

What Do the Calculus I Students Say About the Impact of IBL on Their Math Anxiety

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Math anxiety negatively affects student learning and academic performance. Students with high math-anxiety exhibit physical, mental, and emotional symptoms. These symptoms often have a short-term and long-term impact on students' mathematics learning and their performance both inside and outside of school. This study investigated the effects of inquiry-based learning (IBL) on Calculus I students' math anxiety, compared to lecture-based instruction. The short version of the Mathematics Anxiety Rating Scale (MARS-S) was used as a pre- and post-test to identify the students whose anxiety from pre- to post-test—greatly increased, greatly decreased, and did not change much. The selected participants were interviewed one-on-one to understand their perceptions and experiences of learning Calculus I. The results showed that some activities, such as the opportunity to work in groups, optional and ungraded homework, and the instructor's welcoming, caring, and amicable nature decreased IBL students' anxiety. On the other hand, the instructor's readiness to explain the material in class when students asked him to do so and his care for student success decreased lecture-based students' anxiety. However, the tests and exams and anticipating the instructor's call for a response increased anxiety among both groups of students.

Keywords: math anxiety inquiry-based learning, collaboration

Math anxiety affects student learning and academic performance. Highly math-anxious students exhibit physical, mental, and emotional symptoms. Physical symptoms include nausea, sweaty palms, and increased cardiovascular activity (Ashcraft, 2002; Chang & Beilock, 2016). Mental symptoms include an inability to concentrate and mind blanking (Plaisance, 2009; Ruffins, 2007). Emotional symptoms include extreme nervousness and apprehension (Mattarella-Micke et al., 2011). These symptoms often have a short-term and long-term impact on students' mathematics learning and their performance both inside and outside of school. In a short term, students may begin to dislike mathematics and take fewer mathematics courses, and in the long term, they tend to avoid mathematics and mathematics-related courses (Godbey, 1997; Hembree, 1990).

Due to the substantial impact of math anxiety on mathematics learning and mathematics performance, it is essential to diagnose the causes of math anxiety and to determine some potential interventions to reduce such anxiety. Therefore, this study investigated the effects of inquiry-based learning (IBL) pedagogy on Calculus I students' math anxiety, with lecture-based instruction as a comparative group.

Literature Review

Math anxiety has been a part of the human experience for centuries. The verse, "Multiplication is vexation ... and practice drives me mad" goes back at least to the 16th century (Dowker et al., 2016). In 1957, Dreger and Aiken introduced the concept "number anxiety," and math anxiety received increasing attention thereafter. Richardson and Suinn (1972) conducted the first formal study of math anxiety, who characterize math anxiety as "feelings of tension and anxiety that interface with the manipulation of numbers and the solving of mathematical problems in a wide variety of ordinary life and academic situations" (p. 551). Since then, studies on math anxiety have been substantially investigated.

Traditional lecturing, which is a predominant mode of instruction in college mathematics courses across the United States (Stains et. al., 2018) and is ineffective in helping students learn mathematics (Boaler, 2008), could be one of the possible reasons for evoking math anxiety among students. The lecture-based does not offer substantial opportunities for students to share each other's ideas and experiences with their teachers and peers. On the other hand, IBL, which is an active learning pedagogy, provides extensive opportunities for students where they can work in pairs or groups to make conjectures, gather information for problem-solving, and present their work to groups and to the whole class (Kogan & Laursen, 2014). Through a comparative study, Laursen et al. (2014) reported that students in IBL math-track courses achieved greater learning gains than their non-IBL peers in cognitive, affective, and collaborative areas. Similarly, Laursen et al. (2011) found that the IBL students were involved more in interacting with each other, with the instructor, and they were more involved in setting the course pace and direction. It is also reported that IBL enhances students' conceptual understanding (Jensen, 2006), communication skills, confidence, and self-efficacy (Laursen et al., 2011). Considering the benefits of IBL as a ground, this study sought to examine the relative changes in the scores of Calculus I students' math anxiety, using a short version of the Mathematics Anxiety Rating Scale (MARS-S).

