Improving Students' Learning Outcomes in Mathematics Courses using Asset-Based and Equity-Minded Approaches

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Article Info

Abstract

Teaching mathematics courses, for example Calculus, at the university level presents unique challenges due to the diverse academic, cultural, and socioeconomic backgrounds of students. This paper explores the implementation of asset-based and equity-minded pedagogical approaches to improve student learning outcomes in entry level mathematics courses. By recognizing and leveraging the unique strengths and experiences each student brings to the classroom, the instructor fosters a more inclusive and supportive learning environment. The study outlines the logistics of initiating such an approach, including the use of peer learning strategies like "study buddy" model. The paper details the methods used to implement these strategies and discusses their impact on student engagement, motivation, and academic performance. Findings suggest that when students feel valued and supported, their confidence and competence in mathematics significantly improve. This approach offers a replicable model for educators seeking to enhance equity and effectiveness in STEM education.

Introduction

When a tertiary level institution is considered an open admission institution, students of diverse backgrounds, skills and individual assets come in and the institution must provide student academic services for all students to improve their likelihood of success. The students may come from both public or private institutions, low- or high-income families, rural or urban high schools, and multi-racial-ethnic-religious upbringing or not. Most open admission type liberal arts colleges and universities usually equip themselves with a systematic approach of placing students at the correct levels, so these students feel comfortable and successful. In these scenarios, teaching entry level mathematics courses comes with a unique set of challenges for instructors. Rollins (2020) indicated that mathematics instructors need to provide appropriate instruction and support to meet the needs of all learners. Association of State Supervisors of Mathematics & Association of Mathematics Teacher Educators (2024) issued a position statement that highlights the importance of adopting asset-based practices in mathematics education. It emphasized recognizing students' strengths, talents, and resources to foster positive mathematical identities and inclusive learning environments. Martin et al. (2025) discussed the use of a networked improvement community model to support asset-based mathematics teacher preparation. It highlighted the importance of partnerships among stakeholders to build on the resources that students bring to learning settings. An Institute for Learning. (2021) article outlined three practices that support an asset-based approach in mathematics classrooms. It focuses on centering student thinking and reasoning, solidifying mathematical understanding, and bolstering positive mathematics identities. Vithal et al. (2023) reviewed research on equity in mathematics education from 2017 to 2022. It discussed conceptualizations of equity, equity-focused practices, pedagogies, and teacher education, as well as equitable curriculum content and pathways. Marzocchi et al. (2024) explored the transition of mathematics instructors to equity-minded active instruction through professional development (PD) guided by a community practice framework. It emphasized incremental and supportive PD to facilitate instructional transformation. Esmonde & Langer-Osuna (2013) addressed issues of equity in mathematics education using intersectional perspectives. It focused on the participation of traditionally and historically marginalized students and provides insights into creating equitable learning environments.

Significance of Studying Asset-Based and Equity-Minded Teaching Approaches

Asset-based and equity-minded teaching approaches are crucial for fostering inclusive and supportive learning environments. These approaches emphasize (1) recognizing and building students' strengths and (2) addressing systemic inequities in education at all levels. By focusing on what students bring to the table and ensuring all students have equitable opportunities to succeed, educators can create more engaging, effective, and just educational experiences. Lin & Wang-Hiles (2024) explored how an asset-based approach to social-emotional learning (SEL) could transform the educational experiences of multilingual learners. The authors argued that emotions are powerful resources for intellectual growth and social change, advocating for a co-learning approach that recognizes and harnesses students' sociocultural assets. Delgado & Barazon (2024) investigated the impact of asset-based teaching strategies on the reading proficiency of senior high school students. The findings indicated that focusing on students' strengths and providing varied reading experiences significantly improves their comprehension skills. Steinhardt (2024) discussed the importance of asset-based education in achieving equity in

classrooms. It highlighted how recognizing and building on students' strengths can lead to more inclusive and effective teaching practices. Soicher et al. (2024) presented a mixed-methods research design aimed at advancing inclusive and equitable teaching practices in higher education. The authors emphasized the importance of data-driven approaches to tailor teaching development initiatives to the needs of diverse academic departments. DeKorver (2025) outlined five key commitments for promoting equity in teaching. Based on interviews with students with disabilities and the author's reflections, it provided practical strategies for creating inclusive and accessible learning environments. "Every Learner Everywhere (2024)" is a guide that emphasizes the importance of culturally responsive teaching as a cornerstone of equity-minded education. It provides strategies for educators to be conscious of the realities of race and institutional racism, ensuring that all students feel valued and supported. For STEM degree programs, most outsiders consider Calculus, in this case, Single Variable Calculus or Calculus 1, as a gatekeeper and is branded as a difficult course for STEM majors to successfully complete. Burdman & Anderson (2022) discussed how Calculus serves as a significant barrier in college admissions, particularly affecting Black, Latinx, Indigenous, and low-income students.

