International Electronic Journal of Mathematics Education
2023, 18(2), em0732
e-ISSN: 1306-3030
https://www.iejme.com

MODESTUM

Research Article

OPEN ACCESS

Promoting engagement via engaged mathematics labs and supportive learning

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Citation: Mohammad, N., Nica, M., Levere, K. M., & Okner, R. (2023). Promoting engagement via engaged mathematics labs and supportive learning. *International Electronic Journal of Mathematics Education, 18*(2), em0732. https://doi.org/10.29333/iejme/12960

ARTICLE INFO

Received: 02 Aug. 2022

Accepted: 10 Feb. 2023

ABSTRACT

Out-of-class activities play a crucial role in student learning. However, student opinions on the design of these activities are rarely measured across several different classes. The purpose of this study is to understand students' preferences and attitudes towards new "Engaged Mathematics Labs" in which professors and teaching assistants assisted students in completing an assignment during lab time. We analyze both qualitative and quantitative survey responses from ~200 first year students participating in "Engaged Mathematics Labs" across two different levels of mathematics classes at a large Canadian public university. Results indicate that students enjoy being able to work in groups regardless of major or gender. Moreover, students learned to effectively use resources available in the course to solve questions that deepen their understanding of course concepts. Understanding the student preferences from this study can help form the design of future learning activities and future pedagogical studies.

Keywords: mathematics labs, MathMatize, Top Hat, teaching assistants, collaborative learning

INTRODUCTION

Teaching is a complex combination of systems that influence what happens in the classroom through interactions between teachers, students, curriculum, colleges, and universities. Different approaches have been employed to the teaching of mathematics (Ingram et al., 2019), but the use of instructional resources have been recognized as the most meaningful way to approach mathematics teaching (Sunday et al., 2021). Mathematics instructional resources are kept and used in the school mathematics labs. Labs are an environment, where students can meet with their peers and teachers to share something interesting from what they have learned in lectures (Singh et al., 2010). The impact of this interaction is so powerful that it is independent of students' majors.

Academic engagement happens when students dive deep into learning activities, when they are emotionally and mentally fascinated by the study materials, and often when interacting with peers (Carmen & Clara, 2021). Positive interpersonal relationships enhance individuals' enthusiasm for learning (Mercer & Dörnyei, 2020). Finding effective and meaningful ways to engage students, where we integrate equity, diversity, and inclusion principles with the development and assessment of learning outcomes is a perpetual challenge. This challenge is felt even more heavily in large classes, where students feel "like a number", and in so-called "terminal classes" in which a course is not a prerequisite for any other part of a student's degree, (but rather just a requirement for their degree). Creating a sense of community and belonging is paramount when class sizes can make students feel unsupported and unnoticed.

Since 2012, there has been a national call to incorporate research on the affective domain of the student experience as a key line of inquiry in discipline-based education research (National Research Council, 2012). Therefore, this paper reflects an ongoing effort to improve undergraduate teaching experiences in undergraduate calculus courses, where students' learning experience through "Engaged Mathematics Labs" was the main focus rather than on assessing individual mathematical domain knowledge.

In this paper, we first describe the environment of an "Engaged Mathematics Lab" for completing assignments and how undergraduate students in two different courses interacted in this environment. Second, we discuss student preferences regarding collaboration on assignments within the "Engaged Mathematics Labs" (group, individual, no preference).

Next, we compare student preferences of this new setting to traditional formats (i.e., take home assignments, online quizzes, etc.). We discuss the skills that students identified that they developed when working on a group lab assignment. We conclude with a summary of the lessons learned and some advice for fellow instructors considering adopting a similar learning environment.

LITERATURE REVIEW

Student Engagement

Determining the most effective strategies for student engagement is crucial to improving student learning. However, understanding students' experience and feeling inside the mathematics lab can be difficult. To think that students go to the lab engage and ask questions comfortably is a misunderstanding. Several labs implemented ways for the students to ask questions, including raising their hands, using technology or using flags. However, many students do not ask for help, or feel uncomfortable to display that flag. Almeda et al. (2017) discuss in their paper that some students do not know how to ask for help or develop strategies of avoidance of seeking help. They found that, except at very high or very low knowledge, help avoidance negatively affects learning.

Research suggests that student engagement is a key contributor to academic success (Fredricks et al., 2004; Skinner et al, 2008). Cooper (1994) developed an engaged lab format for general chemistry and organic chemistry labs that exposed students to the process of scientific problem solving, emphasized collaborative work, and required students to communicate their results both orally and in writing. Archambault et al. (2008) divide engagement into three important categories: behavioural (involvement and compliance to rules), affective engagement (i.e. experience, feelings, attitudes, sense of belonging, interest, willingness to learn), and cognitive engagement (i.e. cognitive functions involved in a student's learning process). Nadeem et al. (2016) characterize affective engagement by student feelings, attitudes, and perceptions towards the institution, as well as student relationships with their teachers and classmates.

Recent scholarship continues to affirm the efficacy of engaged learning pedagogies such as undergraduate research, learning communities, and service learning (Lloyd, 2019). However, meaningful engagement is deeper than simple participation and involvement (Speight el al., 2018).

There is a natural tendency to focus on cognitive engagement such as, for instance, the use of technology, apps, etc. for motivating students (for instance, Mohammad et al., 2018). Motivation and engagement are closely related. Understanding them as individual constructs is important, but perhaps more important is the understanding that one influences the other (Peter & Colin Ha, 2022). Motivation and engagement have a reciprocal relation. They both influence, and are influenced by, students' reading experiences (De Naeghel et al., 2012).

An attractive task design is also beneficial for academic engagement. A task is emotionally captivating if its design is physically appealing and if the students appreciate the type of the activity and its content (Mercer & Dörnyei, 2020).

Because existing research has shown real-world community-based learning experiences enhance student engagement (NSSE Annual Results, 2019), and engaging problems are relevant for the students and their future career (Amerstorfer, 2020). We chose to design our "Engaged Mathematics Labs" in a way to involve motivation, collaboration and engagement in small groups to enhance our students learning.

Collaborative Learning

Collaborative learning involves a team of students who learn through working together to share ideas, solve a problem, or accomplish a common goal. The next feature of the "Engaged Mathematics Labs" that engaged students the most was the opportunity to collaborate with students from their own sections or other sections from the same course.

