.7	8.8	91.9	8.8	20.3	17.6	21.0	217.0
		% within QLC Use	21.7%	2.8%	42.4%	3.2%	10.1%	6.5%	13%	100%
		Adjusted Residual	-.5	-1.7	.0	-1.1	.7	-1.6	3.2	
	QLC	Count	25	7	44	6	8	12	2	104
		Expected Count	23.3	4.2	44.1	4.2	9.7	8.4	10.0	104.0
		% within QLC Use	24.0%	6.7%	42.3%	5.8%	7.7%	12%	1.9%	100%
		Adjusted Residual	.5	1.7	.0	1.1	-.7	1.6	-3.2	
Total		Count	72	13	136	13	30	26	31	321
		Expected Count	72.0	13.0	136.0	13.0	30.0	26.0	31.0	321.0
		% within QLC Use	22.4%	4.0%	42.4%	4.0%	9.3%	8.1%	9.7%	100%

TABLE 4.3.2: Chi-Square Contingency Table for QLC Use v. Students' Main Difficulties

expected for students who had not attended the QLC ($p < .0036$).

Reasons for Seeking Support

Table 4.3.3 displays the frequencies of the responses that students gave when asked for their main reason for seeking support.

	No QLC Use (N=216)		Used QLC (N=104)		Overall (N=321)	
Response	#	%	#	%	#	%
Exam	78	36	27	26	105	33
Homework	58	27	42	40	100	31
Concepts, Ideas, or Procedures	68	31	30	29	98	31
Other	12	6	5	5	17	5

TABLE 4.3.3: Overall Main Difficulty in Challenging Topics

The overall distribution of responses was fairly evenly split among the three given options. However, when comparing the responses of students who had not visited the

QLC to the responses of students who had, it appears that their may be a relationship between QLC use and reason for seeking support. Specifically, a higher proportion of students who had visited the QLC responded that they sought help for homework whereas a higher proportion of students who had not visited the QLC responded that exam preparation was their main reason. A chi-square test was performed to see if there was any statistically significant relation, and this revealed no significant relationship between QLC use and students' reported reason for seeking support with $\chi^2(3, 320) = 6.551$, $p = .088$. Thus, we cannot conclude that there is any correlation between QLC use and reason for seeking help.

Difficulties with Solving Math Problems

In both surveys, students were asked "When you are seeking help with doing math problems, what is usually the main area you are having difficulty with?" Students were allowed to choose all answers that they felt applied, with six specified options, an additional option for a write-in answer, and the option that they do not seek help with doing problems. The overall results from the Q course responses to this question are shown in Table 4.3.4 along with the responses split into categories of QLC Use and no QLC use.

Notably, over half the students responded that setting up the problem so that they can solve it using math techniques was one of their main difficulties and almost half chose that understanding the steps that they need to take to solve the problem. When comparing those who had visited the QLC with those who had not, no major differences appear to be present except possibly in the responses "other" and "I don't seek help with doing problems". In fact, after treating each option as its own variable

	No QLC Use (N=217)		Used QLC (N=104)		Overall (N=321)	
Response	#	%	#	%	#	%
Setting up the problem so I can solve using math techniques	114	53	57	55	171	53
Understanding the steps I need to take	98	45	45	43	143	45
Understanding what is being asked	57	26	39	38	96	30
Understanding the requirements of the problem	53	24	24	23	88	27
Recalling prior knowledge	61	28	24	23	85	26
Understanding the problem's topic	45	21	24	23	69	21
Other	2	1	4	4	6	2
I don't seek help with doing problems	16	7	1	1	17	5

Table 4.3.4: Areas of Difficulty in Solving Math Problems

and running a chi-square test for each with QLC use as the independent variable, there were no significant relationships found among any of the other options and use of the QLC. The chi-square and corresponding p values for each test are reported in Table 4.3.5. To test the relationship between QLC use and each of the responses "other" and that students do not seek help with doing math problems, a Fisher's Exact test was run due to low expected values in half of the cells. No relationship was found for "other" ($p = .089$), but a statistically significant relationship was found between QLC use and not seeking help with problems ($p = 0.015$).

The four students who had visited the QLC and chose other said that their difficulty arose from not receiving adequate support in class. One of the students who chose other who had not visited the QLC said that everything was difficult, and the other said that exams did not match with example problems.

Variable	$\chi^2(df = 1, N = 321)$	p
Setting up the problem so I can solve using math techniques	.146	.702
Understanding the steps I need to take	.102	.750
Understanding what is being asked	3.228	.072
Understanding the requirements of the problem	3.010	.083
Recalling prior knowledge	.915	.339
Understanding the problem's topic	.228	.633

Table 4.3.5: Chi-Square Values for QLC Use and Areas of Difficulty in Solving Math Problems

Specific Problems

In the final section of the survey, students were asked to describe a specific situation in which they sought help for their mathematics Q course. Two closed-response questions were asked pertaining to these specific situations. Their responses are discussed here.

Main difficulty in the student's specific situation. Students were asked to choose the main thing they found difficult about the topic they described in their open response. The frequencies of responses from the Q course survey are presented in Table 4.3.6.

In the overall responses, the frequencies mirror those from when they were asked this question in general with the exception that here, when describing a specific situation in which they sought help, students reported that following procedures were their main difficulty more frequently than understanding when a problem requires that topic, which is reversed from what was seen in the main difficulties in Table 4.3.1. Upon inspection, it also appears that there may be some relationship between QLC use and responses to this question, specifically when considering the frequencies for

	No QLC Use (N=117)		Used QLC (N=62)		Overall (N=179)	
Response	#	%	#	%	#	%
Applying the topic to specific problems or examples	44	38	15	24	59	33
Clarity of key ideas related to the topic	29	25	20	32	49	27
Following procedures	21	18	12	19	33	18
Understanding when a problem requires that topic	11	9	5	8	16	9
Understanding prerequisite material	2	2	1	2	3	2
Other	10	9	9	15	19	11

Table 4.3.6: Main Difficulty in Students' Specific Situation of Seeking Help

applying the topic, clarity of key ideas, and other. However, a chi-square test found no significant relationship between QLC use and this variable, $\chi^2(5, 179) = 4.526$ ($p = .476$).

Area of difficulty in solving their specific problem. Students were also asked to select all options that they felt answered the question, "If it was a problem that you sought help with, what do you think it was about that problem that made it challenging?" The responses and frequencies are presented in Table 4.3.7.

All but one of the students who chose "other" for the Q course survey listed that what they had learned in class was insufficient. The exception to this was a student who thought that all of the course was easy.

From the frequencies of the responses, it appears that there may be some relationship between QLC use and the students' responses to this question. To test this, each response was treated as its own variable (coded as 0 if the student did not choose that response and 1 if they did) and a chi-square test was run for each response with the

	No QLC Use (N=121)		Used QLC (N=60)		Overall (N=181)	
Response	#	%	#	%	#	%
Lack of practice solving similar problems	50	41	25	42	75	41
Setting up the problem so that I can solve it using math techniques	45	37	28	47	73	40
Understanding what was being asked	29	24	22	37	51	28
Understanding the steps I needed to take to solve the problem	33	27	27	45	60	33
Understanding the requirements of the problem	27	22	21	35	48	27
Recalling prior knowledge	28	23	10	17	38	21
Understanding the problem's topic that we recently covered	17	14	14	23	32	18
Other	3	3	4	2	8	4
I didn't seek help with doing a problem	23	10	1	2	13	7

TABLE 4.3.7: Students' Difficulties Solving their Specific Mathematics Problem

exceptions of "Other" and "I didn't seek help with doing a problem". The chi-square value and significance for each test are reported in Table 4.3.8. For the two responses of "Other" and "I didn't seek help with doing a problem", the expected values of over 20 percent of the cells were less than five, so instead, a Fisher's Exact test was run for each, neither of which were significant ($p = .22$ and $p = .06$ respectively).

In only one case was a significant relationship found. For the response of "Understanding the steps I need to take", the chi-square test revealed a statistically significant relationship between QLC use and this response. The contingency table shows that for students who use the QLC the expected value was 19.5 but the actual count was 27, and the significant chi-square value shows that QLC users were significantly more likely to choose this response than non-QLC users.

Variable	$\chi^2(df = 1, N = 181)$	p
Setting up the problem so I can solve using math techniques	1.497	.221
Understanding the steps I need to take	5.688	.017
Lack of practice solving similar problems	.002	.965
Understanding what is being asked	3.197	.074
Understanding the requirements of the problem	3.313	.069
Recalling prior knowledge	1.013	.314
Understanding the problem's topic	2.436	.119

Table 4.3.8: Chi-Square Values for QLC Use and Areas of Difficulty in Solving Math Problems in their Specific Help-Seeking Situation

4.3.2 Open Response Section

Finally, it is interesting to consider the responses that students gave on the Q course survey when asked about a specific help-seeking situation. Here I present the results from the thematic analysis of the open responses. Their comparison to the QLC survey responses will be discussed in the Discussion of Findings, Chapter 5.

The two open response questions that students were asked to respond to were:

- Choose one of the topics from the previous question. Describe a specific situation when you sought help and when the support you received was successful in helping you to understand that topic. Please include the type of problem, why you sought help, what resource you used, and any other details that will be useful to understand the challenge involved.

- If you sought help from a person or video, what did the person do or say to help you to understand the topic? OR If you sought help from a written source (textbook, written handout, etc.) what did the resource offer that helped you to understand the topic? If you sought help from a different type of resource, how did that resource help you? Be as specific as possible.

The analysis of these responses yielded six main strategies that students described as desirable from a support resource. These are discussed below, in order of most frequently mentioned to least. Following these six strategies, less mentioned strategies are briefly listed. From this analysis, many of the same strategies appeared as did in the analysis of the responses from the QLC survey.

Step-by-step. Thirty six students representing all four courses described that the support they received was successful in part because the resource was able to lay out all the steps for them. One student from MB&E wrote that QLC tutors "walked [the student] through it step by step with guidance". This is a standard way that students described their support whether it was online, at the QLC, with a friend, or with a professor. Students described needing it to be broken down into smaller steps.

More examples. A total of 23 students representing all four courses mentioned that they needed to see more examples of similar problems in order to be able to complete their own problem or topic. One student who had gone online to understand optimization described that they "looked online for some related practice problems and after maybe three of these I was able to correctly frame my problem and solve it". This strategy was described as something that was successful in seeking support online, in the textbook, at the QLC, with a professor, in the class notes, and with friends.

