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Cluster analysis of student satisfaction in a criteria-based assessment course with a project-based learning approach

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Abstract

The quality of courses plays a significant role in shaping effective future educators, particularly in mathematics education, where innovative assessment and teaching methods are crucial. This study investigates the experiences and satisfaction of future mathematics teachers enrolled in a course on criteria-based assessment (CBA) techniques, delivered using a project-based learning (PjBL) approach. A total of 98 participants from a university in Kazakhstan provided survey data that were analyzed using cluster analyses. The k-means algorithm identified three distinct clusters of participants: "less engaged or satisfied," "moderately satisfied," and "highly engaged and satisfied." The optimal number of clusters was determined using the elbow method, and 3D scatter plots provided a visual representation of the data patterns. Additional analyses examined gender, prior experience with assessment techniques, and prior experience with in PjBL, highlighting significant variations in satisfaction and engagement levels across these factors. Results showed that students with intermediate knowledge of assessment techniques and prior PjBL experience were more likely to belong to the highly satisfied cluster. Gender distribution indicated a slight tendency for female students to benefit more from the CBA course. Key challenges included complex tasks such as reliability calculations, which impacted the less engaged group more significantly. Findings highlight the importance of aligning course design with learner needs, offering structured support, and integrating foundational training in CBA and PjBL methodologies. This study provides actionable recommendations for enhancing teacher education programs and improving the implementation of innovative teaching and assessment strategies.

Keywords: cluster analyses, course developments, criteria-based assessments, project-based learning

INTRODUCTION

Assessment plays a central role in education, shaping not only how students learn but also how they perceive their own growth and achievements. Criteria-based assessment (CBA) has gained importance as an approach that aligns assessments with predefined standards and objectives. Ajjawi et al. (2021) points to the need for clarity in distinguishing between criteria and standards to ensure effective implementation. This method promotes transparency for both teachers and students by making evaluation criteria explicit and consistent, thereby influencing students' learning approaches (Bhatnagar, 2018). For future mathematics teachers, mastering techniques that facilitate detailed and effective evaluation, such as structured assessment criteria, is vital for fostering problem-solving, analytical reasoning, and conceptual understanding–skills fundamental to mathematics education (Viro et al., 2020).

Project-based learning (PjBL) has been recognized as an effective pedagogical approach for teaching complex skills, including assessment techniques. PjBL emphasizes applying knowledge to real-world contexts,

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Contribution to the literature

- This study presents a detailed cluster analysis of student satisfaction within a Criteria-Based Assessment course delivered through a Project-Based Learning approach.
- It bridges the gap in understanding how diverse prior experiences, such as knowledge of assessment techniques and familiarity with Project-Based Learning, influence engagement and satisfaction among future mathematics teachers.
- It indicates the critical role of aligning course design with learner needs, stressing actionable feedback, foundational knowledge, and task clarity.

promoting student engagement and deeper understanding (Bell, 2010; Kokotsaki et al., 2016). Previous studies have demonstrated the effectiveness of PjBL and CBA in various educational contexts. For example, Kim et al. (2019) revealed that pre-service mathematics teachers developed more positive perceptions of PjBL after engaging with it, noting its role in improving engagement and understanding of mathematical concepts. Holmes (2015) illustrated that continuous e-assessment, a variant of CBA, enhanced student engagement and encouraged active learning.

Despite these findings, limited research explores the integration of PjBL and CBA in teacher education programs, particularly in mathematics education. This study seeks to address this gap by investigating future mathematics teachers' satisfaction with a course designed to teach CBA techniques using a PjBL approach. It aims to uncover how PjBL enhances satisfaction, the challenges and benefits of integrating these methods, and their influence on students' confidence in applying assessment techniques to real-world contexts. The novelty of this research lies in its focus on combining two innovative educational approaches–CBA and PjBL–to prepare future mathematics teachers. While prior research has highlighted the benefits of each approach individually, this study explores their synergy within a teacher education context. By employing cluster analysis to categorize student satisfaction and engagement, this study offers a unique perspective on how diverse student backgrounds and experiences influence their interaction with CBA and PjBL methodologies.