Method

Research Context and Participants

The students, who were enrolled in Calculus I course and were taught using either IBL or lectures during Spring 2021 at a university located in the Midwestern United States were the sample for this study. Students, who were engaged via IBL pedagogy were IBL group and those who were lectured were lecture-based group. In this study, about 65% ($n = 15$) of the students off the 23 from the two IBL sections and about 41% ($n = 20$) students off the 49 from one of the lecture-based sections responded to both the pre- and post-MARS survey. Table 1 shows the distribution of IBL and lecture-based participants by their gender and academic standing.

Table 1. Distribution of IBL and lecture-based students by their major and academic standing.

Characteristics	IBL Group		Lecture-Based Group	
	Frequency	Percentage	Frequency	Percentage
Gender				
Male/Man	5	33.3%	8	40.0%
Female/Woman	10	66.7%	11	55.0%
Non-Binary	0	0.0%	1	5.0%
Academic Standing				
Freshman	11	73.3%	15	75.0%
Sophomore	2	13.3%	1	5.0%
Junior	2	13.3%	4	20.0%
Senior	0	0.0%	0	0.0%

Regarding the instructors, the IBL instructor had 15 years of experience in teaching Calculus I at the university and high school level via active learning, including an IBL. The lecture-based instructor had 2 and a half years of experience in teaching Calculus I at the university level and 14 years of experience in teaching undergraduate-level mathematics courses via a lecture-based approach. Both the instructors taught remotely using audio-visual conferencing platform; the IBL

instructor taught using Microsoft Teams, whereas the lecture-based instructor taught using Zoom. Throughout the semester, both IBL and lecture-based classes had class meetings every Monday, Wednesday, and Friday.

The IBL instructor engaged students collaboratively in sequentially organized pre-tasks and tasks in and out of the class. Students were supposed to practice the pre-tasks before the class for a better understanding of the material during the next day's class meeting. The instructor usually began the class by welcoming each student and briefly describing the tasks and activities for that day. Then, the students were sent to Teams breakout rooms, where they shared each other's ideas, asked questions, made conjectures, and solved problems while they were working with their small group members. The instructor visited each group at least once, or as needed and prompted students if they had any questions or concerns. In the end, the students were returned to the main room, where the instructor facilitated whole class discussion. On the other hand, the lecture-based instructor began the class by asking students whether they had any questions or concerns from the previous class. If they had, then, the instructor solved the examples or explained the concepts as needed. After that, the instructor usually began the lecture by solving preselected examples using the Notability app from his iPad. Occasionally, the instructor paused during the lecture and asked some questions to the whole class. Students were never sent to breakout rooms and never provided opportunities for group discussions.

Data Collection and Analysis

Qualtrics online survey was used to collect the pre- and post-MARS data from both IBL and lecture-based groups after receiving an institutional review board (IRB) approval. The MARS-S survey is the 30-item anxiety measuring instrument that was developed by Suinn and Winston (2003). The pre-MARS survey, in conjunction with a demographic questionnaire, was administered during the second week and the post-MARS was administered during the eleventh week of the class. Based on the change in anxiety scores from pre- to post-test, 9 students from the IBL group (3-greatly increased, 3-greatly decreased, and 3 did not change much) and 3 students from the lecture-based group (1 student from each of the categories) were invited for a semistructured interviews. Additionally, eight classes of each of the two sections of IBL group and eight class of one lecture-based group were observed remotely. The data thus collected were transcribed using NVivo, a qualitative data analysis software, and generated several codes. Thematic analysis was conducted to identify various emergent themes. The results were then organized based on the themes generated.

Results

In this section, I present the major findings from the analysis of the data obtained from observations and interviews. While doing this, I compare the findings from both the IBL and lecture-based groups.

The in-class group work and lecturing reduced IBL students' anxiety; out-of-class group chats reduced lecture-based students' anxiety. IBL students were partly lectured and partly engaged in collaborative work in each class; lecture-based students were fully lectured, but some students managed to chat via GroupMe. Because of the collaborative learning opportunities, IBL students became closer to each other and were not scared of asking questions, responding to their groupmates' questions, proposing their own solution strategies, and listening to their peer's various perspectives. Such types of activities made them feel relaxed and also reduced their anxiety. On the other hand, lecture-based students initiated out-of-class collaboration via GroupMe. They maintained it throughout the semester, where they felt comfortable asking

questions and responding to each other. Cooperation and mutual support received by these students reduced their anxieties and frustrations with learning Calculus I.