Guidance. Students also mentioned that their support was successful because the resource they used was able to give them guidance on where they had made a mistake in their work and also be there while they were attempting a problem to catch mistakes or help them to figure out the next step. Ten students from each of the courses except CB&E wrote about this method. For one student working on a series problem in calculus 2 at the QLC, this guidance was helpful because they had a lack of confidence in their knowledge. They said, “In most cases I did know what was going on I just wasn't confident enough in my calculations that I thought I had messed up”. However, because they were working with a tutor they had the assurance that someone more knowledgable was approving their work.

Simplify. Nine students representing all four courses suggested that the resource's ability to simplify the concept was one aspect that helped them to understand the topic or problem they were seeking help with. While talking to a friend about derivatives, a student from CB&E gained clarity because “They were able to explain the topic in simpler terms that were easier to understand.? Students reported increased understanding when the resource simplified the language used or showed a simpler example first.

Why. Here, students are seeking more than just a step-by-step explanation and want to understand why each step works as well. Nine students wrote about this and the only course that had no students report this was CB&E. A student from Calculus 2 who was struggling to understand Taylor polynomials said that their teaching assistant was able to “explain why each step helped to solve the problem”. This helped the student to understand the procedure and the logic behind it.

Visuals. Six students, 2 from calculus 1, 3 from calculus 2, and 1 from CB&E, said that the resource they used was successful because of their use of visuals. For a student in calculus 2 who was working on a mixing problem using differential equations, the tutor at the QLC was able to explain the concept by drawing a picture to show what was happening and explain how the equation used to solve the problem related to the information that was given. This visual aid helped the student to grasp the concepts behind the procedure.

Insights. Four students also mentioned that the resource they used was able to share insights that helped them to be successful. For example, a student in Calculus 2 said that their TA and professor were able to add material that they might not have thought to ask about. Similarly, a calculus 1 student wrote about their TA being able to tell them about specific exceptions to the rules. These are things that the students might not have picked up on or thought of on their own that the resource was able to give to them.

Other strategies. Some other strategies surfaced that were only mentioned by a few students but still are worth noting for the purposes of our study.

- Three students mentioned that they appreciated when a resource would begin with general examples to show how things work then work back to the specific example being asked about.

- Three students mentioned that they appreciated when the resource related the material to something that they already know about.

- Two students mentioned that they needed the one-on-one support.

- Two mentioned that they needed a resource that could slow down and work through the material at a lesser pace than was used in class.

- One student also mentioned appreciating being able to figure out the answer on their own rather than being told the answer.

4.4 Chapter Summary

This chapter has discussed the findings from the various analyses in this study.

In response to Research Question 1, the findings related to the mathematical needs of the students who visit a QLC were explored through the perspectives of both tutors and students. The analysis of data from tutor observations and interviews revealed that tutors believe students have difficulties with prerequisite material, current material, moving from concepts to problem solving, and learning from class. The students' perspective was gained through the analysis of survey data and interviews. Surveys revealed that half the QLC users believed their main difficulty in mathematical topics was applying the topic to specific problems or examples and that the majority of QLC users use the QLC with main purpose of completing their homework. Over half the students also felt that setting up the problem to be solved and understanding the steps to solve a problem were main difficulties when solving mathematics problems. From the student interviews, we learned that students have both tangible needs and intangible difficulties, and that difficulties with content often involved both struggling to understand the question and applying the topic.

Research Question 2 explored the successful strategies used by the QLC tutors. The themes that emerged from analysis of the tutor interviews were the students' predetermined goals for the session, the students' challenges, the tutors' view of the nature of mathematics, the tutors' identity, and the strategies they choose to employ. The students' perspectives were gained through both survey responses and interviews. Through the analysis of the survey data, four main strategies emerged including step-by-step instructions, giving more examples, answering why steps were used, and using visuals. Through the interview data, three themes emerged including logistics, support identity, and strategies.

Finally, Research Question 3 compared the responses of students in Q courses who had visited the QLC with those who had not. Significant relationships between the use of the QLC and the students' responses were found in only three cases. A significant relationship was found between the use of the QLC and students choosing that they had not had difficulty with any topics as well as between use of the QLC and students reporting that they had not sought help with doing mathematics problems. In addition, when discussing a specific situation in which the student had sought help a significant relationship was found between the student's use of the QLC and choosing the response "understanding the steps I need to take" when asked what their difficulty had been with solving their specific mathematics problem.

Chapter 5

Discussion of Findings

The purpose of this dissertation was to investigate the mathematical needs of students enrolled in quantitative courses and the successful support strategies used by the tutors at the QLC. In particular, I investigated the perceptions of students enrolled in mathematics quantitative courses and of tutors at a QLC about these two topics.

This design was guided by the following research questions:

1. What are the mathematical needs of the students who visit the QLC

   in the tutors' view and

   in the students' view?

2. What explanations or tutor strategies help the students to understand the mathematical topics they are seeking help with

   in the tutors' view and

   in the students' view?

3. How do the students' views about questions 1b and 2b compare to the views of students enrolled in mathematics Q Courses who do not visit the Q Center?

In this chapter, we will discuss the findings from the analysis, which were presented in Chapter 4. The findings will be discussed in order of research question. Thus, the students' mathematical needs will be discussed first followed by the tutoring strategies that are successful in supporting students. The chapter will conclude with the discussion of the comparisons between the perceptions of students who had visited the QLC and those who had not.

5.1 Research Question 1: Students' Mathematical Needs

The mathematical needs of the students were revealed based on observations of tutoring sessions, interviews with tutors and students, and surveys of students. The findings related to the first research question will be discussed first from the tutors' perspective, then the students' perspective, and finally the two perspectives will be compared.

5.1.1 The Tutors' Perspective

The analysis of observations and interviews revealed the tutors' perspective of their students' mathematical needs. In particular, four areas of need arose: current material, pre-requisite material, moving from content to problem solving, and learning from class.

As was reported in the findings, tutors believed that students needed support in some common topics within their current courses. However, the analysis also revealed that tutors believe that some of the students' difficulties in their current material stems from difficulties with prerequisite material. As new topics arise, the background knowledge and ability to use previously learned skills becomes necessary. The focus within a course is on the new material and instructors may not have time to review previous topics. This sentiment agreed with the findings of a study by Agustin and Agustin (2009), in which the students in a calculus course lost more points on exams due to errors having to do with prerequisite material than from new material. Even problems within upper-level mathematics courses require that the students have a fundamental understanding of mathematical topics, and tutors gave examples of times when they had experienced working with students whose prior knowledge was not sufficient to fully grasp what they were doing within a problem or why they were using a certain procedure.

The tutors' discussion of algebraically manipulating expressions, functions, and trigonometry points to students' challenges with foundational concepts. We also gain specific examples of where these challenges with prerequisite material may be particularly harmful for students. In fact, functions arose repeatedly in the transcripts of tutor interviews and in conversations about various levels of mathematics courses, from precalculus to differential equations. The conceptual difficulties that students have with understanding functions is well-documented in the literature (Dubinsky & Wilson, 2013) and various aspects are suggested as challenging for students, one of which is functional notation. This particular need also emerged from our study. For example, Trace mentions that the notation for the trigonometric functions is misunderstood by students, specifically when trying to simplify expressions. In addition, Shaniya speaks of students not understanding how to plug values into a function, which shows a disconnect with the concept of a function being a representation of how a quantity depends on another quantity. This also relates to a difficulty working with variables, which agrees with the findings of Stewart and Reeder (2016).

Students without a firm grasp of functions and their related concepts will struggle with ideas later in their mathematical careers. Calculus focuses on limits, differentiation, and integration of functions. Without the concept of a function, these ideas lose meaning as each is intended to give information about a given function. Elias gave an example in which he particularly focuses on the students' misunderstanding of a function when they neglect to check the domain when integrating. However, this also points to the neglect of this student to conceptualize the problem beyond thinking of it as a strict computation. Without a firm grasp of the object they are working with, the computation loses its meaning and becomes simply a procedure to follow.

This finding connects to the third theme that emerged from analysis of the observations and tutor interviews. The tutors often spoke of situations in which the student they were working with had difficulty moving from theoretically understanding a concept to solving problems that involved that concept. The students may feel that they understand the concept but when presented with a problem they struggle to identify how to approach it. Tutors seem to believe that for some students this stems from the students' need to have a laid out process for each type of problem, rather than understanding the logic behind those processes. Wayne explains that by repeating problems over and over again you gain practice, but the logical process and understanding why things make sense are what will make a student remember and give them the ability to distinguish different methods for the problems they encounter.

Finally, the findings reveal that tutors see their students struggling to learn from class. A variety of explanations can be given for this phenomenon, but the three that were most evident in the tutors' view were the students' difficulty paying attention during a lecture, the students' need for extra time to spend on examples and practicing using the concept, and the size of classes. In fact, at many institutions of higher education, and especially at large universities, mathematics classes are often offered in large lecture settings. At many IHEs these lecture sections are unavoidable due to the large number of students and insufficient teaching staff or scheduling difficulties. The findings of my study reveal the tutors' perception that a lack of interaction with the instructor is one aspect of the students' courses that is a challenge for the students. To combat the lack of interaction, suggestions have been made to use technology to engage students, including electronic clickers (Mayer et al., 2009) and wireless laptops to promote active learning (Barak, Lipson, & Lerman, 2014). In addition to large lectures, many IHEs are beginning to offer courses in an online format which can make interacting with the professor even more difficult.

Since the challenges faced by students in large lectures and online courses often stem from the lack of interaction with their instructor, students may seek out alternative resources that can provide this for them. The findings suggest that this represents a main need of the students with whom the tutors work. In the tutors' view, students are visiting the QLC for one-on-one support and extra space and time to work through problems and ask questions, two things that are rare in a large lecture or online course. Thus, if large lectures and online courses are an inevitability at a given institution, then the findings suggest that a QLC would provide students with the opportunity for the interactions they may be lacking in the classroom.

Implications that arise from this discussion extend beyond QLCs. As educators, these needs should be in the forefront of our minds as we plan our teaching and reflect on what we can do to support our students.

5.1.2 The Students' Perspective

The students' perspective on mathematical needs was gained primarily through analysis of data collected through surveys and interviews. The findings revealed three main areas of need: intangible difficulties, tangible needs, and content needs.

In terms of intangible difficulties, the transition to higher education and a disconnect with a professor challenged students. These two areas can be closely related for some students. For example, Whitney mentioned that she was more comfortable with her current mathematics professor than the professor she had during her first semester because the current professor was more like the teachers she had had in high school. Many studies refer to students' experiences moving from high school to IHEs and the influence that math tutoring centers have. Part of the transition often includes adjusting to different instruction. Solomon, Croft, and Lawson (2010) found that almost half the participants in their study believed that mathematics teaching at the university level was not as good as at the high school level and interviews revealed that becoming independent learners was a struggle for participants but that the learning center provided a space where they could learn to do so.