Research Questions

1. How do distinct clusters of students differ in their levels of satisfaction with the CBA course?
2. What factors, such as prior experience with assessment techniques and participation in PjBL, influence student satisfaction in the CBA course?
3. What are the key challenges students face in completing complex tasks, and how do these challenges vary across clusters?

LITERATURE REVIEW

Course Design

Effective course design for a CBA techniques course must harmonize instructional strategies, assessments, and learning outcomes to create a cohesive and impactful learning experience. By starting with clear, measurable learning outcomes–such as the ability to develop and apply assessment rubrics–educators can design activities and assessments that harmonize with these goals (Lewis, 2021). Constructive harmonizing, as outlined by Biggs and Tang (2011), emphasizes the integration of intended learning outcomes with teaching and assessment methods, thereby supporting the preparation of future mathematics teachers to implement effective assessment strategies in diverse classroom settings.

Additionally, the course should adapt reflective thinking to enhance future teachers' professional growth. Reflective practices are instrumental in enabling students to critically analyze their learning processes and adapt to new challenges. Embedding reflective assignments, such as assessment analysis journals or collaborative discussions, harmonizes with Khuzwayo et al.'s (2020) findings on the value of active and experiential learning, which emphasize the importance of engaging students in meaningful, context-driven activities. Integrating technology, such as online platforms for rubric creation and digital assessments, further enhances the course's relevance in modern educational settings, enabling students to practice using tools that they will likely encounter in their professional practice. Finally, harmonizing these course elements with instructional design principles (Fries et al., 2021) can ensure a comprehensive approach that prepares future mathematics teachers to implement CBA effectively and confidently in diverse classroom settings.

Criteria-Based Assessment Techniques

CBA is an approach that aims to improve the fairness and reliability of evaluations by using clear, measurable criteria to assess student performance. Kanatovna and Jumakhmetovna (2020) highlight that CBA provides a structured framework for evaluating student achievements and supports the overall improvement of the educational process. This structure allows students to understand specific expectations, which may contribute to better engagement with learning materials. In the context of mathematics education, where critical analysis and problem-solving are essential competencies, CBA offers a standardized approach to assessing diverse skills.

The impact of CBA on student self-assessment and self-esteem has been explored in educational research, with positive findings in specific contexts. Syzdykbayeva et al. (2021) demonstrated that in primary education, CBA contributes to the development of self-esteem by making learning goals transparent and attainable. This clarity helps students feel more confident in their abilities, leading to a sense of accomplishment. Furthermore, Andrade (2010) emphasizes that engaging students in self-assessment using clear criteria not only improves their ability to evaluate their work but also promotes a growth mindset and self-regulated learning. By empowering students to actively reflect on their progress, CBA helps them build essential skills for academic success and lifelong learning.

Teacher perceptions and implementation of CBA are critical to its success. Grossman (2021) points out the importance of modeling professional practice in teacher education, advocating for collaborative approaches to develop criteria and standards-based assessments. They highlight that such collaboration not only harmonizes assessment practices with educational objectives but also enhances teachers' understanding and application of CBA. Similarly, Andrade (2010) discusses the role of formative assessment in promoting self-regulated learning, emphasizing the necessity for teachers to be well-versed in assessment strategies to effectively guide students. Adelabu and Alex (2023) explored the views of first-year mathematics student teachers on online baseline assessments, revealing enthusiasm and motivation for computer-based assessments but also highlighting challenges in solving mathematical problems using technology.

In the context of educational reform, several studies have examined the role of CBA in national education systems. In Kazakhstan, for instance, multiple researchers have explored how CBA harmonizes with educational modernization efforts. Davletkaliyeva et al. (2016) stated that CBA contributes to the qualitative development of teaching and learning processes by transforming classroom activities. Their study found that CBA enhances practices such as self-assessment, motivation, and cognitive engagement, which collectively improve the quality of student learning. Similarly, Kulumbetova et al. (2024) specifically examined the application of CBA in teaching chemistry, finding that it enhances students' functional literacy by linking theoretical knowledge with practical application.

