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To cite this article:

Aldridge, K., & Theiss, K. (2025). What is the impact of student reflections and intentional project-based learning on student success and attitude in a mathematics classroom? *International Journal of Education in Mathematics, Science, and Technology (IJEMST), 13*(6), 1582-1594. https://doi.org/10.46328/ijemst.5278

International Journal of Education in Mathematics, Science and Technology

2025, Vol. 13, No. 6, 1582-1594 https://doi.org/10.46328/ijemst.5278

What is the Impact of Student Reflections and Intentional Project-Based Learning on Student Success and Attitude in a Mathematics Classroom?

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Article Info

Article History

Received:
25 June 2025
Accepted:
12 October 2025

Keywords

Math anxiety
Project based learning
Math autobiography

Abstract

Our study focused on the challenges of student attitudes towards math has on their performance in the mathematics classroom. We sought out to see the impact of reflective opportunities on how students feel about the mathematics they are learning as well as how they view themselves as mathematicians. We also incorporated Project Based Learning to allow students to collect and analyze their own data, interview professionals, and present their findings. Our results highlight the need for educators to use methods which allow students to reflect, and to be provided with a variety of learning methods in the math class setting. Our findings further suggest that utilizing these teaching practices may reduce anxiety, and students have opportunities to create memorable and valuable learning experiences.

Introduction

Mathematics anxiety is typically defined as a feeling of tension and anxiety that interferes with the manipulation of numbers and solving mathematical problems in a wide variety of ordinary life and academic situations (Campbell, 2005). Students feeling anxiety are less likely to be able to focus resulting in less productivity and success. Mathematics anxiety is a universal problem (Luttenberger et al., 2018) which impacts students young and old; it has become socially acceptable in some circumstances to admit that you have low confidence when it comes to completing math. The causes and contributing factors may vary from student to student but may include adult influences (Maloney et al., 2015) as well as learning experiences and environment (Kaskens et al., 2020).

Students have low confidence when it comes to expressing their ideas in math class, and this can be one of the overlooked factors related to their achievement (Kunhertanti & Santosa, 2018). Campbell (2005) notes that math-anxious individuals avoid educational tracks and career avenues that depend on math despite increasing demands. Though student anxiety in mathematics has been studied for decades, the impact of the COVID-19 pandemic which began in 2020 has undeniably affected students' learning (Jack et al., 2023). Our research seeks to find out what impact student reflection and PBL has on their attitude towards mathematics.

Literature Review

The COVID-19 pandemic forced teachers to teach differently, and for students to learn differently. Educators navigated their way through various challenges including the transition to remote learning, socioemotional impacts, and the impacts on student learning. As we return to a post-pandemic "regular" teaching environment, focusing on excellent teaching within the classroom can help overcome the ongoing learning challenges students are facing (Engelbrecht et al., 2023). According to Choi et al. (2017), online learning demands a *greater degree of learner autonomy* and self-regulation compared to traditional learning environments. A pre-pandemic study conducted by Liu et al. (2022) showed that student grade level and prior academic performance were strong predictors of success in online courses, while ethnicity and socioeconomic status showed statistically significant differences in performance, indicating equity concerns in virtual environments. Additionally, hybrid or virtual schooling modes cannot support student learning in the same way as fully in-person instruction can, at least during the elementary and middle school period (Jack et al., 2023). Learning mathematics had already been a challenge for some, and to add on the challenges of learning online during that period, students may have had increased anxieties and/or experienced a drop in success during distance learning (Pulungan et al., 2022).

According to Ashcraft and Moore (2009), math anxiety is evident in students as young as elementary school. Several studies show that students have less favorable attitudes towards math in high school than they do in primary grades. Bru et al. (2010) cite several studies undertaken in Norway that show that elementary-school children have more positive perceptions of their learning environments than their secondary school counterparts. Schielack (2010) suggested that curriculum may play a role in students' difficulty transitioning to high grades. Notably the books have different color schemes, greater word density, a smaller font size, more word problems, and more computational items in the exercise sets. Wang and Eccles (2013) study revealed that students' motivation in middle school is shaped not only by their ability or prior achievement but also by their relationships with teachers, the structure of classroom activities, and the perceived relevance of the material. Students describe motivational highs when they feel challenged yet supported, and lows when instruction feels disconnected or punitive. These thoughts continue with many students through high school and beyond (Samuelsson, 2023). Powell and Seed (2010) suggest assigning students a writing task via a mathematical autobiography to learn about students' previous experiences in mathematics in hopes to identify possibly sources of anxiety and struggle.