Carlisle et al. (2017) reported that community-based learning improves students' ability to work with others and openness to new ideas. In mathematics education, collaborative learning's popularity surged in the 1980s, but it has since continued to evolve (Bigg et al., 2018) found that student collaboration across two universities in a large-scale community-based project reinforced students' academic learning through its engaged approach, and also fostered a sense of shared community between students.

The implementation of collaborative practices in classrooms is however a challenge (Wise & Schwarz, 2017). The natural setting for enacting collaboration is the small group. Guidance, which is adaptive to the needs of the learners, is necessary for collaboration to occur (Rummel et al., 2016).

Collaborative learning has been shown to significantly reduce test anxiety and build self-esteem in students (Anderson, 1995; Norwood, 1995). It encourages students to seek help and accept tutoring from their peers, which enhances the satisfaction of students with the learning experience, and a team approach to problem solving while maintaining individual accountability (Hagelgans et al., 1995; Hattie, 2009; Michaelsen et al., 2008). It also develops social interaction skills and creates a stronger social support system (Alexander & DeAlba, 1997). The advantages of collaborative learning are not limited to educational attainment, according to a study conducted by Johnson and Johnson (1998). Rather, there are many advantages to collaborative learning for the student, whether in the area of relationships, mental or emotional health, or later in the individual's social and professional life. Abd Algani (2018, 2019) highlights the importance of interactivity among the students and the teachers, which is very significant for education environments.

Mathematics Labs

Mathematics labs or tutorials are great environments to facilitate collaborative learning. According to John (2017), there are numerous objectives of math laboratory, as follows:

1. To make mathematics learning very meaningful to the students.
2. To make mathematics learning exciting and enjoyable to the students.
3. To stimulate and encourage creativity among the students.

4. To remove the weakness of present-day mathematics education.
5. To generate interest in the subject.
6. To make the students divergent thinkers.
7. It provides a means of practicing cognitive and psychomotor skills.

Small group tutorials were introduced into the teaching of a large foundational algebra and calculus course at the University of Auckland in 1993, and since then, they have become an integral part of the teaching and assessment of most undergraduate mathematics courses at the university (Oates et al., 2016). Through an ongoing effort by the mathematics department at Michigan State University to improve undergraduate learning outcomes, computational team labs were introduced in calculus II classes (Krause et al., 2021). Students reviewed the group lab setting as a positive learning experience, especially when the diverse expertise within the group provided support when students struggled to grasp conceptual mathematical ideas or lacked programming experience to interpret Matlab code. Shaqlaih and Celik (2013) highlighted students' preferences and attitudes towards mathematics labs in two-year and four-year colleges, where rather than looking at students' performance or lab administrators' preferences, the focus was on students' preferences on the use of the mathematics labs.

The "Engaged Mathematics Lab"

"Engaged Mathematics Labs" were implemented using three of the weekly labs or setting three of the lecture's time with 50 minutes each. Students formed their own groups of two-four when they arrived. If the students did not have a group to work with which is very common for first year students, instructors and TAs helped the students to form their groups. During the lab time each student were given a set of questions to work on them in group but at the end of the lab time they submitted their own individual lab assignment paper. TAs were given the sets of lab questions prior to the labs time to be prepared to help students. Professors and TAs assisted students in completing their assignments. At the end of the lab time the TAs collected all the lab assignments papers from each individual student, marked them and returned them to the students with their comments. To encourage the students on working on these lab assignments and to help them focus on learning the concepts rather than just the grades we gave them one free point out of five just to participate on the lab assignment.

METHODOLOGY

Measuring student engagement and perception can be difficult because engagement and perception are a first-person experience. Using quantitative measures for engagement such as grades and attendance rates fail, however, to capture qualitative indicators of engagement such as enthusiasm and interest in learning (Parsons & Taylor, 2011). The most common qualitative approach to measuring student engagement is to ask students to self-report on their level of interest and their emotional reactions to various existing and new methods. Self-reports can include open-ended responses, checklists, and summative rating scales. Because we were most interested in students' emotional engagement, particularly their enthusiasm and interest, we opted to capture students' self-reported responses to the "Engaged Mathematics Lab" through survey.

This study employs an interpretative approach, where qualitative data were collected and analyzed. We conducted an online survey available to all 807 students in participating "Engaged Mathematics Lab" courses in Fall 2021 /Winter 2022 regarding student opinions of the assessments and the "Engaged Mathematics Lab" environment that they experienced, and 222 students participated in this survey. The survey questions verified for validity and reliability before using them. This data helped capture student opinions rather than basing our results on grades.

Research Design

Two large first-year mathematics courses were investigated in this study. Each course was delivered in-person format. The format and scope of teaching for each course are, as follows.

Business mathematics (MATH*1030) introduced single-variable calculus with an emphasis on mathematical modelling related to business and economics. In the Winter 2022 semester, business mathematics was delivered in-person. Additionally, an online classroom response system ("Top Hat") was used to actively engage students in problem solving during lecture and to give an opportunity for feedback on student progress. Online virtual office hours were provided by teaching assistants (TAs) and the instructor. Questions were also answered by the instructor via email. There was no scheduled lab section in this course. However, three lecture times were assigned to be run as engaged labs. Students were assessed in two in-person Midterm Tests, three in-person lab assignments, in-class "Top Hat" questions (optional) and an in-person final exam.

Calculus I (MATH*1200) introduced single-variable calculus and intended primarily for students who expect to pursue further studies in mathematics and its applications. In the Fall 2021 semester, two sections of calculus I with identical exams were offered: one with in person lectures and one with online synchronous lectures. Both sections used a classroom response system "MathMatize" to actively engage students in problem solving during lecture and to give an opportunity for feedback on student progress. Online virtual office hours were provided by TAs and the instructor. Questions were also answered by the instructor via email. There were three different lab sections scheduled at different times in the course (9:30 am, 11:30 am, and 4:30 pm), which were run once a week. Students were assessed in two in-person midterm tests, three in-person lab assignments, in-class "MathMatize" questions (optional), and an in-person final exam.

Professors prepared a set of questions prior to each "Engaged Mathematics Lab" time for which there were three such lab times: one that was completed individually, one in groups of two-four, and a third that students were given the choice to complete either individually or in a group. For calculus I, three of the weekly labs were used for “Engaged Mathematics Lab” assignments. As MATH*1030 (business mathematics) does not have a scheduled lab, three lectures were used to accomplish this task.