Moreover, the integration of clearly defined criteria in CBA has been shown to enhance its effectiveness in educational settings. Ipperciel and ElAtia (2014) discussed the development of a criteria-based competency model for assessing graduate attributes, emphasizing the importance of understanding graduate attributes as constructs of knowledge, skills, and attitudes to create effective assessment scales. This model allows for a comprehensive evaluation of student competencies across institutions. Similarly, Hopfenbeck et al. (2012) stated the importance of distinctly defined criteria in assessments through a national project aimed at improving formative assessment practices in Norwegian schools. Their study demonstrated how clearly articulated criteria can help clarify curriculum goals, improve teaching practices, and enhance student motivation.

The evolution of CBA has also been influenced by educational policies and reforms. In Kazakhstan, researchers like Kulmagambetova and Sultanova (2021) have examined how CBA technologies are being utilized to assess students' knowledge of the English language at the university level. Their findings indicate that CBA not only enhances language proficiency assessments but also harmonizes with global educational standards, preparing students for international communication and collaboration.

Moreover, the professional development of teachers in implementing CBA is crucial. Makhmudjonovna (2022) discusses the qualification requirements necessary for university teachers to effectively employ CBA, pointing out that educators must be well-versed in both the theoretical foundations and practical applications of these assessment techniques. This includes understanding how to design rubrics, provide constructive feedback, and utilize technology to support assessment practices.

In the field of educational technology, Palmer (2016) developed a prototype application to address challenges associated with CBA, particularly in terms of scalability and consistency in large classes. This innovation demonstrates how digital tools can facilitate more efficient assessment processes, allowing educators to focus on providing personalized feedback rather than administrative tasks. Similarly, Gikandi et al. (2011) said the potential of online formative assessment tools to enhance learning experiences by offering immediate, criteria-based feedback.

Project-Based Learning

PjBL is an instructional strategy that engages students in exploring real-world problems through sustained inquiry and collaborative projects. As outlined by Kokotsaki et al. (2016), PjBL promotes deeper learning by requiring students to apply knowledge and skills to authentic challenges, promoting critical thinking, creativity, and problem-solving abilities. This approach is particularly beneficial in preparing students for the demands of the 21st century, as Bell (2010) states, emphasizing its role in developing skills such as teamwork, communication, and adaptability. The integration of PjBL into science education has proven effective, with Kubiatko and Vaculová (2011) reporting that students show greater engagement and retention of knowledge when learning through hands-on, inquiry-based projects. Furthermore, PjBL harmonizes with constructivist learning theories, as students take an active role in constructing their understanding, often through interdisciplinary connections. Nabilah et al. (2024) designed a prototype of an affective domain self-assessment for PjBL by integrating Bloom's taxonomy with PjBL stages, employing both qualitative and quantitative content validation methods,

The successful implementation of PjBL requires careful planning, teacher facilitation, and harmonizing with educational standards. Zhang (2022) outline key principles for managing PjBL, including the importance of clear project goals, scaffolding student inquiry, and ensuring that assessments harmonize with the project's learning outcomes. Teachers play a crucial role in guiding students through the complexities of PjBL, as observed by Rogers et al. (2011), who stress the need for professional development to equip educators with the skills to design and facilitate effective projects. In higher education, Lasauskiene and Rauduvaite (2015) found that lecturers implementing PjBL noted improvements in students' ability to work independently and collaboratively while mastering subject-specific competencies. Similarly, Mohedo and Bújez (2014) state the potential of PjBL to prepare future teachers by promoting the development of basic and professional competencies. Uyen et al. (2023) conducted a systematic review of PjBL in teacher education during the COVID-19 pandemic, revealing its effectiveness in enhancing pre-service teachers' knowledge, professional skills, and learning attitudes, while also highlighting challenges related to knowledge, skills, and technology infrastructure, with implications for future PjBL research and practice.

Student Satisfaction With Courses

Student satisfaction with courses is influenced by a variety of factors, ranging from course design and teaching methods to technological tools and individual characteristics. Across traditional, online, and innovative teaching environments, research consistently highlights the importance of clear structure, engaging content, and effective feedback. For example, Kuznetsova (2019) identified shortcomings in course arrangement, gaps in teaching skills, and subject difficulty as key factors driving dissatisfaction in an applied mathematics program, emphasizing the need for well-structured courses and skilled instruction. Similarly, Davis (2017) and Yunusa and Umar (2021) demonstrated that practical components like homework and familiarity with learning tools are critical for student engagement and satisfaction, particularly in online mathematics courses.