The authors argued that the emphasis on Calculus in high school transcripts is outdated and exclusionary, suggesting that admissions offices should update their guidelines to reflect the diverse mathematical skills relevant to modern careers. Smith & Lee (2024) examined the role of Calculus as a gatekeeper in STEM education and its impact on diversity, equity, and inclusion. The authors highlighted various interventions aimed at reducing the gatekeeping effect of Calculus, such as alternative pathways and support programs for underrepresented marginalized students. Just Equations (2022) is a report that presents findings from surveys of high school counselors regarding the role of Calculus in college admissions. It reveals that while many counselors believe Calculus enhances college prospects, there is a growing recognition of the need for more relevant and inclusive mathematics pathways. How do mathematics departments and in particular Calculus instructors change the kind of mentality about Calculus? Mathematics departments and Calculus instructors are increasingly adopting innovative strategies to change the traditional mindset about this subject. Mollenkamp (2023a) highlighted the growing evidence that traditional Calculus instruction methods are less effective than active learning models. A randomized study at Florida International University showed that students who engaged in active learning performed significantly better across various demographics. The study suggested that incorporating student engagement and reducing lecture time can improve outcomes for diverse groups. Mollenkamp (2023b) discussed efforts to revamp Calculus instruction to make it more inclusive and relevant. It described how educators are integrating real-world problems into Calculus teaching to make the subject more approachable and engaging for students. The aim is to retain more students in STEM fields by making Calculus instruction more practical and less intimidating. Dagley et al. (2018) detailed the implementation of active learning strategies in Calculus courses at the University of Central Florida. The interdisciplinary team developed MATH-GAINS, an initiative to create an ecosystem where faculty consistently apply active learning methods. The study showed positive impacts on student learning, retention, and graduation rates, as well as a cultural shift within the mathematics department. FIU News (2023) reports on a study conducted at Florida International University that reimagined Calculus instruction using active learning approaches. The study found that students learned more effectively when Calculus was taught through interactive and engaging methods rather than traditional lectures. The findings supported the need for widespread adoption of these innovative teaching practices. How do Calculus instructors

introduce interventions so that most STEM students will slowly change their perception of Calculus as a gatekeeper but instead consider Calculus as a STEM degree enabler? Alzaga Elizondo and Larsen (2024) reviewed recent research on improving Calculus teaching and learning, focusing on interventions aimed at enhancing equity and inclusion.

The authors highlighted promising studies that use digital tools and critical theories to support historically marginalized students, helping to reduce the gatekeeping effect of Calculus. How does the department of mathematics change the whole system so that the rate of success in Calculus will slowly increase? Biehler et al. (2024) is a survey paper that explores emerging trends and innovations in university mathematics education, focusing on advanced mathematical topics, transitions between different levels of education, and the role of proof and proving. The authors highlighted the importance of innovative teaching methods and the need for systemic changes to support student success in Calculus and beyond. Why do some STEM majors think it is normal to take Calculus three times before passing? Even their families have been convinced that it is an acceptable feature of STEM education. This paper tells the story of an instructor who tries to implement an asset-based and equity-minded teaching approaches. This paper includes the detailed steps she took to change the students' perception, motivation, and mentality when they take Calculus courses. Bressoud et al. (2023) is a paper that analyzes various predictors of student performance in Calculus, including course times, gender, major, instructor, and term, providing insights for improving student success. Johnson and Ellis (2023) is a research article that examines how different prerequisite paths affect students' performance in Calculus, highlighting the importance of course listings and student preparedness. California State University (2023) suggested that lengthy prerequisite sequences for Calculus pose barriers to students pursuing STEM degrees, emphasizing the need for streamlined pathways to improve student success. California Education Learning Lab. (2023) described an initiative that awards grants to STEM departments to implement strategies aimed at closing equity gaps in Calculus courses, including student engagement, course coordination, and professional development. Citrus College (2023) described a project that aims to minimize the Calculus access barrier for STEM students and improve completion rates through changes in placement policies, embedding pre-Calculus concepts into Calculus instruction, and using interactive pedagogy. This paper focuses on a specific teaching techniques done in Calculus classrooms, in fact, common techniques when teaching Calculus. Its novelty comes with the implementation of both asset-based and equity-minded teaching approaches so that every student feels part of a community who brings special distinctive and unique assets to share with each other. How does an instructor facilitate such a learning environment?