Integrating project-based learning (PBL) can be a key strategy for fostering deeper understanding and real-world application of algebraic concepts (Han et al., 2014). Because of the nature of STEM PBL instruction, students may have to rely more heavily on prior knowledge of the subject or may have to make new connections to knowledge from another subject that previously was just an isolated fact. This process, in turn, may lead students to increase their mathematical self-acknowledgement, which refers to a student's affect toward cognition, as a factor of affective mathematics engagement and value (Lee et al., 2019). Using PBL in the classroom can increase students' interest and desire to pursue a STEM field (LaForce et al., 2017). PBL not only makes math more relevant to students' lives but also promotes a more engaging and active classroom environment. It can provide students with autonomy over their learning by providing them with choices regarding the process for solving the driving question or challenge. Choice promotes intrinsic motivation,

resulting in greater persistence, and allowing students to pursue challenges in ways that are appropriate for them, while at the same time inspiring them to take on greater challenges (Craig & Marshall, 2019). A study by Jenkins (2017) has also shown that using PBL in the classroom has specific positive outcomes for African American students.

After observing the lingering effects of the pandemic on student learning, combined with pre-existing attitudes towards mathematics, the researchers designed this study focused on the combined impact of three key supports: structured student reflections, intentional project-based learning experiences, and periodic one-on-one meetings between students and teacher. The goal was to determine whether these targeted interventions could improve both student performance and their overall attitude towards mathematics.

Methods

The research was conducted in a suburban high school in Southern California with an enrollment of 1,667 during the 2023-24 school year. The student body is made up of 70% Hispanic students, 17.8% Black, 3.6% Filipino, 3.2% White, and 2.3% Asian. 47% of the students are female and 53% male. 81% of students are classified as socioeconomically disadvantaged (Education Data Partnership, 2025).

The 44 students represented in the study are general education ninth grade students in a year-long Algebra 1 class. The teacher met with students daily for approximately 88 minutes. During the second week of school, an attitude survey was administered to determine students' attitudes towards mathematics as well as a content knowledge test that measured how much of the Algebra 1 curriculum students already knew. The first author administered the attitude survey and content knowledge test again at the conclusion of the study. Students were asked five open response questions about their experience learning and doing math, and 11 questions that were measured on a three-point Likert scale (see Table 1). The five open response questions differed slightly from the pre-to-post attitude survey, but the Likert questions remained the same so that comparisons and analyses could take place. Students completed the survey using the Qualtrics platform. On average, students completed the survey in about seven minutes. The content knowledge test was unchanged across the school year and included 13 standards-based questions aligned to the key learning targets for Algebra 1. The students completed the test using Qualtrics which included a range of multiple choice and open response questions.

Table 1. Pre/Post Attitude Survey Questions

Item Number	Survey Statement
1	I think that I am good at math
2	Math is fun
3	Math is an important subject to learn
4	I feel comfortable sharing my ideas

Item Number	Survey Statement
5	I enjoy working with others
6	I am not afraid to get a question wrong
7	My peers think I am good at math
8	I use math every day
9	Mistakes help me learn
10	I feel comfortable asking my teacher for help when needed
11	I am a mathematician

Note. Students rated each item using a three-point Likert scale (agree, somewhat agree, disagree).

Classroom Activities

The mathematical autobiography, which required students to detail their experiences in both learning math, along with their experiences in previous math classes, was also assigned during the second week of school. On average, students took a week to complete the autobiography. The assignment challenged students to think back to their earliest encounters of mathematics where some students detailed learning how to count or add, until the present day. The first author met with each individual student on a quarterly basis to follow up on their goals, areas for growth, and the student had the opportunity to let the first author know how the student could be further supported by the teacher. Students also had the opportunity to reflect 2-3 times per month via a journal prompt assigned by the first author which was reviewed monthly as well as during the quarterly meeting.