In online and hybrid contexts, student satisfaction has been shown to depend significantly on their comfort with the technology and the support provided by instructors. Pereira (2021) revealed that satisfaction in online mathematics courses was strongly correlated with ease of platform use, instructor support, and student motivation. Matzakos and Kalogiannakis (2018) similarly found that first-year engineering students' satisfaction with an online support program was linked to their progress, familiarity with distance learning, and attitudes towards conventional learning programs. These findings highlight the role of support in facilitating student engagement, particularly for those transitioning between educational levels or formats.

Innovative teaching methods, such as flipped classrooms and PjBL, also play a significant role in shaping student satisfaction. Strelan et al. (2020) found that flipped classrooms had a positive, albeit moderate, effect on satisfaction, influenced by factors like pre-class preparation and in-class activities. Khaoloek and Chaiyasung (2022) further supported these findings, showing high satisfaction levels with learning activities and classroom atmosphere in a flipped mathematics classroom, where interactive and problem-solving tasks were central. Similarly, Melguizo-Garín et al. (2022) found that group work competencies in PjBL significantly enhanced satisfaction, suggesting that collaborative learning environments and clear group norms are vital for the success of innovative methodologies.

Future mathematics teachers often perceive PjBL as a dynamic approach that enhances student engagement and deepens understanding of mathematical concepts. Kim et al. (2019) observed a positive shift in pre-service teachers' perceptions of PjBL when exposed to it during training, particularly valuing its ability to enhance student motivation and involvement. Incorporating innovative assessment methods can further improve the perceived effectiveness of PjBL among future teachers. Holmes (2015) found that continuous e-assessment strategies, which provide timely feedback and monitor progress, significantly improve student engagement and confidence. Clark and Zhang (2018) stressed the importance of aligning assessment methods with instructional strategies to encourage positive attitudes toward innovative approaches like PjBL. Empirical studies support these findings. Baysura et al. (2016) conducted a qualitative phenomenological study with Turkish teacher candidates, revealing that while most participants learned about PjBL theoretically, they lacked practical application opportunities.

METHODS

Participants and Context of the Study

The study was conducted during the CBA course offered at a university located at suburb of Almaty, Kazakhstan as an online course from September to December 2024. The course sessions were held twice a week, with each session lasting two 50 minutes and one 50 minutes.

The study included a total of 98 participants, of whom 59% (n = 60) were female and 39% (n = 38) were male. The participants were predominantly from Almaty (75.5%, n = 74), with smaller representations from Kaskelen (6.1%, n = 6), Kyzylorda (4.1%, n = 4), and the rest were from five different cities. The participants' ages ranged from 20 to 28 years, with the majority being 20 years old (59.0%, n = 60), followed by those aged 21 years (31%, n = 32). The rest was between 23 and 28 years old. (6%, n = 6). In terms of prior experience with assessment techniques, 59% of participants reported having *basic knowledge*, 12% reported *intermediate knowledge*, 21% reported *none*, and only 2% reported *advanced knowledge*. When asked about previous participation in courses using PjBL, 41% of participants responded *"yes"*, while 57% responded *"no"*.

The course was designed to equip participants with theoretical knowledge and practical skills for designing and evaluating assessment instruments. Using a PjBL approach, students completed a series of interconnected tasks, resulting in the development of a valid and reliable assessment instrument. Weekly process evaluations provided timely feedback, while the final product was assessed as part of the overall grade.

The theoretical part of the course covered an introduction to educational assessment and measurement (1 week), scales of measurement and descriptive statistics (2 weeks), the meaning and interpretation of test scores (1 week), correlation and its applications in assessment (1 week), reliability and validity of tests (2 weeks), educational objectives and Bloom's revised taxonomy (1 week), item writing techniques for selected-response and constructed-response items (2 weeks), distractor analysis and item improvement strategies (2 weeks), and grading and reporting practices, including communicating assessment results to stakeholders (2 weeks), performance assessments & portfolios, grading, and aptitude tests (3 weeks).