Table 2 and 3 below show sample of the emergent themes, related codes, and student quotations, respectively, for the IBL and lecture-based groups.

Table 2. Emergent Themes, Related Codes, and Sample Student Quotations for IBL Group

Theme	Related codes	Sample quotation
Both lecturing and collaborative learning	• The instructor delivered minilectures • Students were engaged in small group works	He typically starts off with a small lecture ... and then, we'll typically go into a group setting into our breakout rooms.
Students received optional and ungraded homework	• Assigned optional homework • Homework was not graded • Students were less stressed	I know they're just used for practice and prep for the exams and for class. So, I don't feel as stressed about them.
Instructor questioning	• Frequently asked short-answer-type questions • Asked to respond in chat	He would give each individual student a certain problem to do ... and randomly call on people for it.
Engaging in behaviors that decreased anxiety	• Working in group • Asking questions of the instructor outside of class • Talking to groupmates	I think doing the task in a group reduced it for sure, and ... watching the videos in class, like that does not stress me out or anything.
Engaging in behaviors that increased anxiety	• Thinking of being called on by the instructor • Responding to the instructor questions in front of the colleagues	I would definitely say I don't enjoy going to class because I'm scared, he's going to call on me and ask me a question I don't know the answer to.

Instructors' readiness to meet and help students at any time decreased IBL students' anxiety; the long wait for the instructor's email replies increased lecture-based students' anxiety. The IBL instructor's readiness to meet with students at any time and discuss their questions, concerns, or problems in and out of the class decreased IBL students' anxiety. Students could ask questions to the instructor at any time—during the class, at the end of the class, right after the class, or by scheduling a virtual meeting—and discuss their problems. They could approach the instructor at “eleven o'clock” at night or “7:00 am that morning;” he was always ready to meet and talk with them. Students could also send their questions or concerns via email, to which he replied promptly. This kind of flexibility of the instructor made students calm down and reduced their anxiety. Alternatively, although the lecture-based instructor encouraged students to reach out to him with their questions, students had to wait for long hours for his responses. Students were disappointed and frustrated for not receiving a response to their emails for several days. Liz, for example, mentioned, “We have an assignment that's due on Friday, and I need help. And I can't afford to wait three days for you [the instructor] to email me back because this piece of information is necessary for me to do 60 percent of the assignment.”

Table 3. Emergent Themes, Related Codes, and Sample Student Quotations for Lecture-Based Group

Theme	Related codes	Sample quotation
Students received too many online homework problems	• Too many online homework problems • The number of online homework problems gradually decreased	He gave us homework assignments that had eighty-seven problems. ... But that was really the only thing that made me feel anxious about the assignments.
Initiating and maintaining out-of-class collaboration	• Worked together through a GroupMe chat application • Liked helping each other	We all try to help each other out so I would say it's very collaborative.
Instructor questioning	• Frequently asked short-answer-type questions • Asked to respond in chat	He would give each individual student a certain problem to do ... and randomly call on people for it.
The instructional environment that decreased students' anxiety	• Instructor's willingness to review the materials • Recitation classes • Recorded lecture videos	His [instructor] willingness to kind of like go over things makes me feel like very comfortable.
The instructional environment that increased students' anxiety	• Tests and exams • online homework • Online learning • Proctored-track exams	I still get nervous every time when quizzes [are] announced or an exam is announced because like I said, this material has been hard.