The first PBL assignment was during the fourth week of school which aligned to our Descriptive Statistics Unit. Students were tasked with creating their own statistical surveys to collect data on a topic of interest. They created numerical questions, polled 20 random individuals, and subsequently analyzed and graphically represented their results. Through this project, students gained hands-on experience with statistical concepts, including data collection, analysis, and interpretation. Further, they developed skills in presenting their findings by using graphs and charts to communicate their results effectively. This project emphasized the practical application of statistics and enhanced students' ability to work independently in data analysis.

The second PBL assignment on Exponential Functions was assigned at the beginning of the third quarter. It was centered on car depreciation and its connection to exponential functions. Students conducted research on how the value of a car decreases over time, applying exponential decay functions to model the depreciation. They calculated depreciation rates for different car models and analyzed how different factors like age and mileage affected the car's value. This project not only reinforced students' understanding of exponential functions but also helped them develop critical thinking skills as they connected abstract math concepts to real-world situations.

Results

A total of 43 students took the pre content knowledge test, 24 took the post content test, and 21 students completed both. A total of 44 students took the pre attitude survey, 35 took the post survey, and 32 took both the pre and post attitude survey. When comparing both the content test and attitude pre and post survey, just 17 students completed all 4 items which are our sample size. We report on their results below, as other data explorations (i.e. unbalanced samples across the pre and posttests) gave very similar results.

Content Knowledge

All students showed growth from the pre content knowledge test to post content knowledge test except for two students (16 & 17 on Figure 1). Both had pre content knowledge test scores that were higher than average compared to other students participating in the study, and we believe that the significant drop in scores was due to technical error or the student not attempting question(s) on the test. Although the difference in mean test scores was not significant when these students were included (p-value 0.093), this is most likely due to the high standard deviation in the post content knowledge scores. The standard deviation for the pre content knowledge test was 5.455 and the post test was 11.155 showing that the pre content knowledge test scores were a lot closer to the mean than the post test scores. If we remove students 16 & 17 then the p-value is significant (p-value < 0.001) and the standard deviation decreases to 6.290.

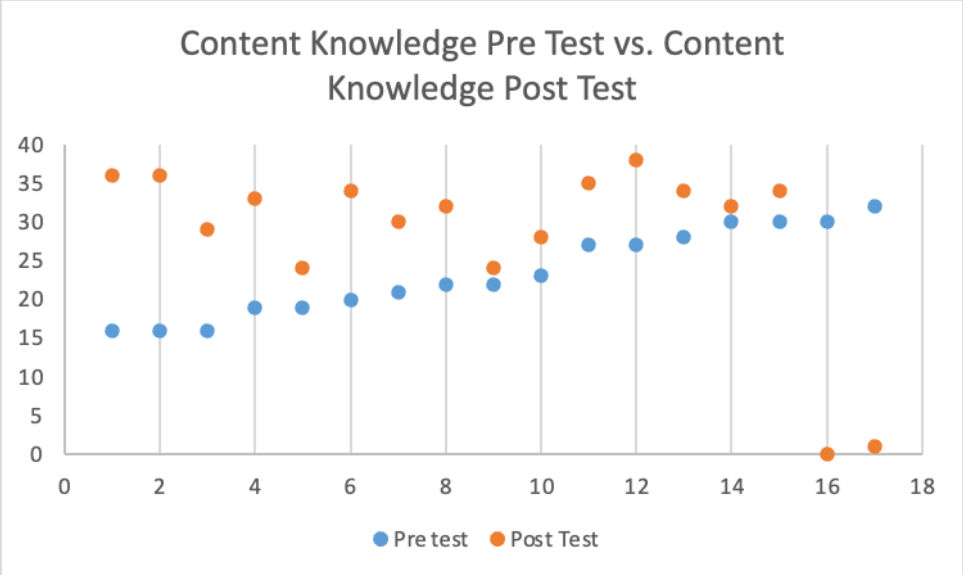

Figure 1. Individual Student Comparisons of Pre and Post Content Score

Thematic Analysis of Open-Ended Questions

In response to the question "When you hear the word math, how does it make you feel/what do you think of?", students initially responded with the following themes: four felt challenged and/or stressed, four thought about math concepts, five felt excited or happy, two felt tired or bored, and two students felt nothing. Students that felt

stressed and/or challenged commented that math made them feel uneasy, they didn't like the pressure from people that have high expectations from them, and that math is their least favorite subject. Our decision to group "challenged" and "stressed" together came from the fact that two out of four students that listed challenged or stressed grouped them together. One student noted "I feel challenged when completing a difficult problem, but it can get stressful". In the responses at the end of the study, the students responded with the following themes: one felt challenged, no one reported being stressed, eight students thought about mathematical concepts, five felt excited or happy, two tired and bored, and one felt nothing. When comparing the pre and post attitude survey themes, there was a reduction in the number of students that felt stressed or thought that math made them feel challenged (4 to 1). There was an increase in students who thought of math concepts and being in math class (4 to 8). One student mentioned they appreciated that there are multiply ways to solve problems in their post survey response.