In both classes, “Engaged Mathematics Labs” were held just prior to a test/exam to make sure that the students understood concepts and were given the opportunity to ask questions. Lab assignment questions were designed to help students to practice the basics of the methods taught in class, but also to push their understanding to new levels with challenging problems or questions that required higher-level problem-solving skills. The goal of the presence and active role of the professor and TAs was to facilitate a sense of comfort, integration of equity, diversity, inclusion and a willingness to ask for help when needed.

For the first engaged lab assignment, students tackled the problems on the assignment individually with assistance from professors and TAs (clarification of a question, and perhaps small hints for how to proceed). Should a common question arise, it was addressed by the professor to the entire class to clarify. The lab assignment covered all content pertinent to the first term test for the course. Assignments collected at the end of the lab time were graded and returned with rich feedback within one week of the assessment (and prior to the first term test).

For the second engaged lab assignment, students formed their own groups of two-four when they arrived. If the students did not have a group to work with which is very common for first year students, instructors and TAs helped the students to form their groups. The lab assignment covered all content pertinent to the second term test for the course. Students tackled the problems on the assignment in these groups, collaboratively. Professors and TAs readily communicated with groups offering assistance and explanation where needed. There was active communication with students about their thought processes and ideas as they worked toward completing the assignment. This communication encouraged a deeper understanding of the course content and challenged students to think more broadly about how the content applies in different circumstances, rather than placing the focus entirely on the assignment and the associated marks. Assignments collected at the end of the lab time were graded and returned with rich feedback within one week of the assessment (and prior to the second term test).

For the third lab assignment, students had the option to work individually or in groups of two-four. The lab assignment covered all content pertinent to the final exam for the course. Students tackled the problems on the assignment either individually or as a group based on the structure that they felt worked best for them. Students worked in groups/individually and were offered regular assistance and explanation and communicated their thoughts and ideas with professors and TAs. Assignments collected at the end of the lab time were graded and returned with rich feedback within one week of the assessment and prior to the final exam.

Throughout each assessment, students were asked to respond to an online poll during each lab via an anonymous polling software, regarding their progress in the lab assignment with possible answers of

(a) struggling and need assistance,

(b) progressing but periodically need assistance, or

(c) the assessment is going well, and I do not need assistance.

The use of a software made responses discreet so that students were more willing to give an honest account of their progress without worrying about the opinions of their peers. “MathMatize” was used in calculus I, and “Top Hat” was used in MATH*1030 (business mathematics).

Based on the responses of the students, students were encouraged to ask more questions. Each lab assignment was weighted at 5% of a student’s final grade with one point for participation and four points for correctness. If a student missed any of these lab assignments the weighting was added to their final exam.

At the end of the semester, a survey was conducted to collect student feedback regarding the set up and performances of the “Engaged Mathematics Lab” environment. Questions regarding the preference of the students related to the style of the lab assignments versus the previous formats; take-home assignments or online quizzes, availability of help, and the skills that students identify that they have gained as the result of this structure were all included in this survey. Moreover, students were given the opportunity to give comments on what they felt were the biggest advantages and disadvantages of the use of lab assignments in their course. Student responses to survey questions were used to statistically analyze the efficacy of the “Engaged Mathematics Labs” as well as to highlight possible changes to promote improvement of this approach.

Participants

The participants of the study were 222 first-year students in two large mathematics classes at the University of Guelph. This sample consists of 222 students who voluntarily chose to answer survey questions out of 807 students who were invited to participate. All students enrolled in the classes were invited to participate in this research project. The **end of semester survey** was brief, requiring less than ten minutes each to complete. The survey consisted of multiple choice, multi-select options and open-ended response questions. The **survey** was open for students to complete in the last three weeks of the Fall 2021 and Winter 2022 semesters. All information was kept confidential, and the investigator had access to the information only after all final grades were submitted to the registrar’s office. No compensation or incentives were offered to the subjects, nor did the subjects incur any costs in participating. The study was approved by the research ethics board prior to the distribution of surveys. There were no known risks to the students.

Context of the Study

This paper aims the following:

1. To investigate if students are willing to ask questions in the new setting of *“Engaged Mathematics Lab”*.

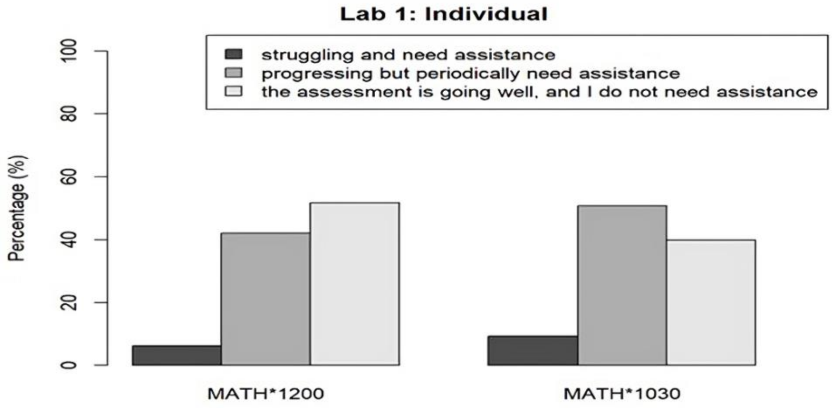

Figure 1. Histogram of online poll "in-class" results from lab 1 (individual) separated by class (Source: Authors' own elaboration)

2. To find out if active communication with the support team and immediate assistance from TA and/or instructors encourages students to persevere through more challenging problems during exams.
3. To examine if this new supportive environment instills a sense of trust and encourages further questions to be asked outside of the "Engaged Mathematics Lab".
4. To capture student opinions and feedback of the "*Engaged Mathematics Lab*" rather than basing our results purely on grades.
5. To improve our understanding of the student perspective and the efficacy of the "*Engaged Mathematics Labs*" relative to the other existing methods of assessments such us online quizzes, individual assignment, and take-home assignment.
6. To examine if the preference of working in groups or individually different based on gender.
7. To find out the advantages and disadvantages of "Engaged Mathematics Lab" from students perspectives.