Collins and Sims (2006) give several reasons why students may need to seek help in the transition from high school to college, including the adjustment to different expectations and environments, being underprepared for the courses you are taking, and being what Collins and Sims call "independent high achievers" (p.). Independent high achievers refers to students who had done well in high school and who are unaccustomed to needing help. In this dissertation, the findings align with this result. In fact, within two of my student interviews, the participants expressed that they had always done well in high school mathematics and were surprised by their difficulties in college mathematics.

Often the aspects of a course that help students to realize they need to seek support are those that have tangible results, there are grades or feedback associated with them. From the findings of the survey and the interviews, it appears that homework is a tangible aspect of mathematics Q courses that students who attend the QLC are often seeking help with. Interviews revealed that for many classes there are 4-5 homework assignments due each week, so this is perhaps not surprising. Additionally, for many students homework consisted of both online and written work, so for the online homework students wanted support getting the correct final answer and on worksheets students wanted to ensure they had done the supporting work correctly as well. Less students suggested that they sought help when studying for exams or with understanding concepts. However, from my conversations with the students in interviews it became clear that while the impetus to seek help may have been primarily for homework support, the students were hoping to also gain a stronger grasp of the concepts and ideas required for completing the homework.

In addition to these tangible aspects of the course, there are findings that speak to the deeper question of what in particular students were struggling with in their homework and with the material. We see in the survey responses that half the students who took the QLC survey believed that applying the topic to specific problems or examples was their main difficulty in challenging topics and this was repeated in the interview analysis. Two main areas of difficulty that emerged from the interview data were understanding the questions that students were asked and actually applying the topic to specific questions.

Again, these implications extend beyond QLCs. While it is important for tutors to be prepared to work with students with both intangible and tangible needs, instructors should also keep these needs in mind, particularly when teaching freshman level courses. Students may be struggling with aspects of their transition to higher education that they may not be aware of.

5.1.3 Comparing the Tutors' and Students' Perspectives

So far, this section has discussed students' mathematical needs through both the perspectives of tutors and the perspectives of students. This allows us the opportunity to compare the findings from each lens to seek out similarities and contrasts between the two perspectives. As was mentioned in the literature review, our search of the literature revealed no studies where the perspectives about students' need and successful strategies of students and tutors at QLCs were compared. Thus, we hope to contribute this exploration to the scholarly community.

One interesting contrast that emerges from the analysis of tutors' and students' perspectives is the disagreement between tutors and students about students' challenges with prerequisite material. For the tutors, this was one of the main needs that they saw in students. However, in interviews with students it was revealed that the participants did not agree. Similarly, in the QLC survey only six percent of students responded that their main difficulty was understanding prerequisite material. When allowed to pick more than one option for why they have trouble solving mathematics problems there was a larger number of participants who chose recalling prior knowledge, but still only 25% chose that option. This mirrors the findings in a similar survey question posed to students in a study by Perkin, Pell, and Croft (2007), in which basic manipulation was given as an option for what main areas students experience mathematical difficulties. In their study, basic manipulation was the option chosen most often by learning center staff and the option chosen least often by students.

This discrepancy between tutors' perception and students' perception raises a question of which perception is accurate. In fact, there are a few possible explanations for this discrepancy. One explanation could be that students do not realize that they struggle with prerequisite material. This is possible, since it is common to not know what you do not know. Another explanation could be that the students do not believe that their challenges with prerequisite material play a large role in their difficulties with new material, even if they do know that they are lacking in that area. If this is true, then how can students be encouraged to seek support in more foundational areas when they only want to focus on the new material? A third explanation could be that the tutors' observations are biased towards a small portion of students. It is possible that the students that tutors remember most vividly are those who have very foundational needs.

Another comparison can be made between the tutors' view that students struggle with moving from concepts to problem solving, the students' theme of content needs and the results from the quantitative data on the QLC survey. In both the tutors' and the students' view there is a need among students for support to apply topics to specific problems and to understand what questions are asking. However, there is a slight distinction between the tutors' perception and the students' perception. The tutors seem to see these skills as part of creative problem solving whereas the students tended to refer to this challenge in terms of procedural skills or methods. For example, Wayne spoke of students struggling with problems when they were expected to read the problem and formulate the mathematics and described his view that this is a result of students' lack of fundamental understanding of the topic. However, when students brought up not knowing how to apply a topic, they primarily focused on not having seen enough of that type of example so they did not have the procedure to follow.

Related to this, topics that include applications of concepts seemed to be mentioned frequently by both tutors and students as challenging topics. Two of these topics included optimization and related rates, both of which were mentioned in the surveys and the interviews. The difficult aspects of these topics seemed to be mainly procedural in both the tutors' and the students' perspectives, however tutor interviews also revealed an underlying conceptual difficulty in students' attempts to solve related rates problems. Students' difficulties with application topics agrees with the tutors' and students' perceptions that students have difficulty moving from concepts to problem-solving. The other topics mentioned by tutors and students as challenging areas in their Q courses were very much in alignment, including difficulties with limits, differentiation, integration, and series and sequences.

The other themes that emerged for both the tutors' and the students' perspectives were very closely aligned. The tutors' focus on students' difficulties learning from class relates to the students' intangible needs, both in the transition to college-level classes and the disconnect with the professor. While tutors did not explicitly discuss a disconnect between students and their professors, they did recognize that students were often visiting the QLC to gain the one-on-one interaction that they either felt were missing in their courses or that they could not gain from their professors due to some form of intimidation or discomfort. The tutors' recognition of this difficulty influences how they see their own role as a tutor, which will be discussed further in Research Question 2.

In addition, the tutors' focus on the students' desire for help on their online homework matches with the main reason that students reported visiting the QLC on the survey as well as with the students' tangible needs that were revealed in the analysis of student interviews. In seeking to support students with this need, tutors carefully avoid giving answers to homework problems. This will be further discussed in Research Question 2.

5.2 Research Question 2: Successful Strategies

The tutors' and students' perspectives of successful tutoring strategies were also gained through observations of tutoring sessions, interviews with tutors and students, and surveys of students. This section will mirror the organization of the previous section, with findings related to the tutors' perspective of successful support strategies presented first, followed by the findings related to the students' perspective, and concluding with a comparison of the two.

5.2.1 The Tutors' Perspective

The five themes that emerged from the analysis of observations and interviews with tutors each influenced the tutors' view of the potential success of their tutoring. These five themes included the students' predetermined goals for the session, the students' mathematical challenges, the tutors' view of the nature of mathematics, the tutors' identities as peer tutors, and the strategies that they chose to employ. An interesting aspect of these themes is that they are interactive. To discuss these themes and their interactions, I will begin by discussing the interactions among three pairs of themes. Within these pairings I will discuss the findings from the individual themes as well as the interactions between the themes. The discussion of the tutors' perspective will conclude with the strategies that emerged.

Predetermined Goals and Mathematical Challenges

The predetermined goals of a student refers to the goals that a student has for a particular tutoring session. The findings report that the tutors believe a student's goal to most often be either to attain support on homework for the purpose of understanding concepts or to get a good grade by getting to the answers on their homework. Researchers are interested in understandings students' approaches to homework and have sought to understand and provide solutions for cheating (Mayer et al., 2009; Pavlin-Bernardić, Rovan, & Pavlović, 2017; Trenholm, 2007). The tutors' perception that many students are seeking just the answer to homework problems could imply that students are hoping to use the tutors as modes of cheating, but the fact that they are attending a QLC as opposed to simply searching for the answer online shows at least some desire for more understanding.

The mathematical challenges of students as perceived by tutors include prerequisite material, current material, moving from concepts to problem solving, and learning from lecture. These have been discussed in Research Question 1. As related to Research Question 2, these challenges play a role in the strategies that tutors choose to use.

While sometimes the tutors' perception of a particular student's goals and challenges will agree, there are other instances in which students will have a goal that does not correspond with their challenge. For example, tutors may notice that a student is struggling with the algebraic manipulation within a differentiation problem.

However, if the student's primary goal is to compute the derivative then they may not be receptive to reviewing algebraic manipulation. Thus, the tutors must maneuver this situation so that they are successful in not only accomplishing the student's goal but also providing the necessary support in the actual challenge the student is facing. Thus, tutors need to be prepared to provide support for students who may have a different goal for the session than would be most beneficial.

This was an interaction that was present in many of the conversations that I had with tutors. As was reported in the findings, Lucas spoke of situations where students came to the QLC for answers to their homework questions and he then needed to find a way to help them without giving them the answers. To do this, he needed to get the students on board with his plan and this required some reflection on his part to appropriately handle the situation.

Nature of Mathematics and Mathematical Challenges

The tutors viewed mathematics as a creative endeavor that requires intuition. In the tutors' view, this intuition often came from a familiarity with prior concepts and flexibility with applying those concepts in different situations. One of the three principles of learning espoused in *How Students Learn: History, Mathematics, and Science in the Classroom* (National Research Council, 2005) is that students need to be engaged with their prior understandings of a concept in order to fully grasp it. In the current study, the tutors' view of intuition being necessary for success in mathematics indirectly points to this principle, particularly in how the tutors spoke about their students' needs. An example of this is Seth's statement that if a student doesn't fully understand or recall the logarithm properties and if "they don't make intuitive sense ... maybe they'll be able to use them on the exam when they realize, oh this is a log problem, but they wouldn't naturally see to use them in doing other math" (p. 3).

An interaction occurs between the tutors' view of the nature of mathematics and their view of the mathematical challenges that the students are facing. An aspect of this interaction involves the tutors' belief that mathematics is creative and their view that their students' do not always appreciate or fully realize this aspect of mathematics. An example of this interaction at play is the tutors' belief that a student's difficulty with applying topics and understanding questions stems from their inability to fully grasp the concept in a way that allows them to creatively apply it to new problems. The students are lacking intuition about the topic and are unable to engage their knowledge about it within a new problem. Thus, as in the previous section, the tutors' views contradict the popular view among the students that their difficulty stems from not knowing the procedure for the problem.

Tutor Identity and Mathematical Challenges

The tutors' beliefs about their own identities leads them to desire to be relatable to their students, to minimize the power dynamic between themselves and the students, and to avoid giving answers. The first two goals relate directly to the literature on peer tutoring. One of the main benefits to peer tutoring is that students may feel less pressure and able to be more open about their difficulties because they are working with a tutor who is a fellow student (Topping, 1996). The final goal of working to avoid giving the answers to their students is both to avoid aiding in student cheating and also to provide support that is beneficial to their students in the long run. Tutors recognize that just receiving answers to homework problems will not benefit the student on exams or future assignments. This also points to the tutors' recognition that although they may want to be relatable to students they need to remain professional and not give in to pressure from students.