On the other hand, the practical part of the course focused on PjBL, where students progressively developed a valid and reliable assessment instrument. Project activities included writing educational objectives, creating selected-response and constructed-response items, administering the test to a group of students, conducting item and distractor analyses, and calculating reliability coefficients (e.g., KR-20, Cronbach's alpha, and point biserial correlation). Additionally, weekly quizzes, presentations, and class discussions and participation complemented the learning process, ensuring learning of theoretical concepts across the semester.

The course was assessed through students' e-portfolios, which included project (both process and product), weekly quizzes, participation in discussions, and presentations of their work also contributed to the assessment process. At the end of the course, students completed a post-survey to evaluate their satisfaction with the CBA course. All 98 year 4 students in the course provided their consent to participate in this study.

Instrument

The study utilized a survey instrument to assess students' perceptions of the CBA course. The survey comprised eight sections, designed to gather comprehensive feedback on the course's design, implementation, and outcomes. It included Likert-scale questions allowing quantitative data collection.

The first section, demographics, collected information about participants' gender, city of residence, age, prior experience with assessment techniques, and familiarity with PjBL. The second section, course design and content, focused on the alignment of course objectives with expectations, the clarity of weekly tasks, and the extent to which the course encouraged critical thinking and problem-solving skills. The third section, Perception of PjBL, evaluated students' engagement with the PjBL approach, the perceived effectiveness of weekly feedback. The fourth section focused on challenges faced in tasks such as creating a blueprint, writing educational objectives, and performing reliability calculations. The fifth section, learning outcomes, investigated students' understanding of key concepts (e.g., Bloom's revised taxonomy, item analysis techniques), their confidence in designing assessment tools, and the transferability of skills gained to professional contexts. The sixth section, CBA course perception, focused on how they were confident in designing valid and reliable instruments, how they were successful in applying assessment techniques in real-world contexts, etc. The seventh section, assessment criteria used in the CBA course, addressed the clarity and usefulness of assessment criteria, their role in self-assessment, and their contribution to motivation and fairness in the evaluation process. Finally, the eighth section, overall satisfaction, measured participants' satisfaction with the course structure and delivery.

For the validity of the instrument, the survey was sent to two professors for their review. They evaluated the items in terms of relevance, clarity, and understandability. Based on their feedback, three items were revised to improve clarity, and one item was removed due to redundancy. Additionally, two students were asked to complete the survey as a pilot test. Their feedback was reviewed, and one item was slightly revised to enhance its understandability and alignment with the survey's objectives. The survey was administered at the end of the course and took approximately 10-15 minutes to complete.

Design and Procedure

The CBA course was offered online for the fifth time during the autumn 2024 term. Algebra was a prerequisite for this course, ensuring that participants had a foundational understanding of mathematical concepts relevant to assessment techniques.

The course aimed to equip students with practical and theoretical knowledge in educational assessment. The learning outcomes included the ability to choose applicable assessment methods, develop appropriate assessment instruments, administer and interpret assessment results, use these results to inform educational decisions, develop valid grading procedures, and communicate assessment outcomes effectively.

The course followed a PjBL approach, with students progressively completing a series of tasks to develop a reliable and valid assessment instrument. In the eighth week, students selected a unit from their subject area and identified the skills, knowledge, and outcomes they wanted their students to achieve. In the ninth week, they created a table of specifications, aligning the objectives with Bloom's revised taxonomy to guide test construction. In the tenth week, students developed a test, typically consisting of 25-30 multiple-choice items. In the eleventh week, the test was administered to a group of students, ranging from 30 to 60 participants, to collect real-world data. In the twelfth week, students conducted item and distractor analyses, calculated point biserial correlations, and determined reliability coefficients (split-half reliability and KR-20). Items were refined or removed based on the analysis results. The final grades were a combination of process evaluation (weekly tasks) and the quality of the final product (assessment instrument).

Data Analyses

Cluster analyses using the k-means algorithm were carried out to categorize participants based on survey responses into three distinct groups: "less engaged or satisfied," "moderately satisfied," and "highly engaged and satisfied." These clusters were determined using the elbow method to identify the optimal number of clusters, which was three, as visualized through a 3D scatter plot. The 3D cluster analysis involved reducing the survey data into three principal components (using principal component analysis [PCA]) to visualize the clusters in a three-dimensional space. Each participant was represented as a point in this space, with clusters differentiated by color. Additional analyses were performed to examine gender, prior experience with assessment techniques, and participation in PjBL courses. The distribution of these variables across the three clusters was visualized with graphs and explained with percentages.