Asset-Based and Equity-Minded Teaching Approaches

Students' Learning Styles and Pretest

The very first step is getting to know every student in the class. Given that almost all students attend the first day of the class, after the class introduction, discussion of the syllabus and course expectations, a short survey focusing on the students' learning styles which has a crucial role in terms of understanding their strengths and weaknesses. Once the survey is done, a Calculus pre-test consisting mostly of algebra and trigonometry problems where common and typical mistakes have been observed to occur is usually administered in the last twenty minutes of the 110-minute class meeting. The pretest has two purposes. First, it measures what the incoming

Calculus students have internalized, remembered, and learned in their pre-Calculus courses, Elementary Algebra and Trigonometry. Second, it helps the Calculus instructor get to know the students' assets and at the same time, their shortcomings. The result of this pretest facilitates the pacing of the course for the first few weeks. If a few common mistakes occur, the instructor immediately ensures that these are highlighted, discussed, and corrected at the next class meeting. Before the first week of the semester ends, the instructor asks for students' feedback about the first week's meetings. If a newer approach makes more sense, the instructor informs the class and uses anonymous voting to see if most of the class wants the change.

Assessments and Strategies for Deep Learning

"Tell me and I forget, teach me and I may remember, involve me and I learn." - Benjamin Franklin. This quote by Mr. Franklin is the focus of how assessments are used for students to learn conscientiously important Calculus concepts. Students in the class are paired with a study "buddy" in the first week of the semester. The two students are encouraged to sit together in class and study after class hours either in person or virtually. When one is absent due to some unforeseen reason, the other student provides the absent student with the lecture notes and even shares important hints taught in class.

Low-stakes Assessment: Quizzes

The first two weeks' initial approach of learning from mistakes is usually continued as newer topics are introduced. The Calculus instructor provides the students with specific questions delving on important Calculus topics where certain algebraic or trigonometric mistakes are commonly made by students. A quiz is administered after a homework set has been thoroughly discussed and answered. If another common mistake not previously emphasized by the instructor occurs in the quiz, the instructor immediately facilitates the class discussion so that the students do not make the same mistake in the chapter tests and comprehensive final exam. This is usually done by ensuring that each student in the assigned pair (the study-buddy pairing system) explains to each other the steps each student takes to obtain an answer. If one did not understand one step leading to an incorrect final answer, the other student acts as peer-tutor and ensures that the partner understands that portion of the solution. The instructor then encourages the student in each pair to explain to each other one more time in class what was incorrectly done and then correctly fixed. The quiz is not a big percentage of the grade and will not be negatively influencing students' weighted averages and therefore, this highlights its crucial position in the of the learning process of each student for the whole semester, Bickel et al. (2021) Lenz (2014) emphasized the role of assessment as an integral part of the learning process rather than a separate evaluative step. Lenz introduced the "Know, Do, Reflect" model used in Envision Schools, where students actively engage in self-assessment and reflection. This approach helps students internalize knowledge, develop critical thinking, and take ownership of their learning, thereby fostering deeper understanding. Desai (2025) explored how generative AI challenges traditional assessment methods and argues for a shift toward evaluating higher-order thinking, creativity, and ethical reasoning. The article suggested that assessments should focus more on learning processes and authentic demonstrations of understanding, aligning with the goals of deeper learning in the digital age. Madland and Richards (2016) found that peer review activities fostered deeper engagement and critical thinking. Although not explicitly framed as

asset-based, the system encouraged students to draw on each other's strengths and perspectives, aligning with asset-based principles by validating peer contributions and promoting collaborative learning.