The interaction between the mathematical challenges that tutors believe the students are facing and their own beliefs about their identity as a peer tutor involves the students' challenge with learning from class. This includes a difficulty with the teaching style as well as a need for more time to practice. In addition to this, tutors recognize that students may have difficulty with approaching their instructor due to factors such as large class size or intimidation. Thus, tutors view their identity as someone who the students can feel comfortable approaching with questions and for further explanations. This directly influences their view that they should be relatable and act as peers to the students they are helping.

Strategies

Finally, all of the previous themes influence the strategies that tutors choose to employ. Each of the seven strategies are discussed below.

Make interpersonal connections. Making interpersonal connections with students is tightly related to the tutors' identity as someone who should be relatable to the students. However, as mentioned in the findings there is a distinction here. Being relatable is about the tutor attempting to have their student see them as a person, more specifically as their peer who has experienced similar challenges and who they can find commonalities with. In contrast, making interpersonal connections involves the tutor getting to know the student and their interests. The tutor is attempting to now know their student as a person, beyond the student's role as a tutee who the tutor is providing support to. In this way, tutors will be able to make connections to what the students know more effectively.

Make connections to what the students know. By getting to know their students, tutors felt they would be better equipped to make connections between what the student was currently learning and what they already knew. For instance, Wayne mentioned getting to know his students so that he could relate the mathematics to the sports they were interested in or their major. In this way, tutors hope to make the content a bit more tangible. This relates closely to the first principle of student learning in *How Students Learn: History, Mathematics, and Science in the Classroom* (National Research Council, 2005). By engaging the students with their prior knowledge and their prior conceptions of topics, the tutors are providing the students a chance to integrate what they already know into their new understanding.

Engage students. Tutors also choose strategies that allow student engagement throughout the process. Tutors attain this by asking the students to complete parts of the problem on their own, explain concepts to each other, or walk them through a problem they have already completed. By engaging the students, tutors hope that students will be able to remain focused on the task at hand. The techniques tutors use to engage students also serve as ways for tutors to avoid giving answers to homework problems. Tutors seem to be using the same ideas as those that instructors use to justify pedagogies that differ from a traditional lecture format. Research has shown that pedagogies that are more student-centered can have a positive effect on student outcomes. For example, in a meta-analysis of 225 studies, Freeman et al. (2014) found that significant improvements in exam scores were found for students taught in an active learning section as opposed to a traditional lecture, and that failure rates were lower in active learning sections than lectures. Thus, there is evidence that these active techniques that tutors are using are truly beneficial to the students.

Write things down and create visuals. Tutors felt that it was useful to write out clearly what they were doing and to create visual representations when appropriate. Interestingly, tutors had slightly different ideas about what writing things down would look like. While they agree that writing things out clearly for students is useful, the differences emerge in the amount that the tutors are writing and the types of information that they are writing for the students. Shaniya mentioned writing out the steps to solve a problem clearly on a piece of blank paper and working on that piece of paper for the entirety of the session so that the student would have something to take with them as a supplemental resource. By writing out the steps clearly, Shaniya believed it would help the student when approaching similar problems. Similarly, Lucas would write out steps on a piece of paper for students. However in Lucas' approach he would be the only one writing things down and the students would be telling him what he should write. Lucas felt that this allowed the students to focus on the content of what they were doing rather than worrying about how to write something down. The difference here was that Lucas stressed that students were not writing anything down themselves and that this was *part of his strategy*. For Shaniya, her strategy included the supplemental notes that she would give to the student, but she still expected the student to work through problems on their own and write things down for themselves as well.

In both Lucas' and Shaniya's strategies, the concept of writing things down for the students is the main feature of their technique. Both expressed that students benefited from having written work rather than just talking about the problem. A potential worry in Lucas' strategy is that students are not getting the practice of writing out the mathematics in proper notation themselves. However, this may be a useful strategy to use for one or two examples or until the student feels more comfortable with the material and their tutor. In particular, if a student is taking an online class and has limited interaction with their instructor then they may actually need further examples of proper notation. This technique could provide that for them while still engaging the student in the content of the problem.

The visual representation aspect of this strategy was also very important to tutors. During the observations I saw many tutors using pictures, both drawn and described, to help their students visualize what was happening in the problem. This often connected back to making connections with material that they already knew about, such as relating the radius of convergence to the radius of a circle. While the tutor did not necessarily need to draw a picture of a circle, they described the concept in a way that allowed the students to visualize what they were talking about.

Avoid overload. The fifth strategy was to avoid overloading the students with excessive amounts of new knowledge. Tutors recognized that students often feel overwhelmed by the amount of material covered in their courses and that they need the tutors to slow it down for them and explain things in smaller pieces. Additionally, tutors were aware that they needed to avoid introducing new concepts in the middle of a student's thought process.

Check understanding. Ensuring that students had a firm grasp of what they were working on was very important to the tutors. Whether or not the student got the correct answer on a homework problem was less important to the tutors than knowing that the student understood what they had been doing to find their answer and understood how it related to the topics they were learning about. For the tutors, checking the students' understanding both during and at the end of a problem was a crucial element of their work. In *How Students Learn: History, Mathematics, and Science in the Classroom* (National Research Council, 2005), the third principle is that students need to engage at a metacognitive level and that they need to learn to reflect and assess their own learning. Shaniya's explanation of her strategy for checking understanding particularly lines up with this idea. At the end of a problem, she and the student go back through their process and talk about what they did, allowing the student to ask any questions that might come up. After this, she asks the students to look it over again while she works with other students and says that she will come back to them to answer any questions that might come up. This process begins to train the student to check their own understanding and to evaluate themselves and their work.

Train in good study habits. Finally, tutors recognized their opportunity to help students build study habits that would serve them not only in their current class, but in future classes as well. Tutors aimed to portray how to appropriately use a textbook or course notes, or how to find additional resources online or on campus. The tutors were very aware of some students' hesitancy to seek help and wanted to help the students see that it was beneficial and they had multiple avenues of support available to them. As was discussed as part of the students' mathematical needs in Research Question 1, many students struggle to adjust during the transition to an IHE and one aspect of this is that students need to develop new approaches to studying and find the support that works for them.

5.2.2 The Students' Perspective

Turning to the students' perspective of effective tutoring strategies, three main themes emerged from the interview data. These themes were logistics, support identity, and strategies. For the purposes of the discussion of the findings, we will include the strategies that emerged from the analysis of the survey responses within the interview theme of strategies, since together they form the students' perspective.

Logistics

The logistics of the QLC included the interaction that students were able to have with the tutor and the convenience of attending the QLC. An important aspect to the students was the ability to interact with the tutors in both one-on-one and group situations. These findings align with studies by Solomon et al., (2010), who found that working in groups was seen as a benefit to students at a QLC where the physical space of the center was able to make students feel like they were working in a community as opposed to isolation. Moreover, our findings extend those of Ariza et al., (2011), who conducted a study involving peer-led study sessions in which collaborative activities were found to be beneficial to the students to build their confidence and their knowledge. Thus, perhaps it would be beneficial for tutors to take more of an active approach in encouraging students from the same class to work together.

The convenience of attending the QLC as opposed to other resources was also evident in student responses. Since a QLC can be open for hours each day as opposed to a professor's office hours only being a few hours a week, for many students the QLC is simply the convenient choice.

Support Identity

Analysis also revealed that the identity of the tutors as peer tutors was a factor in why the students thought that the tutoring was successful. This theme is tightly related to the theme of tutor identity that emerged from analysis of tutor interviews. Since the tutors are the students' peers and many have taken the classes in which the students are currently enrolled, students seem to view the tutors as resources that they can approach without intimidation, that the tutors will understand what they need, and that the tutors will have insights about the classes and the content. This agrees with the general theory behind peer tutoring and agrees with findings across the literature about why peer tutoring is effective (Topping, 1996). This also mirrored the results of Benoit's dissertation (2012) in which the students shared that they were able to gain insights into even their professor's teaching style and key gestures and phrases to pay attention to in class.

Strategies

Finally, analysis of the interviews and surveys revealed various strategies that the tutors employ and that students think are beneficial. Two of these strategies, using visuals and checking understanding, were also revealed in the tutors' perspective. Since these have already been discussed from the tutors' point of view and in relation to the literature, we will not discuss them further here. However, any notable contrasts will be discussed in the next section which will compare the tutors' and students' perspectives. The remaining five strategies included to avoid giving the answer, give more examples, let me explain, work step-by-step, and to explain the logic or the "why" behind concepts and procedures.

Don't give the answer and let me explain. The students who were interviewed were very clear that they did not want the tutors to reveal the answers to them. In fact, they felt that while getting the answer may benefit them in the short-term it would not be useful for them long-term. They also appreciated tutors who would let them explain their thinking. Analysis revealed that students believed this helped them to check their understanding and to learn the content more rigorously. This agrees with the literature that being able to teach others or explain something to others helps you to learn the material. For example, Evans, Flower, and Holton (2001) found that students who were expected to teach new material to a group of their peers felt that they had learned the topic better than they would have otherwise. This relates to the theme of logistics and the ability to work with others at the QLC.

More examples. Students also appreciated that tutors gave them more examples to work through. Many students expressed that they had not seen enough examples or had enough practice with different types of problems in class before being asked to complete the work on their own. This is not surprising and is a common desire among students in various levels of mathematics courses. However, instructors have limited time in the classroom and also must balance giving examples and trying to help students achieve the independence needed to problem-solve and apply concepts in various ways.

Step-by-step and why. Within the problems and extra examples that tutors were working through, students desired step-by-step instruction. While this primarily points to a procedural outlook among students, where students want to understand how to do a problem and to have a process to apply to various situations, there is evidence from the analysis that students want more from this than pure procedures. The students also want to understand *why* the steps work. This is interesting in that the tutors' tendency was to speak of students as wanting the answer, whereas students revealed that they were hoping for more than this. This will be discussed more in the next section.

5.2.3 Comparing the Tutors' and Students' Perspectives

In general, the tutors' and students' perspectives of successful tutoring strategies seem very closely aligned, however an interesting contrast exists between the tutors' and students' perspectives of the students' goals for their tutoring sessions. All the tutors except Drake gave indication that they believed students came to the QLC to get the answer to their homework questions and that the students primarily wanted the answer and were not as concerned with the conceptual understanding that got them there. However, the four students who were interviewed explicitly stated that they were not interested in being given the answer. These statements were unprompted in the interviews and came up naturally in their discussion of their experiences leading to some confidence that they were sincere. There are limitations to the conclusions that can be drawn from only four interviews, however these four students at least show that there are exceptions to what the tutors had observed. An implication of this contrast could be that tutors need to be careful of making assumptions as to their students' goals.