Data Source and Analysis of the Data

A total of 222 students participated in an online survey out of 807 students enrolled in two large first-year mathematics classes. The data were analyzed in the statistical software R. The survey consisted of several questions pertaining to different aspects of the mathematics engaged labs using multiple choice answers, some Likert scale style questions, and open-ended written response questions. Descriptive statistics using percentages were used to analyze multiple choice response questions. Differences across classes (calculus I and [business mathematics]) and genders were analyzed using the Kruskal-Wallis (KW) test. A p-value of <0.05 was considered statistically significant. One sample t-tests were used to determine preferences for one format of lab assessments over another. Finally, open ended student responses were grouped based on key topics and themes.

RESULTS

In-Class Surveys

The results from the in-class surveys (where students were asked about how they were progressing through their labs) are divided into each of the three labs: individual, group, and choice of individual or group.

Lab 1: Individual

For the first lab assignment, students worked on the lab assignments individually. During the lab time, students filled out an online poll about how they progressed through the assignments. The results are summarized in **Figure 1**.

For the first in-class lab, 6.2% of MATH*1200 (calculus I) students and 9.3% of MATH*1030 (business mathematics) students responded, "struggling and need assistance". 42.1% of MATH*1200 (calculus I) students and 50.8% of MATH*1030 (business mathematics) students responded, "progressing but periodically need assistance". Finally, 51.7% of MATH*1200 (calculus I) students and 39.9% of MATH*1030 (business mathematics) students responded, "the assessment is going well, and I do not need assistance". Students were encouraged to ask more questions to gain clarification about assignment questions.

Lab 2: Group

For the second lab assignment, students worked on the lab assignments in groups of two-four. During the lab time, the same questions as the first lab were asked in an online poll about how they progressed through the assignments. The results are summarized in **Figure 2**.

For the second lab, where students were working in groups of two-four, 20.4% of MATH*1200 (calculus I) students and 1.2% of MATH*1030 (business mathematics) students responded, "struggling and need assistance". 52.3% of MATH*1200 students and 31.3% of MATH*1030 students responded, "progressing but periodically need assistance". Finally, 27.2% of MATH*1200 students and 67.5% of MATH*1030 students responded, "the assessment is going well, and I do not need assistance". Although, the material

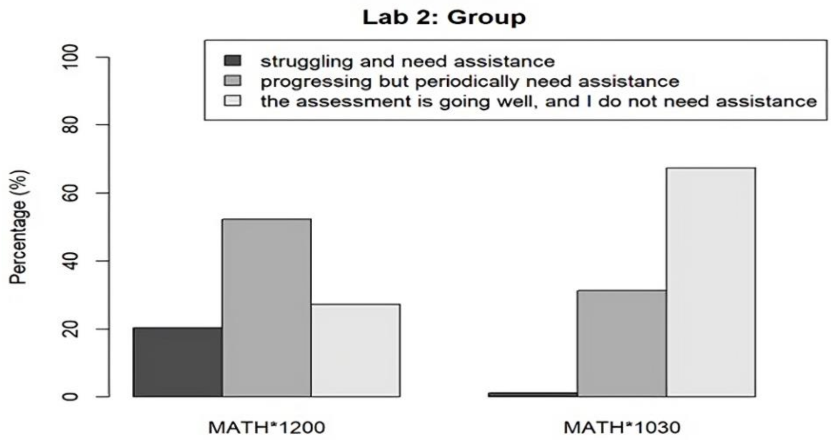

Figure 2. Histogram of online poll "in-class" results from lab 2 (group) separated by class (Source: Authors' own elaboration)

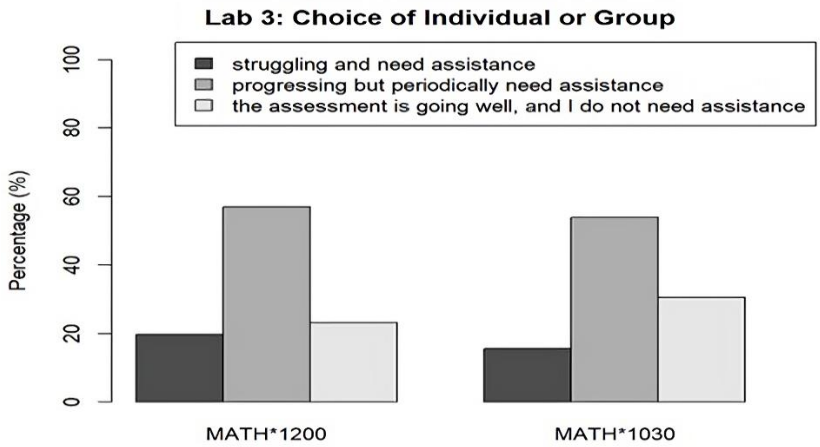

Figure 3. Histogram of online poll "in-class" results from lab 3 (choice of individual or group) separated by class (Source: Authors' own elaboration)

was more challenging in the second lab for both classes, more students from MATH*1200 (calculus I) responded that they were progressing but periodically needed assistance, which may indicate that students were more comfortable getting assistance from instructors or TA's after they were encouraged to do so during the first lab. However more students from MATH*1030 (business mathematics) responded that the assessment was going well, and that they did not need assistance, which may indicate that students were getting assistance from working with their group members and peers.

Lab 3: Choice of individual or group

Lastly, in the third lab, students were given a choice to work individually, or in groups. From MATH*1200 (calculus I), 8.2% students chose to work individually, and 91.8% students chose to work in groups of two-four. From MATH*1030 (business mathematics), 9.4% students chose to work individually, and 90.6% students chose to work in groups of two-four (**Figure 3**).

In the third and final lab, 19.8% of MATH*1200 (calculus I) students and 15.6% of MATH*1030 (business mathematics) students responded, "struggling and need assistance". 57% of MATH*1200 students and 53.9% of MATH*1030 (business mathematics) students responded, "progressing but periodically need assistance". Finally, 23.2% of MATH*1200 (calculus I) students and 30.5% of MATH*1030 (business mathematics) students responded, "the assessment is going well, and I do not need assistance".

End of Semester Survey

At the end of the semester, students filled out an online survey regarding their preferences and attitudes towards group work and general engaged lab setup preferences. The survey responses were first compared by classes (MATH*1200 and MATH*1030), and secondly by gender (male, female, and other) to investigate possible difference in the students' preferences on these factors.

1. **General lab assignment preferences**
    a. *Student lab assignment work preferences*

Students were asked if they preferred working in a group, individually, or if they had no preference during a lab assignment. Overall, working in a group was preferred by students in each class. From MATH*1200 (calculus I) students, 74.4% preferred working in a group, 16% preferred working individually and 9.7% had no preference. From MATH*1030 (business mathematics) students, 78.3% of MATH*1030 students preferred working in a group, 17.4% preferred working individually and 4.3% had no preference (**Figure 4**).