Medium-stakes Assessment: Chapter Tests

As soon as each chapter has been completely covered and the quizzes indicate internalization by 80% of the class, a chapter test is immediately administered. By experience, the instructor includes several questions where common mistakes are usually made by students. The "study-buddy" system establishes the support system each student needs to successfully move forward in the class. The medium-stakes assessment measures whether the "study-buddy" system is effectively increasing the likelihood of success of each student in class. When some pairs of students have questions about the chapter test, the instructor meets with them and ensures that each student can explain to the other what corrections are needed to obtain the correct answer. Masuku et al. (2020) explored how assessment can be used as both a pedagogical strategy and a measurement tool to foster deep learning in higher education. It emphasized aligning assessments with Bloom's taxonomy to promote critical thinking, analysis, and synthesis. The established classroom "study-buddy" system becomes a normal part of each class immediately after each chapter test. Ocumpaugh et al. (2024) advocated for asset-based instructional design in AI-supported learning environments. It supported the idea that peer learning systems, such as study buddy models, should be designed to recognize and build on students' existing knowledge and skills, particularly in diverse and inclusive classrooms. As soon as the quizzes and chapter tests indicate internalization by 80% of the class, an exam covering three chapters is immediately administered. Once again, the study-buddy system provides a scaffolding design to ensure that students' assets are recognized and hence utilized. Suh et al. (2023) described a case study which explored how teachers used learning trajectories and asset-based thinking to design inclusive mathematics instruction. The findings supported the use of similar frameworks in peer learning systems like study buddies, where students' diverse ways of thinking are seen as assets to the learning process. Ukobizaba et al. (2021) and Ocumpaugh et al. (2024) emphasized learner-centered approaches such as cooperative learning, which aligns with the study buddy model. These strategies are consistent with asset-based pedagogy, as they leverage students' existing knowledge and peer collaboration to deepen understanding.

Summative Assessment: Comprehensive Final Exam

Given the three types of formative assessments above, a summative comprehensive final exam covering all chapters is administered at the end of the semester. Buchholtz et al. (2018) presented a case study in which formative and summative assessments were integrated in a mathematics teacher education program. The authors argued that combining these assessments provides a more holistic view of student learning. While not directly about study buddy systems, the study supported the idea that collaborative and reflective practices, key features of asset-based buddy systems, could enhance the effectiveness of summative assessments by contextualizing them within broader learning processes. Ukobizaba et al. (2021) provided a literature review highlighting the role of various assessment strategies, including performance-based and authentic assessments, in developing students' mathematical problem-solving skills. The authors emphasized learner-centered approaches such as cooperative learning, which aligns with the study buddy model. These strategies are consistent with asset-based pedagogy, as they leverage students' existing knowledge and peer collaboration to deepen understanding. Suh et al. (2023)

provided a qualitative case study following elementary educators applying an asset-based lens to curriculum design. Though focused on mathematics instruction, the findings are relevant to peer learning systems like study buddies. Teachers who recognized and leveraged students' diverse ways of thinking were more successful in creating inclusive and supportive learning environments.

Methods

Slavin (2014) explained that cooperative learning boosts academic achievement primarily through motivational mechanisms. When students are accountable to their peers and share group goals, they are more likely to stay engaged and put in effort. This is particularly effective in study buddy models where peer support and mutual responsibility are emphasized. A second-order meta-analysis by Öztürk (2023) found that cooperative learning models, including study buddy systems, have a moderate positive effect on student learning outcomes across various domains. The study synthesized 23 meta-analyses and highlighted that cooperative learning enhances academic performance, especially when structured with clear goals and accountability. Study buddy models encourage cognitive elaboration, where students explain concepts to each other, leading to deeper understanding. This aligns with developmental and cognitive theories of learning, which suggest that peer interaction helps consolidate knowledge through discussion and teaching.

Data Collection

Three batches of students from different semesters were part of the study. There are two groups per batch, the experimental group (with study buddy system and implementation of asset-based and equity-minded approaches), and the control group (without study buddy system and implementation of asset-based and equity-minded approaches). The summary statistics are described in Table 1.