One strategy that was revealed by students as used by tutors but that did not emerge as a code through the analysis of the tutors' interview transcripts was breaking down the problems into step-by-step instructions. This was brought up in many of the student surveys as a technique that was appreciated by the students. This also mirrors the results of Carroll and Gill (2012) who found that students felt the explanations at their QLC were helpful because the tutors slowed down the material and took things step-by-step. This relates to what was discussed in the previous section about the contrast between how tutors and students view students' difficulties with moving from concepts to problem solving. It would seem that students have a procedural mindset both about why they struggle with concepts and about what tutoring strategies are the most beneficial for them.

The remainder of the strategies were very similar across both perspectives. One major similarity was that both the tutors and the students spoke about the identity of tutors as peers to the students. For the tutors, this was an important aspect in their minds as it allowed them to relate and sometimes commiserate with the students about their courses. For the students, this allowed them to feel more comfortable in the QLC environment and also gave them assurance that they were receiving support that would be understandable to them since it was from a fellow student. This agrees with Topping's (1996) literature review on peer tutoring, in which he found that peer tutoring resulted in lower anxiety for students and that this then resulted in more openness from the students. Additionally, within this dissertation the insights that tutors could give as peers was touted as a benefit in both tutor and student interviews, again pointing to the value placed on the tutors being peers by both the tutors and the students.

We also see that tutors and students both believe that creating visuals is beneficial for the students. This came up in many of the survey responses and in interviews with both tutors and students. A heavily used strategy in all seven observations, tutors believe that by writing things down for the students they are able to give the students something to focus on in the often busy QLC. The tutors also try to create visuals for the students when possible, in an attempt to connect the mathematical formulas to something tangible. Students often spoke of this as being one of the main factors in a successful tutoring session.

Finally, both students and tutors felt that checking for understanding was a vital aspect of a successful tutoring session. Rather than helping students through their homework and being satisfied with a completed assignment, tutors also tried to ensure that students had understood the methods they had used and the concepts behind these methods. As was discussed in the findings, many of the tutors would either briefly re-explain the procedure they had used or have the student explain it to them. The tutors also frequently created example problems to target specific concepts within the work that students were doing. This allowed the tutors to gauge the level of a student's understanding and to find the areas that needed further review and practice. Students were also appreciative of this technique.

5.3 QLC Use and its Relationship with Students' Perspectives

The quantitative analysis of closed-response questions on the Q course survey revealed that for the majority of questions there was no relationship between QLC use and student responses. In fact, when questions on the survey were asked generally about the students' experiences in mathematics Q courses, QLC use was only found to have significant relationships with students reporting that they had not had difficulty with any topics and students reporting they had not sought help with doing mathematics problems. In both cases, students who had visited the QLC were less likely to report the option. Since the QLC is intended to provide support to students who need help with their mathematics Q courses, it would be surprising if we had not received this result since one expects that students attending the QLC would have a topic that they were struggling with.

When students were asked to describe a specific situation in which they sought help, the only significant relationship was found between QLC use and students' reporting that a main difficulty they had with solving the problem they were describing was understanding the steps they needed to take. This suggests that in the scenarios they described, students who had used the QLC were more likely to desire guidance in completing a problem. In all other cases it could not be concluded that there was any relationship between a chosen response and QLC use.

These results give more confidence that the results from this study will be of interest to educators and administrators even outside of QLCs. This study largely takes place within the context of the QLC, however the similarity between responses of QLC users and those who had not used the QLC indicate that the study's findings about students' needs may apply beyond QLCs and could be used to improve practice in general.

In addition to the quantitative data, we can also look at the responses from both the QLC users and the non-QLC users when describing a specific situation in which they sought help. The analysis of the responses given by participants in the Q course survey revealed seven strategies that the students appreciated that had been used by the various resources they had accessed. The seven strategies were explaining step-by-step, giving more examples, guidance as they completed their work, simplifying the topic, explaining why something was true or worked, using visuals in explanations, and giving insights into the class or topic. When we compare this to the strategies described by QLC users in the QLC survey we see that the responses are very similar. The QLC survey did not reveal the strategies of guidance or insights but otherwise agreed with the responses from the Q course participants. There were no responses in either survey that contradicted what the participants were saying in the other.

The additional topic of insights match what was seen in the analysis of tutor and student interviews. For example, as peer tutors who have experience with the content they are helping the students with, the tutors often try to share their own insights about the material. This was specifically seen in Drake's comment about sharing effective procedures that he has found with his students. Thus, as with the quantitative data, the qualitative comparisons also suggest that understanding the needs of the students who visit the QLC and the strategies that they find beneficial may apply beyond QLCs and to students who do not use this resource.

5.4 Chapter Summary

In this chapter I have discussed the findings of the dissertation. This study makes a unique contribution to the literature through the comparison of the tutors' and the students' perspectives on the students' needs and successful tutoring strategies. Thus, this chapter has discussed not only the separate perspectives of tutors and students but also how these two perspectives compare.

We see that overall, tutors and students agree about where students have difficulties, however two contrasts do emerge. First, tutors believe that students' difficulties with prerequisite material hinders the students' success whereas students seem to see their difficulties with prerequisite material as less important. Second, tutors and students seem to agree that students struggle with moving from understanding concepts to solving problems, however tutors speak about this in terms of creative problem solving whereas students relate this to following procedures.

We also see that tutors and students mainly agree on why tutoring is successful, however they disagree on whether or not students are attending the QLC just to get homework answers. Finally, the comparison of the perspectives of students who visit the QLC and those who do not was discussed. There are no major differences found.

Chapter 6

Concluding Remarks and Future Research Directions

The purpose of this dissertation was to investigate the mathematical needs of students enrolled in quantitative courses and the successful support strategies used by the tutors at the QLC. With this in mind, I now conclude with a brief discussion of the conclusions and implications that can be drawn from the findings as well as suggestions for future research directions.

6.1 Concluding Remarks

The findings from this dissertation are relevant not only to those who directly work with or in QLCs, but also to educators and administrators in higher education more broadly. Through these findings, insights are gained about the needs of our undergraduate students as well as ways that they can be successfully supported in their mathematics courses. As such, this section will begin by focusing on the insights gained about tutoring at QLCS, then turn to the implications for practice more broadly in higher education.

6.1.1 Tutoring at QLCs

The findings from this dissertation illuminate that students' needs in undergraduate mathematics courses go beyond their difficulties with the content. Students also may be struggling with their transition to higher education. To ease this transition, it may be beneficial for QLCs to aim to be environments where tutors display appropriate study habits and act as examples of how to be independent learners. Since students tend to see tutors as less intimidating than professors, the tutors have the ability to relate to students on a peer-to-peer level and to address the transition by discussing their own experiences and techniques for being successful.

In addition to this, it emerged in both the perspectives of tutors and students that one aspect of tutoring at the QLC that was particularly beneficial was the use of techniques that engaged the students in the mathematics. Rather than tutors simply re-explaining concepts to the students, tutors used strategies that required students to be involved in solving problems on their own. Tutors at QLCs should feel encouraged that these strategies are appreciated by the students that they work with and that the students feel that these strategies have helped them to successfully complete assignments and understand the content they are learning.

Finally, an important implication of the findings is that tutors need to be prepared to handle the conflict between their students' goals for a tutoring session and the actual challenges that the students face. For example, the findings revealed that tutors often recognized that students had difficulty with prerequisite knowledge and that this hindered them in their current courses. However, the students' goals for the sessions rarely included reviewing previous material and mainly focused on completing an assignment or working on new material. As such, tutors need to be prepared to maneuver this situation and to steer students towards their actual needs rather than simply catering to the direct goals of the students. This is necessary if the support provided is going to be successful in helping students to achieve higher proficiency levels in mathematical content.

6.1.2 Implications for Practice

Educators in undergraduate mathematics can also learn about their students' mathematical needs and about ways that students can be supported through considering the findings of this dissertation. The tutors' and students' perceptions can lend valuable insights about these two topics and they shed light on two areas for educators to consider.

First, the needs of students in our mathematics classes may encompass more than just the mathematical content that is being taught. Students, especially those in their first year of higher education, are adjusting to a new environment where expectations and teaching styles may differ from those they were accustomed to in high school. As such, some students may struggle in their college mathematics courses not because of a lack of preparation or effort but rather because they have not learned how to succeed in this new environment. It may be worthwhile for educators to reflect on this and consider if there is anything that they can do to alleviate some of the tension in this transition or to support students in finding the methods that will make them successful college learners.

Second, the success of the tutors' techniques of engaging students during tutoring sessions leads to a suggestion that incorporating some form of active learning within the classroom, in office hours, or in some other way will benefit students. This is not a new concept; there has been a push for active learning to be incorporated in undergraduate mathematics classes, as was discussed in the literature review. However, the success of the tutors' strategies adds to this in that we see that students are actually seeking out support that provides opportunities to engage with the material. Educators may want to ask themselves if there are opportunities for more student engagement within their regular practices.

6.2 Future Research Directions

To end this chapter, I will briefly discuss four directions for future research that result from the findings in this dissertation: (1) continued research into QLCs, (2) help-seeking behavior in mathematics more generally, (3) pedagogical techniques to improve undergraduate mathematics learning, and (4) teacher preparation.

Continuing with QLCs

The research I have done thus far offers many opportunities for expansion. Specifically, my review of the literature left some additional questions unanswered. First, while the literature is clear about what services are being offered at QLCs, the substance of those services is less clear. This dissertation has provided insights into this area through both the perspective of the tutors as well as through the perspective of the students. However, the contrast between the tutors' view that getting the answers to their homework questions was a main goal for students and the students' view that this was not the case leads to future inquiry into where these different perceptions stem from and how these affect the way that tutors interact with students. If tutors expect that students just want the answer, does this change the way that they choose to support them or change their attitudes towards helping them?

Another interesting contrast that emerged was between tutors' and students' perceptions of the role that difficulties with prerequisite material played in the students' challenges with mathematical topics. Further investigation of where this discrepancy is coming from could be beneficial for our understanding of our students' needs as well as how to support them. If students do not realize they have challenges with prerequisite material then there may be cause for finding ways to show them these gaps in their knowledge so that they can resolve them.

Additionally, this dissertation focused on one type of structure for a QLC that used drop-in peer tutoring as its primary support. Future work could investigate different structures to compare findings. Furthermore, study designs that include the perceptions of professors or graduate teaching assistants would provide additional layers to these studies that would enhance our understanding of students' needs and how best to support them.

Help-seeking behavior in Mathematics

Another area of further research that stems from this dissertation is the help-seeking behavior of students in mathematics more generally, their choices in how and when to seek support. Students have many options for seeking help in post-secondary education in addition to QLCs. This would involve collecting data through surveys and interviews with students and instructors as well as investigating the outcomes for students in the form of grades, attitude towards mathematics, and mathematics anxiety. Is there a relationship between the type of support sought and any of these outcomes?