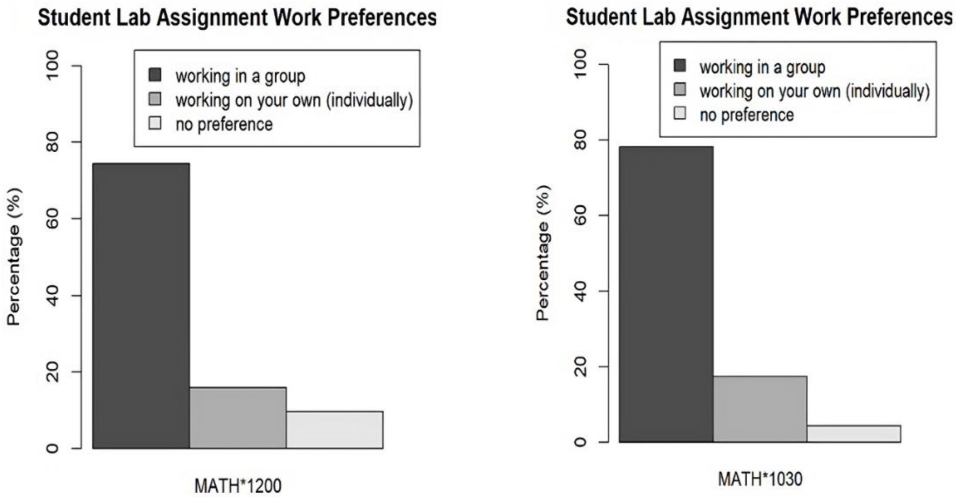

Figure 4. Lab assignment work preferences for MATH*1200 (calculus I) (left) & MATH*1030 (business mathematics) (right) (Source: Authors' own elaboration)

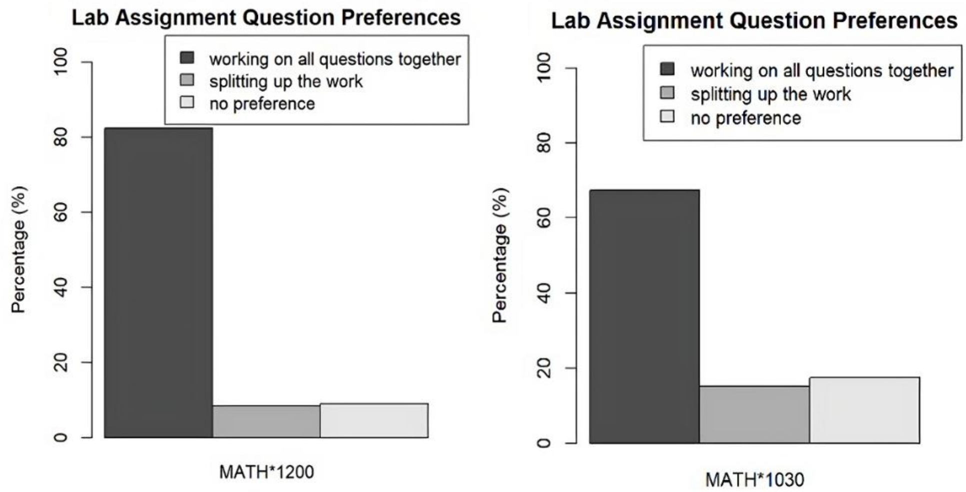

Figure 5. Lab assignment question preferences for MATH*1200 (calculus I) (left) & MATH*1030 (business mathematics) (Source: Authors' own elaboration)

A KW test was conducted to investigate whether there were differences in lab assignment work preferences between MATH*1200 (calculus I) and MATH*1030 (business mathematics). It was found that there was not a statistically significant difference between classes related to the lab assignment work preferences; work in a group, individually, or if they had no preference (p=0.5053).

Next, student work preferences are compared across gender for the same question; do students prefer working in a group, working individually, or no preference? When compared across gender, working in a group is mostly preferred across all genders, with no significant differences between them. From the male student population, 75.2% preferred working in a group, 15.6% preferred working individually, and 9.2% had no preference. From the female student population, 75% preferred working in a group, 18.4% preferred working individually, and 6.6% had no preference. From the student population who do not identify as male or female, 80% preferred working in a group and 20% had no preference. A KW test was conducted to investigate whether there are differences in lab assignment work preferences between gender. It was found that there was not a statistically significant difference between genders for lab assignment work preferences (p=0.9937).

b. Lab assignment question preferences

Students were asked about how they prefer to complete lab assignment questions within a group, working on all questions together, splitting up the work, or no preference. For MATH*1200 (calculus I) students, 82.4% preferred working on all question together, 8.5% preferred splitting up the work, and 9.1% had no preference. For MATH*1030 (business mathematics) students, 67.4% preferred working on all questions together, 15.2% of MATH*1030 preferred to split up the work, and 17.4% had no preference (**Figure 5**).

Differences across classes were investigated through a KW test, where it was found that there were significant differences between classes for lab assignment question preferences (p=0.03).

Although working on all questions of the lab assignment was mostly preferred by students in both classes, a larger percentage of MATH*1200 (calculus I) preferred working on all questions together, while a larger percentage of MATH*1030 (business mathematics) students preferred to split up the questions or had no preference.

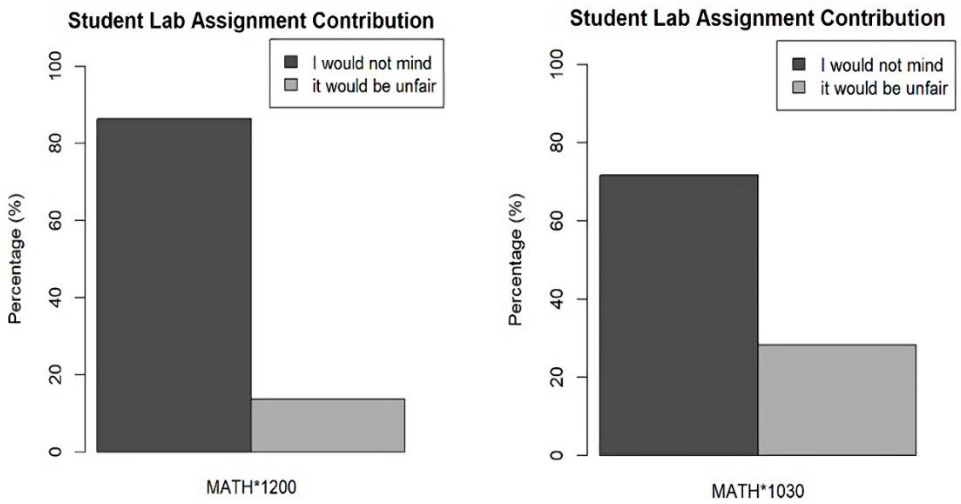

Figure 6. Student lab assignment contribution attitudes for MATH*1200 (calculus I) (left) & MATH*1030 (business mathematics) (right) (Source: Authors' own elaboration)