Table 1. The Descriptive Statistics of Students Involved in the Study

Variables		N_1	N_2
	Semester 1	10	9
Batch	Semester 2	12	9
	Semester 3	12	9
Age	18-21	24	23
	other	10	4
Gender	F	29	25
	M	5	2
Total	61	34	27

To compare, the experimental group (N_1) versus the control group (N_2), there are 5 pairs (10 students) in the first experimental group versus nine unpaired control group students, no study buddy system was set up for the first batch, 6 pairs (12 students) in the second experimental group versus nine unpaired control group students, no study buddy system was set up for the second batch, and 6 pairs (12 students) in the first experimental group

versus nine unpaired control group students, no study buddy system was set up for the third batch.
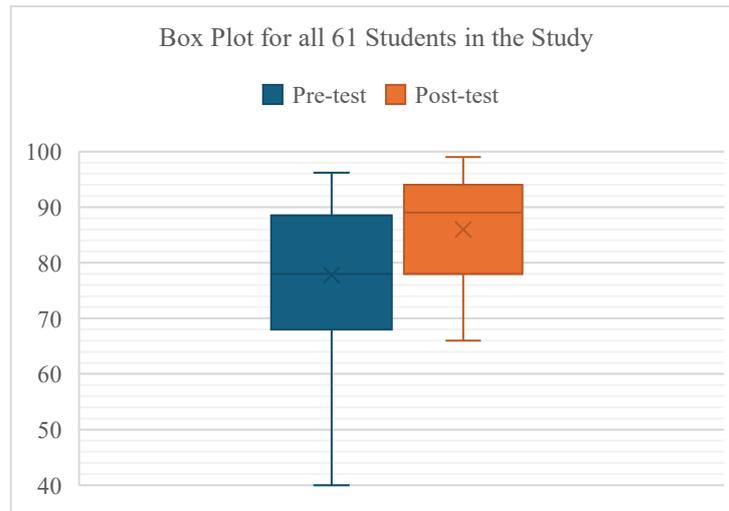

Figure 1. Box Plot Showing the Pre- and Post-Test

We use the box plot to easily show the pre- and post-tests of every student in the study. As shown in Table 1, there are 61 students (34 experimental and 27 control). We created two columns of the combined batches' scores and performed box plot command on Excel (see Figure 1). Table 2 shows the results when we use t-test (paired) to determine the statistical significance of the difference of the scores of the pre- and post-tests. At alpha = 0.05, the *t*-test (paired) result is highly significant. This means that there is a difference between the pre- and post-tests scores of the experimental group and the control group when all three batches or cohorts are combined.

Table 2. Results for the *t*-Test (Paired Two Sample for Means)

	Pre-test	*Post-test*
Mean	77.78983607	85.96721311
Variance	169.613635	76.73224044
Observations	61	61
Pearson Correlation	0.669094239	
Hypothesized Mean Difference	0	
df	60	
t Stat	-6.598589735	
P(T<=t) one-tail	6.02652E-09	
t Critical one-tail	1.670648865	
P(T<=t) two-tail	1.2053E-08	
t Critical two-tail	2.000297822	

Slavin (2014) found that during cooperative learning, motivation is the primary driver, i.e., students in these groups work harder when they feel responsible for their peers. In order to test whether there is a difference in motivational and cognitive mechanisms between these two groups per batch, the scores of each student in the semester course project, and final exam are used and then graphed using a scatter plot. Figure 2 describes the

scatter plot of the three batches of students with respect to the course project grades. The vertical axis are course project grades and the horizontal axis are the three batches. The blue colored points represent the students' scores of each student who are part of the study buddy system, the experimental group. The orange colored points represent the control group students per batch.
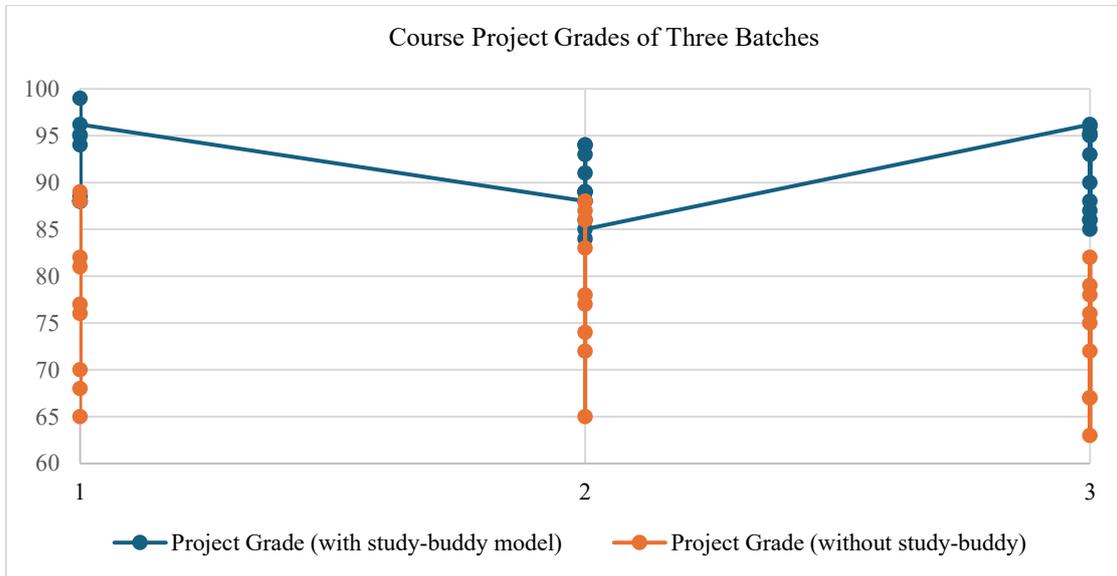