Optional tasks and ungraded assignments decreased IBL students' anxiety, and the overwhelming number of online homework problems, especially at the beginning of the semester, increased lecture-based students' anxiety. In addition to the midterms, the IBL instructor engaged students in both optional and mandatory works, which were rarely graded. His pretasks were optional and ungraded but recommended for students to complete before class. However, the tasks, mock exams, and group competitions were mandatory and were required to complete during class but were rarely graded. Students did not feel stressed working with the optional and ungraded tasks and activities because they did not impact their grades; rather, these activities reduced IBL students' anxiety by developing confidence and problem-solving ability. Lecture-based students, on the other hand, experienced stress, frustrations, and anxieties when they confronted as many as 87 online problems as homework assignments during the first week. Students were anxious, thinking that they might continue receiving problems in the same manner. However, their anxiety reduced as the online homework problems decreased as the semester progressed.

Both IBL and lecture-based students felt anxious about being called on during the lectures and whole-class discussions. Students in both groups experienced extreme anxiety in the class, more specifically during the whole-class discussions, thinking that the instructor might randomly call on them for a response at any time. Recall that IBL student Camila stated, "the rest of the

time, I am comfortable until he directly calls on me.” These students were worried about their colleagues’ judgments when they could not respond to the instructor’s questions correctly and instantly. Likewise, lecture-based students were worried about being called on during the lecture for similar reasons. Unlike the IBL students, lecture-based students were usually busy “trying to write everything down” that the instructor wrote, and they experienced nervousness when they did not respond quickly to the instructor’s abrupt questions. One of the lecture-based students, Liz, stated “Occasionally he would ... call on someone, and if they wouldn’t know, he’d be like, you should know this. I would be, like, woo, I should know this by now, which would freak me out a little bit.”

Tests and quizzes, online learning, and proctored-track exams increased both IBL and lecture-based students’ anxiety. Both IBL and lecture-based students were anxious about taking exams, remote learning, and proctored-track exams. Although midterms and final exams were cumulative for IBL students, they were more anxious about taking the final exam than the midterms. In contrast, the lecture-based students were anxious about taking the tests and the final exams because they weighed the largest proportion of the overall grades. Also, lecture-based students were anxious to see a few questions on the exams because they would lose huge points if they did even a single problem incorrectly.

Online learning was another aspect that induced anxiety among both groups of students. IBL and lecture-based students occasionally missed a part of or the entire class due to the poor Wi-Fi connection, which added an extra pressure on students. Moreover, proctored-track exams caused anxiety among both groups of students. They were anxious about being watched by someone remotely and hearing a loud noise when someone asked clarifying questions to the instructor,

Instructors’ questions increased both IBL and lecture-based students’ anxiety. Instructor questions—either during lectures or whole-class discussions—increased IBL and lecture-based students’ anxiety. Three out of nine IBL students said that they feared the instructor’s questions, specifically when they were unsure of the answers and were still processing the information. Maria said she is terrified of instructor questions thinking of giving an incorrect answer in front of her colleagues, who were not from her small collaborative group. Although lecture-based students experienced similar types of anxieties in responding to instructor questions, they were also anxious by the instructor’s verbal pressures, such as “There’s been a couple of times when he [the instructor] said, you should know this, and I did not know it, and that made me very anxious,” Recall what Liz from the lecture-based class said before.

Discussion

Findings from the analysis of the interviews and observations show that the factors, such as the instructor’s amicable and cordial nature, readiness to help students at all times, in-class group work, and optional and ungraded homework assignments decreased IBL students’ anxiety. However, some other factors, such as thinking of being called on for a response and asking questions in front of their peers, increased these students’ anxiety. On the other hand, the classroom activities, such as the overwhelming number of online homework problems that were due every week, thinking of being called on for a response in class, responding to the instructor’s questions in front of their colleagues, instructor’s questions, and fast-paced teaching increased lecture-based students’ anxiety. Still, other factors, such as the instructor’s readiness to explain the materials in class reduced the anxiety of lecture-based students.

Based on the findings from the present study, I recommend that although some factors of the instructional environment, student behaviors, and instructor behaviors have been found to be increasing anxiety among both groups of students, there are many other factors that have

lessened their stress, frustration, and anxiety. It is suggested to the instructors of Calculus I and other similar mathematics courses to implement IBL in their classes or at least transition toward the student-centered approaches to instruction because of the benefits of such instructional practices on students' ability to critical thinking, reasoning, and problem-solving. It is also suggested to avoid the instructional activities that have been found to increase students' anxiety.

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