Through the findings of this dissertation, the needs and successful support strategies were revealed for students who visit the QLC as well as students who were enrolled in MB&E, CB&E, Calculus 1, and Calculus 2. Would any of these findings change if the students were enrolled in different mathematics courses? Would the strategies need to change for students in low-level mathematics courses such as precalculus or problem solving courses as opposed to high-level mathematics courses such as abstract algebra or real analysis?

Through this further investigation we may find effective ways to encourage students to seek support when needed and to improve the support structures that exist.

Alternative pedagogical approaches

Additionally, my research on the support structures available to students in mathematics leads naturally to an investigation of pedagogical approaches within the classroom that have been shown to improve students' critical thinking and problem-solving abilities in mathematics. The research and academic community benefits from continued explorations of the potential role that these alternatives to lecture-based classrooms play in the students' abilities to complete difficult mathematical problems as well as the relationship between these alternative approaches and the students' conceptual understanding and retention of material in ways that they themselves find benefit their learning.

Teacher Preparation

Finally, a further research direction is inspired by my experience teaching mathematics content in algebra and geometry to pre-service elementary teachers together with my research on tutoring strategies. These have led to questions about the possible connections between tutoring and teaching strategies as well as the potential implications of these in pre-service and in-service teachers' pedagogical content knowledge.

Bibliography

[Agustin and Agustin, 2009] Agustin, M. Z. N. and Agustin, M. A. (2009). Algebra and precalculus skills and performance in first-semester calculus. *International Journal of Case Method Research & Application*, XXI(3):232–236.

[Ariza et al., 2011] Ariza, C., Davis, J. M., Frye, M., and Harmsen, E. (2011). Getting science students to pass-uiw: A successful collaboration between students, staff, and faculty. *Learning Assistance Review*, 16(2):55–70.

[Armstrong, 2000] Armstrong, W. B. (2000). The association among student success in courses, placement test scores, student background data, and instructor grading practices. *Community College Journal of Research and Practice*, 24(8):681–695.

[Bannier, 2007] Bannier, B. (2007). Predicting mathematics learning center visits: An examination of correlating variables. *The Learning Assistance Review*, 12(1):7–16.

[Barak et al., 2006] Barak, M., Lipson, A., and Lerman, S. (2006). Wireless laptops as means for promoting active learning in large lecture halls. *Journal of Research on Technology in Education*, 38(3):245–263.

[Beasley and Schumacker, 1995] Beasley, T. M. and Schumacker, R. E. (1995). Multiple regression approach to analyzing contingency tables: Post hoc and planned comparison procedures. *The Journal of Experimental Education*, 64(1):79–93.

[Benoit, 2012] Benoit, S. W. (2012). *An exploratory study of the experiences of undergraduate students seeking peer-tutoring university resources at a four-year public institution*. PhD thesis, Lamar University, ProQuest LLC (UMI Number: 3510139).

[Berry et al., 2015] Berry, E., Mac An Bhaird, C., and O'Shea, A. (2015). Investigating relationships between the usage of Mathematics Learning Support and performance of at-risk students. *Teaching Mathematics and Its Applications*, 34:194–204.

[Black, 2016] Black, M. (2016). Case study: Symbolic and quantitative resource center at lewis & clark college. In Coulombe, G., O'Neill, M., and Schuckers, M., editors, *A Handbook for Directors of Quantitative and Mathematical Support Centers*. Neck Quill Press, http://scholarcommons.usf.edu/qmasc_handbook.

[Bodnar and Petrucelli, 2016] Bodnar, J. R. and Petrucelli, S. L. (2016). Strengthening academic writing. *NADE Digest*, 9(1):40–43.

[Cai et al., 2015] Cai, Q., Lewis, C. L., and Higdon, J. (2015). Developing an early-alert system to promote student visits to tutor center. *The Learning Assistance Review*, 20(1):61–72.

[Capaldi, 2014] Capaldi, M. (2014). Non-traditional methods of teaching abstract algebra. *PRIMUS*, 24(1):12–24.

[Carroll and Gill, 2012] Carroll, C. and Gill, O. (2012). An innovative approach to evaluating the University of Limerick's Mathematics Learning Centre. *Teaching Mathematics and Its Applications*, 31:199–214.

[Chen and Soldner, 2013] Chen, X. and Soldner, M. (2013). STEM attrition: College students' paths into and out of STEM fields. Technical report, National Center for Education Statistics, Institute of Education Sciences, U.S. Department of Education, Washington, D.C.

[Collins and Sims, 2006] Collins, W. and Sims, B. C. (2006). Help seeking in higher education academic support services. In S. A. Karabenick and R. S. Newman (Eds.), *Help Seeking in Academic Settings: Goals, Groups, and Contexts* (pp. 203-223). Mahwah, New Jersey: Lawrence Erlbaum Associates, Publishers.

[Colvin, 2012] Colvin, T. S. (2012). *The role of academic help-seeking attitudes, achievement goal orientations, and dissertation self-efficacy in dissertation progress*. PhD thesis, The University of Memphis, ProQuest LLC (Accession No. ED554984).

[Complete College America, 2016] Complete College America (2016). Corequisite remediation: Spanning the completion divide. https://completecollege.org/spanningthedivide/.

[Coulombe, 2016] Coulombe, G. (2016). Case study: The mathematics & statistics workshop at bates college. In Coulombe, G., O'Neill, M., and Schuckers, M., editors, *A Handbook for Directors of Quantitative and Mathematical Support Centers*. Neck Quill Press, http://scholarcommons.usf.edu/qmasc_handbook.

[Creswell, 2012] Creswell, J. W. (2012). *Educational Research: Planning, Conducting, and Evaluating Quantitative and Qualitative Research (4th ed.)*. Boston, Massachusetts: Pearson.

[Daugherty et al., 2013] Daugherty, T. K., Rusinko, J. P., and Griggs, T. L. (2013). Math beliefs: Theory-framed and data-driven student success. *The Learning Assistance Review*, 18(2):67–78.

[Dubinsky and Wilson, 2013] Dubinsky, E. and Wilson, R. T. (2013). High school students' understanding of the function concept. *The Journal of Mathematical Behavior*, 32:83–101.

[Evans et al., 2001] Evans, W., Flower, J., and Holton, D. (2001). Peer tutoring in first-year undergraduate mathematics. *International Journal of Mathematical Education in Science and Technology*, 32(2):161–173.

[Fetters et al., 2013] Fetters, M. D., Curry, L. A., and Creswell, J. W. (2013). Achieving integration in mixed methods designs-principles and practices. *Health services research*, 48(6 Pt 2):2134–2156.

[Freeman et al., 2014] Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., and Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences of the United States of America*, 111(23):8410–8415.

[Gillman, 2011] Gillman, R. (2011). Introduction. Retrieved from http://sigmaa.maa.org/ql/about.php.

[Gordon, 2008] Gordon, S. P. (2008). What's wrong with college algebra? *PRIMUS*, 18:516–541.

[Grant, 2016] Grant, J. S. (2016). Responding to institutional needs. In Coulombe, G., O'Neill, M., and Schuckers, M., editors, *A Handbook for Directors of Quantitative and Mathematical Support Centers*. Neck Quill Press, http://scholarcommons.usf.edu/qmasc_handbook.

[Grbich, 2013] Grbich, C. (2013). *Qualitative Data Analysis: An Introduction*. Thousand Oaks, CA: Sage.

[Griffith, 2010] Griffith, A. L. (2010). Persistence of women and minorities in STEM field majors: Is it the school that matters? *Economics of Education Review*, 29(6):911–922.

[Hager, 2018] Hager, A. E. S. (2018). *How does peer-assisted learning effect math anxiety, help-seeking behavior, and performance in undergraduate mathematics?* PhD thesis, Plymouth State University, Available from ProQuest Dissertations & Theses Global. (2160779437).

[Halcrow and Iiams, 2011] Halcrow, C. and Iiams, M. (2011). You can build it, but will they come? *PRIMUS*, 21(4):323–337.

[Karabenick and Knapp, 1988] Karabenick, S. A. and Knapp, J. R. (1988). Help seeking and the need for academic assistance. *Journal of Educational Psychology*, 80(3):406–408.

[Kessels and Steinmayr, 2013] Kessels, U. and Steinmayr, R. (2013). Macho-man in school: Toward the role of gender role self-concepts and help seeking in school performance. *Learning and Individual Differences*, 23:234–240.

[Knowles and Paglia, 2004] Knowles, J. M. and Paglia, A. K. (2004). The K-P Model of collaborative mathematics support: A holistic approach. *The Learning Assistance Review*, 9(1):31–48.

[Longuevan and Shoemaker, 1991] Longuevan, C. and Shoemaker, J. (1991). Using multiple regression to evaluate a peer tutoring program for undergraduates. Paper presented at the annual CERA Meeting.

[Ma et al., 2008] Ma, H. J., Wan, G., and Lu, E. Y. (2008). Digital cheating and plagiarism in schools. *Theory into Practice*, 47(3):197–203.

[Mac An Bhaird et al., 2009] Mac An Bhaird, C., Morgan, T., and O'Shea, A. (2009). The impact of the mathematics support centre on the grades of first year students at the National University of Ireland Maynooth. *Teaching Mathematics and Its Applications*, 28:117–122.

[Mayer et al., 2009] Mayer, R. E., Stull, A., DeLeeuw, K., Almeroth, K., Bimber, B., Chun, D., Bulger, M., Campbell, J., Knight, A., and Zhang, H. (2009). Clickers in college classrooms: Fostering learning with questioning methods in large lecture classes. *Contemporary Educational Psychology*, 34(1):51–57.

[McCallum et al., 2015] McCallum, S., Schultz, J., Sellke, K., and Spartz, J. (2015). An examination of the flipped classroom approach on college student academic involvement. *International Journal of Teaching and Learning in Higher Education*, 27(1):42–55.

[Menz and Jungic, 2015] Menz, P. and Jungic, V. (2015). A university math help centre as a support framework for students, the instructor, the course, and the department. *Journal of University Teaching & Learning Practice*, 12(1).

[Merriam, 2009] Merriam, B. S. (2009). *Qualitative Research: A Guide to Design and Implementation*. San Francisco, CA: John Wiley & Sons, Inc.

[Miles and Huberman, 1994] Miles, M. B. and Huberman, A. M. (1994). *Qualitative Data Analysis: An Expanded Sourcebook*. Sage, Thousand Oaks, CA, 2 edition.

[National Research Council, 2005] National Research Council (2005). *How Students Learn: History, Mathematics, and Science in the Classroom*. Washington, D.C.: The National Academies Press.

[Patton, 2002] Patton, M. Q. (2002). *Qualitative Research & Evaluation Methods (3rd ed.)*. Thousand Oaks, CA: Sage.