Figure 2. Scatter Plot Showing the Course Project Grades of Each Student from Three Batches

In order to test whether there is a difference in student learning outcomes (cognitive) in a summative fashion between these two groups per batch, the summative comprehensive final exam scores of each student are used and then graphed using a scatter plot (see Figure 3).
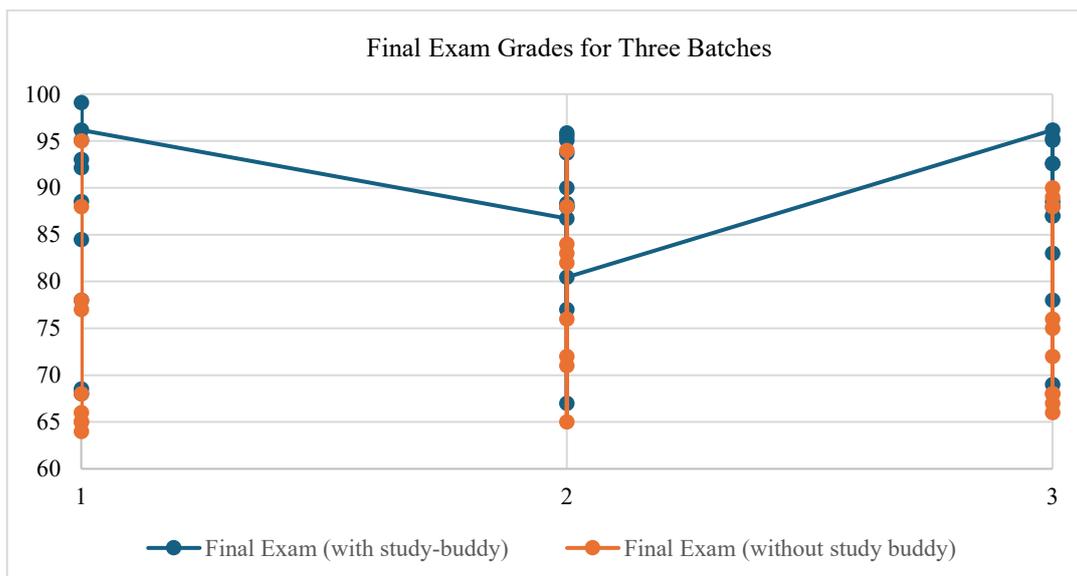

Figure 3. Scatter Plot Showing the Final Exam Grades

The vertical axis are final exam scores and the horizontal axis are the three batches. The blue colored points represent the students' scores of each student who are part of the study buddy system, the experimental group.

The orange colored points represent the control group per batch.

Results: Comparing the Two Groups Per Batch

Since there are two independent groups per batch with three batches, we use *t*-test assuming unequal variances, Tables 2a, 2b, and 2c show that at alpha = 0.05, there is a significant difference in course project grades for the experimental group for all three batches.