When asked what students' "Favorite part about doing math", the results of the post attitude survey overwhelmingly showed an increase in the number of students which enjoyed not just practicing math but understanding math concepts specifically. Our pre attitude survey results include: four students enjoyed understanding concepts, eight students noted specific concepts they liked, three mentioned learning new things, and two enjoyed activities. A few students described the satisfaction of getting a difficult question right and when they understand what they are doing. Most students that enjoyed concepts described that they enjoyed solving equations/solving for the unknown. The post survey results showed that 13 students identified understanding concepts as their favorite, two for learning new things, and two enjoyed the activities. There was one fewer student that acknowledged their favorite part was learning new things, and the number of students enjoying activities remained the same. Four students used the word fun in their post reflections as compared to no usage of the word in the pre attitude survey. Students also commonly described solving equations as their favorite concept to understand and do in the post attitude survey.

When identifying students' least favorite part about doing math, the responses were widely varied. One student noted that showing work was their least favorite part, three disliked word problems, three students disliked the repetition/boredom, two noted quizzes and tests, two mentioned the difficulty of the subject, two making simple mistakes, one said taking notes, and three had no least favorite part. The Post attitude survey showed that two students expressed that their least favorite part about doing math was working with decimals and/or fractions. Four students stated that the difficulty is their least favorite, one student said completing big projects, one taking notes, one said when they got bored, two said that they don't like when they get confused, one said they don't like explaining their work, two said word problems, two said testing, and just one person said nothing. One student noted that they don't like it when they get decimal answers because it makes them feel like they are incorrect. No one mentioned repetition in the post attitude survey as compared to three students that mentioned it in the pre attitude survey. The same number of students expressed that tests/projects were their least favorite part, and two more students added that the difficulty of the content was their least favorite part about doing math.

The post attitude survey results showed that none of the students had negative memories in math class this year,

as compared to four which had a negative memory at the beginning of the year. The pre attitude survey showed that three students' most memorable experience was learning how to multiply, one how to count with their dad, two earning an award, three mentioned that 8th grade was most memorable for them, one student recalled a compliment that a teacher gave them, one student was proud to share that they improved their standardized test scores, one student enjoyed working with classmates, another students' most memorable experience was when the concepts were easy to learn, and four had negative memories. Several students shared that they remember being embarrassed about getting a question wrong in front of the class in their pre survey response. At the end of the year, all students had a positive experience to share. Eight students enjoyed the projects we completed; one student's most memorable experience was doing well on the tests, five students enjoyed the games/challenges that we completed, and four noted that they enjoyed working with classmates to complete tasks.

Analysis of Attitude Statements

We measured students' attitudes using a Likert scale of agree, somewhat agree, or disagree. After reviewing our initial results, we categorized the responses into three groups to assist in our analysis. The themes include: Student Perception of Themselves, Learning in a Mathematics Classroom, and Math Enjoyment and Practicality.

Student Perception of Themselves

1. I think I am good at math
2. My peers think I am good at math
3. I am a mathematician

These statements tap into the way students view themselves as mathematicians, as well as their perception of of the ideals of their peers which may influence their confidence. Students who experienced embarrassment in front of their peers are likely to have anxiety towards learning and it may impact their abilities (Ashcraft & Moore, 2009). The pre attitude survey showed that 58.8% of students agreed, 29.4% somewhat agreed, and 11.7% disagreed when asked to respond to the statement "I think I am good at math". The post attitude survey showed the exact same results with 58.8%, 29.4%, and 11.7% respectively. For the statement "My peers think I am good at math", 47% agreed with the statement in the pre attitude survey, 29.4% somewhat agreed, and 23.5% disagreed. The post survey results had 52.9 % agreeing with the statement, 35.2% somewhat agreed, and 5.9% disagreed ($p = 0.236$). When asked whether or not students identified as a mathematician, the pre attitude survey showed that 23.5% of students agreed with the statement, 47% somewhat agreed, and 29.4% disagreed. The post survey showed a jump to 41.1% of students that agreed, 41.1% somewhat agreed, and 17.6% disagreed ($p = 0.056$).