[Pavlin-Bernardić et al., 2017] Pavlin-Bernardić, N., Rovan, D., and Pavlović, J. (2017). Academic cheating in mathematics classes: A motivational perspective. *Ethics & Behavior*, 27(6):486–501.

[Perkin et al., 2007] Perkin, G., Pell, G., and Croft, T. (2007). The mathematics learning support centre at Loughborough University: Staff and student perceptions of mathematcal difficulties. *Engineering Education*, 2(1):47–58.

[Ralph, 2015] Ralph, R. A. (2015). Post secondary project-based learning in science, technology, engineering and mathematics. *Journal of Technology and Science Education*, 6(1):26–35.

[Retsek, 2013] Retsek, D. Q. (2013). Chop wood, carry water, use definitions: Survival lessons of an IBL rookie. *PRIMUS*, 23(2):173–192.

[Rheinheimer et al., 2010] Rheinheimer, D. C., Grace-Odeleye, B., Francois, G. E., and Kusorgbor, C. (2010). Tutoring: A support strategy for at-risk students. *Learning Assistance Review*, 15(1):23–24.

[Rickard and Mills, 2018] Rickard, B. and Mills, M. (2018). The effect of attending tutoring on course grades in calculus i. *International Journal of Mathematical Education in Science and Technology*, 49(3):341–354.

[Roby, 2016] Roby, T. (2016). Case study: Quantitative learning center at uconn. In Coulombe, G., O'Neill, M., and Schuckers, M., editors, *A Handbook for Directors of Quantitative and Mathematical Support Centers*. Neck Quill Press, http://scholarcommons.usf.edu/qmasc_handbook.

[Rosenthal, 1995] Rosenthal, J. S. (1995). Active learning strategies in advanced mathematics classes. *Studies in Higher Education*, 20(2):223–228.

[Rueda and Sokolowski, 2004] Rueda, N. G. and Sokolowski, C. (2004). Mathematics placement test: Helping students succeed. *The Mathematics Educator*, 14(2):27–33.

[Saldana, 2009] Saldana, J. (2009). *The Coding Manual for Qualitative Researchers*. Thousand Oaks, CA: Sage.

[Schoenfeld, 1983] Schoenfeld, A. H. (1983). Problem solving in the mathematics curriculum. a report, recommendations, and an annotated bibliography. Technical Report 1, Mathematical Association of America, Washington, D.C.

[Seymour, 1995] Seymour, E. (1995). Guest comment: Why undergraduates leave the sciences. *American Journal of Physics*, 63:199–202.

[Solomon et al., 2010] Solomon, Y., Croft, T., and Lawson, D. (2010). Safety in numbers: mathematics support centres and their derivatives as social learning spaces. *Studies in Higher Education*, 35(4):421–431.

[Srivastava and Rashid, 2018] Srivastava, R. and Rashid, M. (2018). Who is at edge - Tutors or tutees? Academic, social, and emotional elevation through peer tutoring. In *Arab World English Journal*. Proceedings of 1st MEC TESOL Conference 2018.

[Steen-Utheim and Foldnes, 2018] Steen-Utheim, A. T. and Foldnes, N. (2018). A qualitative investigation of student engagement in a flipped classroom. *Teaching in Higher Education*, 23(3):307–324.

[Stewart and Reeder, 2016] Stewart, S. and Reeder, S. (2016). Investigating college students difficulties with algebra. In Fukawa-Connelly, T., Infante, N., Wawro, M., and Brown, S., editors, *Proceedings of the 19th Annual Conference on Research in Undergraduate Mathematics Education*, pages 1302–1304, Pittsburgh, PA.

[Suresh, 2006] Suresh, R. (2006). The relationship between barrier courses and persistence in engineering. *Journal of College Student Retention: Research, Theory & Practice*, 8(2):215–239.

[Topping, 1996] Topping, K. J. (1996). The effectiveness of peer tutoring in further and higher education: A typology and review of the literature. *Higher Education*, 32(2):321–345.

[Trenholm, 2007] Trenholm, S. (2007). A review of cheating in fully asynchronous online courses: A math or fact-based course perspective. *Journal of Educational Technology Systems*, 35(3):281–300.

[Xu et al., 2001] Xu, Y., Hartman, S., Uribe, G., and Mencke, R. (2001). The effects of peer tutoring on undergraduate students' final examination scores in mathematics. *Journal of College Reading and Learning*, 32(1):22–31.

[Young, 2011] Young, E. (2011). Onsite peer tutoring in mathematics content courses for pre-service teachers. *Issues in the Undergraduate Mathematics Preparation of School Teachers*.

Appendix A

Questions on the [QLC] Survey

1. What is your gender identity?
    - Male
    - Female
    - Transgender
    - Other
2. Are you of Hispanic, Latino, or Spanish origin?
    - No, not of Hispanic, Latino, or Spanish origin
    - Yes, I am of Hispanic, Latino, or Spanish origin
    - Unavailable/Unknown
    - Decline to Answer
3. Which category best describes your race?
    - American Indian/Alaska Native
    - Asian
    - Black or African American
    - Native Hawaiian/Other Pacific Islander White
    - Some other race Unavailable/Unknown
    - Decline to Answer
4. Is this your first semester at Storrs campus as a transfer or campus change student?
    - No
    - Yes, first semester as transfer student
    - Yes, first semester as a campus change student from [location options]
5. How often do you visit the [QLC]?
    - I've only visited once.
    - I've visited 2-5 times this semester.
    - I've visited 5-8 times this semester.

- I visit about once a week.
- I visit more than once a week.

6. For which mathematics course(s) have you sought help at the [QLC]? (Select all that apply.) [Course options offered by the QLC]

7. Typically, how many hours outside of class do you spend studying and preparing for each of the course(s) you visited the [QLC] for?

   - 0 to less than 1 hour per week
   - 1-3 hours per week
   - 4-6 hours per week
   - 7-9 hours per week
   - 10-12 hours per week
   - More than 12 hours per week

8. In addition to the [QLC], what other resources have you used to prepare for your math Q courses outside of class? (Choose all that apply.)

   - Course notes
   - Textbook
   - Internet
   - Studying with peers
   - Friends who have taken the course previously
   - Office Hours
   - Tutoring (not through [QLC])
   - Other:

9. What is your preferred resource when you are seeking support with your math Q courses?

   - Course notes
   - Textbook
   - Internet
   - Studying with peers
   - Friends who have taken the course previously
   - Office Hours

QLC tutoring

QLC review sessions

- Tutoring (not through [QLC])
- Other:

10. What would you say is the main thing you find difficult about the topics for which you have visited the [QLC]?

    - Clarity of key ideas related to the topic
    - Following procedures
    - Applying the topic to specific problems or examples
    - Understanding prerequisite material
    - Understanding when a problem requires that topic
    - Other:
    - I have not had difficulty with any topics.

11. What is your most frequent reason for visiting the [QLC]?

    - Approaching exam
    - Completing the homework
    - Understanding concepts, ideas, and/or procedures
    - Other:

12. When you are seeking help with doing math problems, what is usually the main area you are having difficulty with? (Choose all that apply.)

    - Understanding what is being asked.
    - Setting up the problem so I can solve it using math techniques.
    - Understanding the requirements of the problem.
    - Recalling prior knowledge.
    - Understanding the problem's topic that we recently covered.
    - Understanding the steps I need to take to solve the problem.
    - Other:
    - I don't seek help with doing problems.

13. How often do you feel that the tutors provide the support that you are looking for?

- All the time
- Almost all the time
- More than half the time
- About half the time
- Less than half the time
- Almost none of the time
- None of the time

14. If there have been occasions when you were unable to understand the initial explanation given by a tutor, how often was this due to the tutor assuming you had a greater math background than you do?
    - All the time
    - Almost all the time
    - More than half the time
    - About half the time
    - Less than half the time
    - Almost none of the time
    - None of the time
15. List three topics that you went to the [QLC] for help with this semester:
16. Choose one of the topics from the previous question. Describe a specific situation when you went to the [QLC] and when the support you received was successful in helping you to understand that topic. Please include the type of problem, why you sought help, and any other details that will be useful to understand the challenge involved.
17. What would you say is the main thing you found difficult about the topic that you described in the previous question?
    - Clarity of key ideas
    - Following procedures
    - Applying the topic to specific problems or examples
    - Understanding prerequisite material
    - Understanding when a problem requires that topic
    - Other:

18. If it was a problem that you sought help with, what do you think it was about that problem that made it challenging? (Choose all that apply.)
    - Understanding what was being asked.
    - Setting up the problem so I can solve it using math techniques.
    - Lack of practice solving similar problems.
    - Understanding the requirements of the problem.
    - Recalling prior knowledge.
    - Understanding the problem's topic that we recently covered.
    - Understanding the steps I needed to take to solve the problem.
    - Other:
    - I didn't seek help with doing a problem.
19. What did the tutor do or say to help you to understand the topic? Be as specific as possible.
20. A similar survey was sent to all students taking specific mathematics classes this semester. Please indicate if you completed that survey too.
    - Yes, I completed the other survey as well.
    - No, I did not complete the other survey.
21. If you are willing to be contacted for more information about your experiences, please leave your email below. Your email will not be shared with anyone outside the research team.

Thank you for completing the survey!

Appendix B

Questions on the Q Course Survey

1. What is your gender identity?
   - Male
   - Female
   - Transgender
   - Other
2. Are you of Hispanic, Latino, or Spanish origin?
   - No, not of Hispanic, Latino, or Spanish origin
   - Yes, I am of Hispanic, Latino, or Spanish origin
   - Unavailable/Unknown
   - Decline to Answer
3. Which category best describes your race?
   - American Indian/Alaska Native
   - Asian
   - Black or African American
   - Native Hawaiian/Other Pacific Islander White
   - Some other race Unavailable/Unknown
   - Decline to Answer
4. Is this your first semester at Storrs campus as a transfer or campus change student?
   - No
   - Yes, first semester as transfer student
   - Yes, first semester as a campus change student from [location options]
5. Which course are you enrolled in?
   - MB&E
   - CB&E
   - Calculus 1

- Calculus 2
- None of these

6. Typically, how many hours outside of class do you spend studying and preparing for this course?

- 0 to less than 1 hour per week
- 1-3 hours per week
- 4-6 hours per week
- 7-9 hours per week
- 10-12 hours per week
- More than 12 hours per week

7. What resources have you used to prepare for this course outside of class? (Choose all that apply.)

- Course notes
- Textbook
- Internet
- Studying with peers
- Friends who have taken the course previously
- Office Hours

QLC tutoring

QLC review sessions

- Tutoring (not through [QLC])
- Other:

8. What is your preferred resource when you are seeking support with this course?

- Course notes
- Textbook
- Internet
- Studying with peers
- Friends who have taken the course previously
- Office Hours

QLC tutoring

QLC review sessions

- Tutoring (not through [QLC])
- Other:

9. What would you say is the main thing you find difficult about the topics that you have sought help with in this course?
    - Clarity of key ideas related to the topic
    - Following procedures
    - Applying the topic to specific problems or examples
    - Understanding prerequisite material
    - Understanding when a problem requires that topic
    - Other:
    - I have not had difficulty with any topics.
10. What is your most frequent reason for seeking help in this course?
    - Approaching exam
    - Completing the homework
    - Understanding concepts, ideas, and/or procedures
    - Other:
11. When you are seeking help with doing math problems, what is usually the main area you are having difficulty with? (Choose all that apply.)
    - Understanding what is being asked.
    - Setting up the problem so I can solve it using math techniques.
    - Understanding the requirements of the problem.
    - Recalling prior knowledge.
    - Understanding the problem's topic that we recently covered.
    - Understanding the steps I need to take to solve the problem.
    - Other:
    - I don't seek help with doing problems.
12. List the three most challenging topics from this course so far this semester:
13. List three topics that you went to the [QLC] for help with this semester:

14. Choose one of the topics from the previous question. Describe a specific situation when you sought help and when the support you received was successful in helping you to understand that topic. Please include the type of problem, why you sought help, and any other details that will be useful to understand the challenge involved.