Table 2a. Results for *t*-Test (Unpaired Two Sample for Means)

Batch/Cohort 1

	Experimental	*Control*
Mean	92	77.33333333
Variance	17.77777778	72.5
Observations	10	9
t Stat	4.67714723	
P(T<=t) one-tail	0.000337336	
t Critical one-tail	1.795884819	

Table 2b. Results for *t*-Test (Unpaired Two Sample for Means)

Batch/Cohort 2

	Experimental	*Control*
Mean	89.16666667	78.88888889
Variance	11.06060606	60.61111111
Observations	12	9
t Stat	3.714412871	
P(T<=t) one-tail	0.002006015	
t Critical one-tail	1.812461123	

Table 2c. Results for *t*-Test (Unpaired Two Sample for Means)

Batch/Cohort 3

	Experimental	*Control*
Mean	91.04333333	73.22222222
Variance	19.87380606	40.94444444
Observations	12	9
t Stat	7.153938881	
P(T<=t) one-tail	2.45238E-06	
t Critical one-tail	1.761310136	

Similarly, Tables 3a, 3b, and 3c show that at alpha = 0.05, there is a significant difference in course final exam grades for the experimental group for all three batches.

Table 3a. Results for *t*-Test (Unpaired Two Sample for Means)

Batch/Cohort 1

	Experimental	*Control*
Mean	86.307	74
Variance	127.21829	128
Observations	10	9
t Stat	2.370941033	
P(T<=t) one-tail	0.01491302	
t Critical one-tail	1.739606726	

Table 3b. Results for *t*-Test (Unpaired Two Sample for Means)

Batch/Cohort 2

	Experimental	*Control*
Mean	87.13666667	79.44444444
Variance	74.21540606	84.02777778
Observations	12	9
t Stat	1.952501859	
P(T<=t) one-tail	0.033773208	
t Critical one-tail	1.739606726	

Table 3c. Results for *t*-Test (Unpaired Two Sample for Means)

Batch/Cohort 3

	Experimental	*Control*
Mean	87.685	75.9
Variance	63.52800909	92.76666667
Observations	12	10
t Stat	3.087378419	
P(T<=t) one-tail	0.003176119	
t Critical one-tail	1.734063607	

Using the one-tailed *t*-test for unpaired two samples for means, all results are significant, i.e., there is a significant difference in the scores for experimental group, i..e., all *p*-values are smaller than alpha =0.05.

Discussion

The findings of this study underscore the significance of implementing asset-based and equity-minded teaching approaches in open admission tertiary institutions, particularly in entry-level mathematics courses. Given the diverse academic, socio-economic, and cultural backgrounds of students in such institutions, it is imperative that instructional strategies not only address academic gaps but also affirm students' identities and leverage their existing strengths. The statistically significant improvement in the post-test scores of the experimental group, as

shown in Table 2, provides compelling evidence that the integration of asset-based practices and the study buddy system positively influenced student learning outcomes. This aligns with Rollins (2020), who emphasized the need for mathematics instructors to tailor instruction to meet the diverse needs of learners. The paired t-test results ($p < 0.00001$) suggest that the experimental group benefited from a more inclusive and supportive learning environment, which likely contributed to their academic growth.

The scatter plots in Figures 2 and 3 further illustrate the impact of these interventions. Students in the experimental group consistently outperformed their control group counterparts in both course project grades and final exam scores. These results support Slavin's (2014) assertion that cooperative learning environments enhance student motivation and accountability. The study buddy system may have fostered peer-to-peer support, increased engagement, and reduced feelings of isolation—factors that are especially critical in mathematics learning.

Moreover, the asset-based approach, as advocated by the Association of State Supervisors of Mathematics & Association of Mathematics Teacher Educators (2024), appears to have played a pivotal role in shaping positive mathematical identities. By centering student thinking and recognizing their unique contributions, instructors likely created a more equitable and empowering classroom culture. This is consistent with the practices outlined by the Institute for Learning (2021), which emphasize the importance of student reasoning and identity development in mathematics education.

The professional development of instructors, as discussed by Marzocchi et al. (2024), also emerges as a key factor. The transition to equity-minded instruction requires sustained support and collaboration, as highlighted in the networked improvement community model by Martin et al. (2025). The success of the experimental group suggests that when instructors are equipped with the right tools and mindsets, they can effectively transform their teaching practices to better serve all students.

Finally, the broader implications of this study resonate with the equity-focused frameworks reviewed by Vithal et al. (2023) and the intersectional perspectives of Esmonde and Langer-Osuna (2013). Addressing systemic inequities in mathematics education requires intentional pedagogical shifts that honor the lived experiences and potential of every student. In conclusion, this study contributes to the growing body of evidence supporting asset-based and equity-minded approaches in mathematics education. It highlights the transformative potential of such practices in fostering academic success and equity in open admission institutions. Future research may explore longitudinal impacts, scalability, and the role of institutional support in sustaining these practices.

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