Next, the same responses are investigated across gender. From the male student population, 75.9% preferred working on all questions of a lab assignment together, 12.8% preferred splitting up the work, and 11.3% had no preference. From the female student population, 85.5% preferred working on all questions of a lab assignment together, 5.3% preferred splitting up the work, and 9.2% had no preference. From the student population who do not identify as male or female, 80% preferred working on all questions together and 20% have no preference. When the same responses are compared across gender using the KW test, there was not a significant difference between genders found in lab assignment question preferences (p=0.2985).

c. Lab assignment contribution attitudes

Next, students were asked how they felt about contributing more than their fair share during a group lab assignment with possible responses of "I would not mind", or "it would be unfair". For MATH*1200 (calculus I) students, 86.3% of students did not mind and 13.7% felt that it was unfair to contribute more than their fair share in a group lab assignment. For MATH*1030 (business mathematics) students, 71.7% of students did not mind while 28.2% felt that it was unfair to contribute more than their fair share in a group lab assignment (**Figure 6**).

When compared between classes, the KW test revealed significant differences between classes (p=0.02). In group work settings, there is often a concern for the equality of that effort and contribution from each student. A higher percentage of students in MATH*1200 (calculus I) seem to not mind contributing more than their fair share in group assignments and a higher percentage of MATH*1030 (business mathematics) students felt that it was unfair.

The same questions regarding student contribution attitudes were compared between genders. 28.9% of female students responded, "it would be unfair", while only 9.9% of male students responded, "it would be unfair". 90.1% of male students, 71.1% of female students, and 80% of students who identify as other responded "I would not mind" contributing more than their fair share.

The KW test revealed significant differences in responses between genders (p=0.0016) in lab assignment contribution attitudes. For differences between genders, a post hoc Dunn test is conducted to find which of the three groups (male, female, and other) significantly differ from each other. The significant difference is found in the pairwise comparison between female and male students (p=0.001).

Based on the post hoc Dunn test and **Figure 6**, female students responded that it would be unfair to contribute more than your fair share on a group assignment significantly more than male students.

d. Group lab assignment setup preferences

Next, students were asked if they enjoyed the general setup of the lab assignments (i.e. working in assigned/selected groups and having the TAs available for help). Overall, most students from both classes answered "yes" to the question "do you like the setup of the group lab assignments?"

For MATH*1200 (calculus I), 79.5% answered "yes", 6.3% answered "no", and 14.2% had no preference. For MATH*1030 (business mathematics), 91.3% of students answered "yes", 2.2% answered "no", and 6.5% had no preference (**Figure 7**).

The KW test indicated that there was not a significant difference in responses between classes for group lab assignment setup preferences (p=0.07).

When comparing responses across gender, most students responded "yes" when asked if they like the setup of group lab assignments. 79.4% of male students, 88.2% of female students, and 60% of students who identify as other responded "yes". Only 6.4% of male students, 2.6% of female students, and 20% of other students responded "no".

When the same question regarding student group lab setup preferences were compared across genders, the KW test revealed that there was not a significant difference in responses between genders for the setup of group labs (p=0.15).

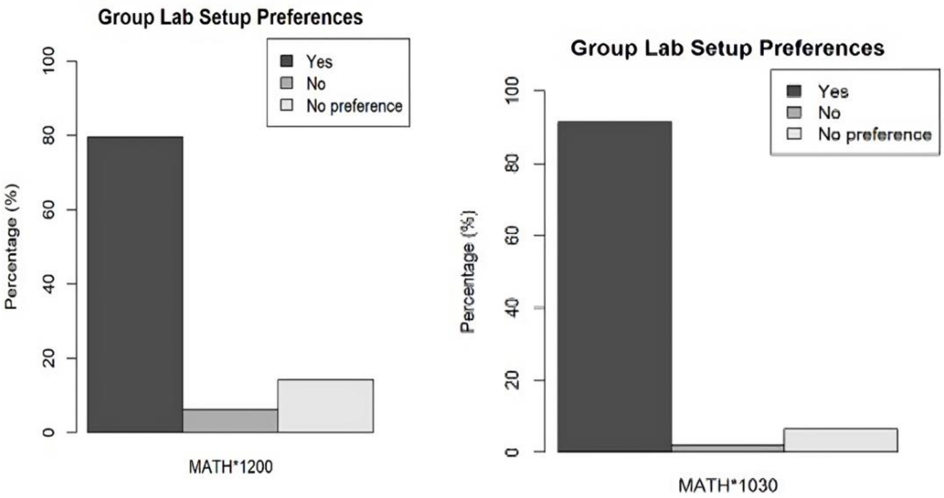

Figure 7. Group lab setup preferences for MATH*1200 (calculus I) (left) & MATH*1030 (business mathematics) (right) (Source: Authors' own elaboration)

2. **General mathematics assessment preferences**

   a. *Open book vs. closed book assessments*

Students were asked if they found that open-book group/individual lab assignments have been useful in helping them keep up with course materials.

From MATH*1200 (calculus I), 90.9% of students agreed that open-book lab assignments have helped them keep up with course material while 9.1% did not feel that open-book lab assignments have helped them keep up with course material.

From MATH*1030 (business mathematics), 97.8% agreed that open-book lab assignments have helped them keep up with course material and 2.2% did not feel that open-book lab assignments have helped them keep up with course material.

The KW test suggests that there was not a significant difference between classes in open book preferences (p=0.12).

   b. *Online quizzes vs. in-class lab assignments*

Online quizzes are one of the more traditional forms of assessment in mathematics classes. Students were asked if they preferred online quizzes (written with no help from your peers or the TAs) instead of the new in-class **group** lab assignments, and if they preferred online quizzes over in-class **individual** assignments. Firstly, there was not a significant difference found between classes in preferences for online quizzes over in class **group** lab assignments (p=0.14). In addition, there was not a significant difference found between classes in preferences for online quizzes over in class **individual** lab assignments (p=0.43).