Learning in A Mathematics Classroom

1. I feel comfortable sharing my ideas
2. I am not afraid to get a question wrong

3. Mistakes help me learn
4. I feel comfortable asking my teacher for help when needed

This set of statements focus on the learning experience of students. The learning process includes asking for help, making mistakes, and justifying your reasoning with others. For the statement "I feel comfortable sharing my ideas", 47% agreed with the statement in the pre survey, 47% somewhat agreed, and 5.9% disagreed. The post survey showed that 52.9% agreed, 35.2% somewhat agreed, and 11.7% disagreed ($p > 0.5$). "I am not afraid to get a question wrong" yielded 31.3% students that agreed, 43.8% that somewhat agreed, and 25% which disagreed in the pre survey. The post survey showed that 41.1% of students agreed, 47% somewhat agreed, and 11.7% disagreed ($p = 0.164$). When students were asked whether they agreed with the statement "Mistakes help me learn", the pre attitude survey showed that 94.1% of students agreed with the statement, 5.9% somewhat agreed, and no students disagreed. The post survey showed a drop to 76.4% of students agreeing that mistakes help them learn, 23.5% of students somewhat agreed, and 0% disagreed ($p = 0.188$). The pre attitude survey showed that 76.4% of students agreed, 23.5% somewhat agreed, and 0% disagreed with the statement "I feel comfortable asking my teacher for help. The post survey showed that 82.3% of students agreed with the statement, 17.6% somewhat agreed, and 0% disagreed ($p = 0.332$).

Our statement "I enjoy working with others" is placed alone as it stands to see how well students enjoy working with their peers. The pre survey showed that 52.9% of students agreed with the statement, 35.2% somewhat agreed, and 11.7% disagreed. The post attitude survey showed a slight growth with 58.8% of students agreeing with the statement, 29.4% somewhat agreed, and the same amount disagreed (11.7%; $p = 0.0718$).

Math Enjoyment and Practicality

1. Math is fun
2. Math is an important subject to learn
3. I use math every day

This group of statements evaluated how students view the importance of mathematics in their world. For the prompt "Math is fun", 52.9% of students agreed with the statement in the pre survey, 17.6% somewhat agreed with the statement, and 29.4%. The post survey showed that 35.2% agreed, 64.7% somewhat agreed, and 0% disagreed ($p = 0.496$). "Math is an important subject to learn" yielded 70.5% of students that agreed, 29.4% that somewhat agreed, and 0% that disagreed in the pre survey. The post attitude survey showed that 41.1% of students agreed, 58.8% somewhat agreed, and 0% disagreed ($p = 0.020$). The question "I use math every day" included 29.4% of students that agreed on the pre survey, 58.8% somewhat agreed, and 11.7% disagreed. The post results showed that 31.3% of students agreed with the statement, 56.3% somewhat agreed, and 12.5% disagreed ($p = 0.669$). Though there was a drop in the number of students agreeing that math is fun, no students disagreed with the statement as compared to 29.4% at the beginning of the year. No student disagreed with the statement "Math is an important subject to learn", and there were slight increases of students that agreed that they use math every day.

Discussion

Though our sample size was unusually small, it is evident that a personalized approach to teaching by assigning a mathematical autobiography and conducting several Project Based Learning opportunities has a positive impact on student learning. The results of our post attitude survey show that 47% of students noted that their most memorable experience in a math class this year was completing a project as compared to 0% that mentioned projects in the pre survey. Teachers who engage their students in activities to promote autonomy support their students' learning, confidence and success in mathematics (Samuelsson, 2023). Writing a mathematical autobiography at the start of the year allowed students to reflect on past experiences they've encountered in their math journey. Students opened up about the positive experiences as well as the negative experiences they've encountered. Most students came to class having a negative math memory at some point in their career. Four students noted a negative math memory when asked to describe their most memorable math experience in the pre attitude survey

Students benefited from working alongside peers to complete daily tasks, participate in team competitions, and complete PBL projects; We agree that this was an inevitable outcome. Students are believed to be able to achieve higher efficacy and reduced anxiety by working in a group (Lou et al., 2015). There was an increase of 5.9% who enjoyed working alongside others. Additionally, the results of our study showed that students' perceptions of themselves as mathematicians positively increased. At the beginning of the year, just 23.5% of students identified as seeing themselves as a mathematician as compared to the post survey in which 41.1% of students agreed to the statement. Students have anxieties about learning mathematics beginning at a young age (Siegler et al., 2012) but with a focus on reflection, students can change their thoughts.