15. What would you say is the main thing you found difficult about the topic that you described in the previous question?

    - Clarity of key ideas
    - Following procedures
    - Applying the topic to specific problems or examples
    - Understanding prerequisite material
    - Understanding when a problem requires that topic
    - Other:

16. If it was a problem that you sought help with, what do you think it was about that problem that made it challenging? (Choose all that apply.)

    - Understanding what was being asked.
    - Setting up the problem so I can solve it using math techniques.
    - Lack of practice solving similar problems.
    - Understanding the requirements of the problem.
    - Recalling prior knowledge.
    - Understanding the problem's topic that we recently covered.
    - Understanding the steps I needed to take to solve the problem.
    - Other:
    - I didn't seek help with doing a problem.

17. If you sought help from a person or video, what did the person do or say to help you to understand the topic? OR if you sought help from a written source (textbook, written handout, etc.) what did the resource offer that helped you to understand the topic? If you sought help from a different type of resource, how did that resource help you? Be as specific as possible.

18. If you are willing to be contacted for more information about your experiences, please leave your email below. Your email will not be shared with anyone outside the research team.

Thank you for completing the survey!

Appendix C

Observation Protocol

Instructions for use of observation protocol: In the column labeled tutor, keep track of the tutoring techniques or strategies employed by the tutor during the session. For each strategy, keep note of any notable comments or actions made by the tutor. In the student column, make note of the questions asked and the student's response to the tutor's technique/strategy. As you notice the tutor moving to new techniques/strategies, draw a horizontal line splitting the page and make note of the new strategy under this line in the Tutor column, and continue as before.

Tutor	Student

Appendix D
Tutor Interview Protocol

The interview was semi-structured with the following set of questions used as a guide, but also allowing for elaboration by the participants with follow-up questions permitted to help the interviewer obtain a clear understanding of the participant's views.

Brief Introduction to the project:

As you may be aware, I am interested in learning about the Q Center and about how we can use what happens there to improve both the Q Center and undergraduate mathematics education as a whole. I'm very interested in learning what tutoring strategies or techniques are used by tutors such as yourself, as well as learning about the needs of the students that visit the Q Center. I'm hoping to talk to you about these topics today.

If it is okay with you, I would like to record our conversation today. That way I can concentrate on hearing what you say and I can listen to the recording later on to reflect on your responses. After our interview, I will transcribe our conversation as well. I will assign you a pseudonym on the transcript to protect your confidentiality. If you have any questions or concerns, we can stop the interview at any time. If there are any questions I ask that you don't want to answer, please just let me know.
Is there anything else you would like to know before we get started?

Begin recording

I'd like to start by getting some background about you and your experience at the Q Center.

Background:

- What is your academic year?
    (a) What are you majoring in?
- How long have you been working at the Q Center?
    (a) What math classes do you provide tutoring for?

Before we talk about the observation(s) that you've let me do, I'd like to begin with some more general questions about your experience at the Q Center.

General Questions:

- What do you think is the most frequent reason students visit the Q Center?
    (a) How do the students want you to help them?

- In your experience, what math courses do students visit the Q Center for most often?

  (a)Are there any specific topics that seem particularly difficult for students?

  (b) What do you think it is about that topic that is difficult for them?

  (c) Are there any specific types of exercises that seem particularly difficult for students?

  (d) What do you think it is about those types of exercises that is difficult for them?

Okay, so now we will move into questions based on the observation.

Observation Questions (Ask questions similar to those below, based on the observation.):

- I noticed you (specify strategy/technique and what it was in response to). Do you remember this instance?

  (a) Can you explain why you did this (or why you might use this technique if they don't remember the exact situation)?

  (b) How did you feel that the student responded to this?

  (c) Are there other occasions in which you would use/have used this approach? (which ones, why?)

- I noticed that you changed your strategy/technique when (describe situation)

  (a) What went into making you change this decision? (student's reaction, prior experiences, etc.)

  (b) Have you used this strategy successfully before? Tell me about it: topic, situation, etc.

- Can you tell me of a strategy that you use often (if this one, then the next popular one) and has been successful to you for helping the students.

  (a) Type of problem (difficulty understanding problem statement, or lack of prior knowledge, or specific topic or exercise they seem to struggle with)

- How do you know when a strategy is successful? What are the indicators/clues that you look for to keep or change strategy?

Do you have any questions for me or is there anything else that you think I should know? Thank you for your time!

Appendix E
Student Interview Protocol

The interview was semi-structured with the following set of questions used as guiding questions, but that also allow for additional elaboration by the participants. As a result, follow-up questions are possible to help the interviewer obtain a clear understanding of the participant's views.

Brief Introduction to the project:

I am interested in learning about the Q Center and about how we can use what happens there to improve both the Q Center and undergraduate mathematics education as a whole. I'm very interested in learning what tutoring strategies or techniques tutors use as well as learning about the needs of the students that visit the Q Center. I'm hoping to talk to you about these topics today. If it is okay with you, I would like to record our conversation today. That way I can concentrate on hearing what you say and I can listen to the recording later on to reflect on your responses. After our interview, I will transcribe our conversation as well. I will assign you a pseudonym on the transcript to protect your confidentiality. If you have any questions or concerns, we can stop the interview at any time. If there are any questions I ask that you don't want to answer, please just let me know.

Is there anything else you would like to know before we get started?

Begin recording

I'd like to start by getting some background about you.

Background Questions:

- What is your academic year?
  a. What are you majoring in?
  b. What Q courses have you taken?
- How would you describe your feelings about math?
  a. What experiences have you had that made you feel that way?
- How would you describe your mathematical ability?
  a. What experiences have you had that made you feel that way?

Before we talk about the observation that I did while you were at the Q Center, I'd like to begin with some more general questions about your experience at the Q Center.

General Questions:

- How often do you visit the Q Center?
- What is the most frequent reason that you visit the Q Center?
  - a. What kind of help are you hoping that the tutors will provide?
  - b. What kind of help do they usually provide?
- (If they've taken more than one Q Course tutored by the center) Have you come to the Q Center for [fill in](every Q Course you've taken)?
- Can you think of any specific topics or math skills that you needed to visit the Q Center for?
  - a. What do you think it was about that topic that was most difficult for you?
- Do you use other resources when you need support: TA's office hours, instructor's office hours, classmates, friends, textbook, internet, others
  - a. Which is your preferred resource? Why?
  - b. How often or what clues do you use to help you realize that you need to reach out for any of these?

If the student was recruited through an observation, go to part A. If the student was recruited through a survey, go to part B.

Part A

Okay, so now we will move into questions based on the observation.

Observation Questions (Ask questions similar to those below, based on the observation.):

- Do you remember why you came to the Q Center that time?
  - a. Can you explain what specifically you were seeking help with? (difficulties with statement of problem, prior knowledge, specific topic/exercise)

- Can you describe how you felt about that tutoring experience?
    a. Can you give me an example of why you felt that way?
- I noticed that the tutor did (specify a strategy/technique). Do you remember that?
    a. Did this help you?
        i. How so or why not?
- How did you feel about your understanding of the topic as you left the Q Center that day?
- Was this a typical reason for you to seek help? (difficulties with statement of problem, prior knowledge, specific topic/exercise)

Go to part C.

Part B

Survey Questions (Ask questions similar to those below, based on the observation.):

- You responded to the survey while enrolled in [fill in]. Can you tell me about what you did outside of class to prepare/study/work?
    a. How much time did you spend per week?
- You said your preferred resource was [fill in]. Can you elaborate on why?
    a. What makes them useful? Always useful, or for this topic/course (indicating a habit)/section (as opposed to how other material was presented in the book)?
- You said the thing you found most difficult about the topics you were challenged by was [fill in]. Can you explain what you meant by that?
    a. Do you feel the same way? (depending on what they say go with it)
        i. Can you tell me a little more about these? (experience, what does [fill in] mean to you (example?),
        ii. Was this a typical reason for you to seek help? (difficulties with statement of problem, prior knowledge, specific topic/exercise)
- You talked about a situation where you sought help for [fill in]. Do you remember it?
    a. Do you remember what it was about [fill in] that was difficult for you?

b. Do you remember what it was about the tutor's explanation that helped you?

c. (If they said something else in the survey) You also mentioned [fill in]. Why was this helpful for you?

d. How did you feel about your understanding of the topic as you left the resource that day?

e. How did you end up doing on the exam/worksheet when you were asked about that topic?

- You said the typical reason(s) you sought help with math is/are: [fill in]

  a. Do you feel the same way? (depending on what they say go with it)

  b. Can you tell me a little more about these? (experience, what does [fill in] mean to you (example?),

  c. Was this a typical reason for you to seek help? (difficulties with statement of problem, prior knowledge, specific topic/exercise)

- Are there any other experiences that you think were helpful and that I should know about?

  a. (mention resources they said they had used)

  b. What did they do that helped?

- You said... another resource (e.g., notes) how are they useful to you? What makes them useful? Always useful, or for this topic/course (indicating a habit)/section (as opposed to how other material was presented in the book)?

- Researcher chooses another important challenge/helpful strategy and inquiries whether this has been something the student has struggled with/experienced and whether he/she finds that helpful. Check also whether they find this one even more important than the one they focused on.

Go to part C.

Part C

Are there any questions you have for me? Is there anything you would like to share that you think would be useful for this study? THANK YOU for your time!