A one sample t-test indicated that in general (in both classes), students do not prefer online quizzes over in-class group assignments (mean=2.57 on a scale of three, where yes=1, no preference=2, and no=3, p=1). In addition, students do not prefer online quizzes over in-class individual assignments (mean=2.25 on a scale of three, where yes=1, no preference=2, and no=3, p=1).

   c. *Take-home assignments vs. in-class lab assignments*

Take-home assignments are another type of assessment used in mathematics classes. Students were asked if they preferred take home assignments (written with no help from peers) instead of the new in-class **group** lab assignments, and if they preferred take home assignments over in-class **individual** lab assignments.

Firstly, there was not a significant difference between classes in preferences for take home assignments over in class **group** lab assignments (p=0.24). However, significant differences were found between classes in preferences for take home assignments over in class **individual** lab assignments (p=0.03).

The one sample t-test indicated that students do not prefer take-home assignments over in-class group lab assignments (mean=2.27 on a scale of three, where yes=1, no preference=2, and no=3, p=1). However, it was found that students prefer take-home assignments over in-class individual lab assignments (mean=1.87 on a scale of three, where yes=1, no preference=2, and no=3, p=0.025).

   d. *Types of mathematics assessment preferences*

Students were asked about which type of mathematics assessment they preferred from group lab assignments, take-home assignments, individual lab assignments, online quizzes, or no preference.

From MATH*1200 (calculus I), 57.7% of students preferred group lab assignments, 21.7% of students preferred take-home assignments, 10.9% of students preferred individual lab assignments, 2.3% of students preferred online quizzes, and 7.4% of students had no preference.

From MATH*1030 (business mathematics), 56.5% of students preferred group lab assignments, 32.6% of students preferred take-home assignments, 6.5% of students preferred individual lab assignments, 2.2% of students preferred online quizzes, and 2.2% of students had no preference.

Table 1. Skills developed by students in group lab assignments

Item on survey	MATH*1200 calculus I (n=173)	MATH*1030 business mathematics (n=44)
1. Teamwork	86.7%	79.5%
2. Communication	83.8%	88.6%
3. Time management	61.3%	56.8%
4. Academic development	58.4%	45.5%
5. Leadership	55.5%	52.3%
6. Significantly higher confidence in your ability to complete similar questions again	74.0%	61.4%

Table 2. Biggest benefits of group lab assignments

Item on survey	MATH*1200 calculus I (n=173)	MATH*1030 business mathematics (n=44)
1. I can use the strengths of my peer group.	76.4%	81.8%
2. I can share the workload.	59.8%	68.2%
3 I develop interpersonal and teamwork skills.	52.3%	61.4%
4. I learn from my peers.	78.2%	81.8%
5. I increase my self-confidence.	57.5%	54.5%
6. I learn to effectively use resources available in the course to solve questions.	56.3%	61.4%

Table 3. Group lab assignments comments separated by disadvantages and advantages per class

<table>
<tr><th></th><th></th><th>MATH*1200 (calculus I)</th><th>MATH*1030 (business mathematics)</th></tr>
<tr><td rowspan="2">Drawbacks</td><td>Relying on other group members, not contributing fair share</td><td>29 students mentioned that relying on other group members & not contributing their fair share is a significant disadvantage of group lab assignments.
"If you are unfamiliar with material, it is possible to rely on strong group members to get a good mark, which might negatively affect your work ethic."</td><td>14 students mentioned that relying on other group members & not contributing their fair share is a significant disadvantage of group lab assignments.
"I think the only drawback is that in some cases, one person may be doing all the work while everyone else just copies the answers."</td></tr>
<tr><td>Time constraints</td><td>15 students mentioned the time constraints of group lab assignments.
"Time slips always very quickly as you are trying to explain concepts while doing the assignment."</td><td>Four students mentioned the time constraints of group lab assignments.
"Lack of time to complete all questions."</td></tr>
<tr><td rowspan="2">Advantages</td><td>Sharing ideas through teamwork & collaboration</td><td>43 students commented about being able to share ideas through teamwork and collaboration.
"The ability to bounce different ideas off one another to determine the best way to solve a problem."
"Being able to bounce ideas off other people to come up with a solution when you are stuck on a problem rather than being alone, which could take people time to come up with a solution themselves. You are also developing teamwork skills, which are needed for future for your career."</td><td>12 students commented about being able to share ideas through teamwork and collaboration.
"Having peer support and talking through questions together helps promote learning that is memorable."</td></tr>
<tr><td>Learning from/ teaching other group members</td><td>17 students mentioned learning from, and teaching peers is a big advantage of group work.
"Biggest advantage is that if you are struggling on a problem your group is able to help & you can learn from them."</td><td>11 students mentioned learning from, and teaching peers is a big advantage of group work.
"Helps improve your work through communication and learning from your peers."</td></tr>
</table>

The KW test indicated there are no significant differences in mathematics assessment format preferences between classes (p=0.69).

3. Advantages and disadvantages of "Engaged Mathematics Lab" from students perspectives

a. Skills and benefits gained from mathematics labs

Mathematics labs allow students to gain skills and benefits not provided during traditional lectures. Students responded to what skills they felt they could develop when working on a group lab assignment, as well as what they felt were the biggest benefits of working on group lab assignments. These survey questions had an option to check all the options that apply to the student. The results are summarized in **Table 1** and **Table 2**.

Based on **Table 1**, the skills gained the most by students in MATH*1200 (calculus I) was teamwork, while student in MATH*1030 (business mathematics) gained skills in communication the most. Regardless, a combination of numerous valuable skills can be developed by students through engaged mathematics labs. Based on **Table 2**, the benefits of group lab assignments by students in MATH*1200 (calculus I) was learning from peers. Similarly, students in MATH*1030 (business mathematics) felt the biggest benefits of group lab assignments were using the strengths of their peer groups and being able to learn from their peers.

b. Student comments (advantages and disadvantages).

Student comments on the advantages and disadvantages of lab assignments for each class were counted based on topics and frequency of the comments being mentioned. For students that preferred group lab assignments, they were asked to comment on what they felt were the biggest drawbacks and advantages of working in groups for lab assignments. The results are summarized in **Table 3**.