The notion that students' perceptions of teacher support generally decline as students move through elementary to secondary schools (Bru et al., 2010) seemed to remain consistent with our study as there was a slight decrease in the number of students who felt comfortable asking their teacher for help. Though we maintained 0% of students disagreeing with the statement, we are proud to share that students in our study felt more confident at the end of the year when it came to not being afraid of making mistakes. At the beginning of the year 31.3% of students agreed with the statement "I am not afraid to get a question wrong." The post attitude survey showed an increase of 9.8% and the reduction of students that disagreed with the statement was 24% in the pre survey to 11.7% in the post survey. Though there was a drop in the number of students that believed that mistakes help them learn, it is important to note that all students believe to a degree that making mistakes aids in the learning process. When educators allow the space for students to make mistakes, it is believed to help students become aware of their strengths, weaknesses, and progress in learning (Granello et al., 2025). There were notable gains in the number of students that were not afraid to get a question wrong and slight gains with the number of students that felt comfortable sharing their ideas and the number of students which felt comfortable asking their teacher for help.

Although not statistically significant, there was an improvement of 4.83% in scores between the pre- and post-content assessments. Self-reflection is generally beneficial for all students, but it may not be as effective for

already high performing students (Choi et al., 2017). We had hoped to see larger gains, but the small sample size and other variables noted below may have contributed to some of the outcomes.

Though the initial 45 students who took the post attitude survey artificially dropped due to reasons out of our control, the students in our sample experienced growth in both content knowledge and attitude towards math. The limitations of our study were clearly the small sample size. There were a few changes in rosters which prevented a couple of students from completing the post attitude survey and post content knowledge test.

Conclusions

In conclusion, we agree that our methods can facilitate growth, student engagement, and achievement for students in mathematics. By incorporating PBL and assigning the Mathematical Autobiography, students are given opportunities to engage in authentic learning experiences that deepen their understanding of mathematical concepts while building their critical thinking skills, collaboration, and problem-solving skills. In addition to success in the math classroom, research supports that utilizing evidence-based strategies may help develop a growth mindset, reduce mathematics anxiety, and may also be useful in motivating more students to consider STEM careers (Cribbs et al., 2021).

Recommendations

Educators looking to model their instruction based on our study should take a few things into consideration:

Timing of Assignments

If possible, assessments should be offset by other required/planned assessments. We administered the pre content knowledge test within a week of a mandated district assessment, and the post content knowledge test within a week of both a district assessment and course final exam. To measure the program's effectiveness, you may opt to use assessments already assigned.

Technology

Ensure that students have access to the technology needed to complete the assessments; because surveys and assessments were administered at the very beginning and very end of the school year, all students didn't have access to technology, and some students had to borrow devices from peers or from another teacher. This may have affected their focus and comfortability when completing tasks. Ensuring that all students have adequate technology at the time of assessment and survey administration will encourage consistent outcomes.

PBL Implementation

Though not required, educators are encouraged to seek professional development on Project Based Learning.

The researchers completed eight sessions of PBL training with PBL Works. Through our training, we were provided with an overview of ideal components PBL projects should include to maximize learning outcomes for students. Completing PBL training allowed us to cultivate lessons that not only aligned to the curriculum but provided us with resources that assisted with the development of rubrics.

Acknowledgements

The authors would like to thank E. Barrett, C. Duenas, K. Hamdan, T. Normore, and K. Stagg for their support of this research. The authors would like to gratefully acknowledge funding for this project from the National Science Foundation Robert Noyce Master Teacher Fellowship (MTF) Track (1949973; second author co-PI). The project received IRB approval from California State University, Dominguez Hills (IRB-FY2023-105).

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