Table 4. Individual lab assignments comments separated by disadvantages and advantages per class

		MATH*1200 (calculus I)	MATH*1030 (business mathematics)
Drawbacks	Lack of peer collaboration and discussion	17 students mentioned the lack of collaboration and peer discussion as a disadvantage. "You do not have access to other people's ideas/perspectives when problem solving."	Two students mentioned the lack of collaboration and peer discussion as a disadvantage. "Not having the ability to work together."
Advantages	Use of individual knowledge helps in test preparation	12 students mentioned that individual lab assignments better prepare students for tests through use of individual knowledge. "It's similar to a test so it feels like better preparation. You cannot talk to people in an exam, so this is like starting to mimic mentality I go into when I enter an exam."	One student mentioned that individual lab assignments better prepare students for tests through use of individual knowledge. "It is fair as each student shows their own knowledge & there is no student who is relying on their peer's knowledge to get them a good mark."
	Increased focus & less distractions	Eight students commented on being able to focus and less distractions with individual lab assignments. "Ability to focus without distractions, gives you an idea of your own skill level."	

For students that preferred individual lab assignments, they were asked to comment on what they felt were the biggest drawbacks and advantages of working individually for lab assignments. The results are summarized in **Table 4**.

DISCUSSION

The study was aimed at the qualitative investigation of students' perceptions regarding aspects of their academic engagement (learning gain, develop skills, use resources available, social relations) through a small group mathematics lab assignment. This study presents findings that describe how ***"Engaged Mathematics Lab"*** can provide unique insights into the quality of instruction experienced by students in mathematics. These insights are capturing both the instructional expectations and the student responses expectations. Abd Algani (2018, 2019) highlights the importance of interactivity among the students and the teachers, which is very significant for education environments. The ***"Engaged Mathematics Lab"*** described in this paper results in strong evidence of the effectiveness of this new design of mathematics labs to motivate and engage students. Motivation and engagement influence each other (Afflerbach & Harrison, 2022). Students reviewed the group lab setting as a positive learning experience, especially when the instructor, TAs or peer students within the group provided support when other students struggled to grasp conceptual mathematical ideas. The study also provides evidence that students are enjoying working in groups over individual labs, online quizzes and take-home assignments. Moreover, the students are willing to ask questions comfortably and this evidence in students' responses to the survey question and our observation during the labs time. Positive interpersonal relationships enhance individuals' enthusiasm for learning (Mercer & Dörnyei, 2020). It seems that this finding underpins our initial thought to use ***"Engaged Mathematics Lab"*** as a supplemental tool to manage engagement, motivation, cooperation in mathematics labs. and to improve students experience learn and use resources available in the course.

CONCLUSIONS

This study pointed out many noteworthy results. Students enjoy being able to work in groups regardless of major or gender. The benefits from the point of view of the students who prefer to work in groups during labs 74.4% of MATH*1200 (calculus I) and 78.3% of MATH*1030 (business mathematics), were sought through learning from their peers, being able to use the strengths of their peer groups, can gain various skills such as teamwork, self-confidence, learn to effectively use resources available in the course to solve questions and communication.

For students who prefer to work individually during labs 16% of MATH*1200 (calculus I) students and 17.4% of MATH*1030 (business mathematics), advantages present themselves through increased ability to focus and more effective test preparation, as students are only relying on their own knowledge to complete lab assignments (**Table 4**).

In summary, from the point of student preference, the "Engaged Mathematics Labs" offer students both a cognitive and effective engagement experience. When students work effectively with others, their engagement may be amplified as a result (Wentzel, 2009), mostly due to experiencing a sense of connection to others during the activities (Deci & Ryan, 2000). Moreover, students learned to effectively use resources available in the course to solve questions that deepen their understanding of course concepts (**Table 2**). Also, students developed teamwork skills, where they were ability to bounce different ideas off one another to determine the best way to solve a problem (**Table 3**). "Teaching teamwork skills requires new methods of teaching and changes in the structure of traditional education with support from communities" (Brown, 2010, p. 1). Furthermore, students gain confidence and a willingness to ask questions to broaden their understanding (Table 3). Finally, students gain communication and collaborative skills, which are invaluable skills for everyday life (**Table 3**). High-quality teacher-student relationships are another critical factor in determining student engagement, especially in the case of difficult students and those from lower socioeconomic backgrounds (Fredricks, 2014). By forging strong interpersonal relationships with others, students have a sense of belonging, promoting a more positive self-image.

Limitations

This paper focuses on first-year mathematics student population in large classes; therefore, the implementation of the results is restricted to colleges that have similar student body and academic majors. This paper follows an observational study design, so we are expecting many confounder variables. For example, the content of the first and second lab assessment was completely different, so students could be asking for more help because the content is harder.

Recommendations and Future Directions

The findings above suggest some important recommendations. In colleges with diverse student populations or with a large population of "freshman and sophomore" students, administrators may consider scheduling more lab sections for mathematics classes because not all mathematics classes have dedicated lab time. Moreover, TAs in labs should be prepared primarily to help students during the labs.

This study brought an alternative approach to investigate methods for improving students' engagement through "Engagement Lab Assignments". Indeed, its recommendations are based on students' perspectives rather than students' performance. Conspicuously, improving grades rates was not one of the design goals we focused on. Therefore, using grades such as analyzing term grade point average scores can be revisited for further investigation with this approach.

Since a survey technique was used, one should be careful in generalizing the findings of this study and should do so to only to a population with similar characteristics of the target population (Graziano & Raulin, 2013). Furthermore, differences in lab preferences can be investigated across additional factors such as ethnicity, major, or university level, similar to Shaqlaih and Celik (2013) study settings.

Finally, running an experiment rather than an observational study will solve the issues with the confounder variables. For example, if it is possible, to set one of the sections, where you can divide the students randomly into two groups one of them, where they can work individually and the other section as groups can solve the issues of the confounder variables, but that will require approval from the ethic board and the students.

Author contributions: All authors have sufficiently contributed to the study and agreed with the results and conclusions.

Funding: No funding source is reported for this study.

Ethical statement: Authors stated that the study was approved by the Research Ethics Board (REB) at University of Guelph.

Declaration of interest: No conflict of interest is declared by authors.

Data sharing statement: Data supporting the findings and conclusions are available upon request from the corresponding author.

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