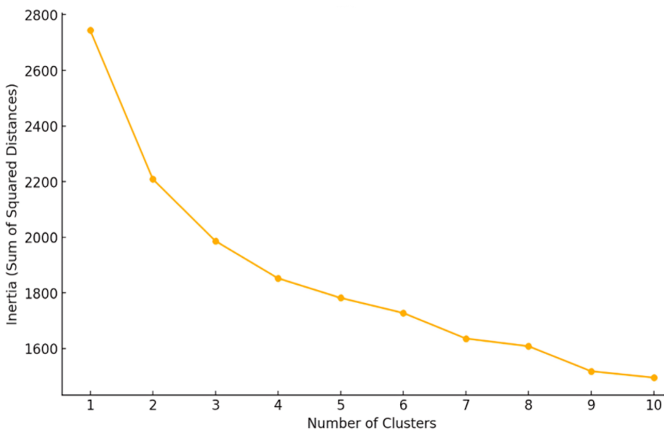

Figure 1. Elbow method for optimal number of clusters (Source: Authors' own elaboration)

RESULTS

Cluster Analyses

We first determined the optimal number of clusters and then applied the k-means algorithm to extract clusters.

The elbow method suggests that the optimal number of clusters is around 3, where the inertia begins to level off. Thus, we chose 3 clusters for the k-means analysis, which is supported by this method (**Figure 1**).

We conducted the clustering analysis and it is visualized in the 3D scatter plot of the clusters based on PCA components (**Figure 2**). The clusters are represented by different colors. The clusters in the analysis represent groups of participants who share similar perceptions and experiences with the course, based on their survey responses. By applying k-means clustering to the numerical responses, we grouped the participants into three clusters based on patterns in their data. The number of students in each cluster was 39, 23, and 36, respectively.

As shown in **Figure 2**, cluster analyses revealed three clusters. Each cluster is detailed below. Clusters are labeled 0, 1, and 2 according to k-means clustering system.

Cluster 0. Less engaged or satisfied

This group generally has lower scores across most dimensions, such as course design, PjBL engagement, and learning outcomes, with an average satisfaction score of 3.81. This cluster represents students who were less engaged or found the course less aligned with their expectations. This group has an average age of 20.48

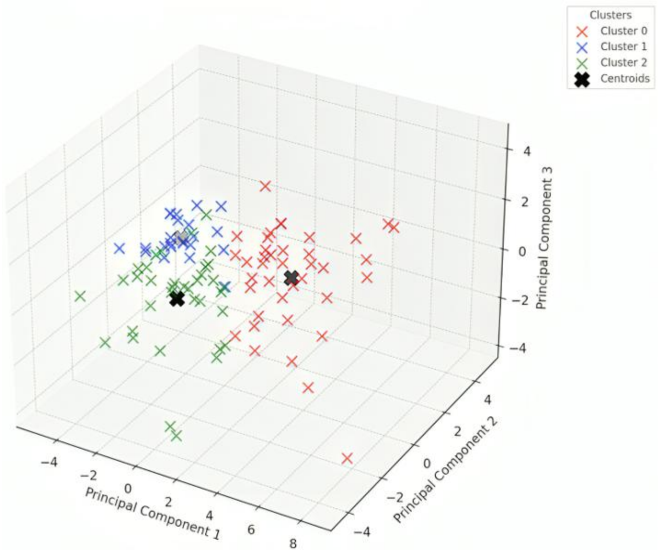

Figure 2. 3D cluster analyses: 3D PCA cluster visualization with centroids (Source: Authors' own elaboration)

years, suggesting relatively young participants in the course. They rated course design-related items (B1 to B4) lower than the other clusters. For example, they rated the clarity of weekly tasks (B2) and the effectiveness of course materials (B3) at about 3.7/5, indicating they were less satisfied with these aspects. They also rated PjBL (C1 to C4) less positively, especially in terms of the ownership and balance between tasks and the final product. Their ratings were around 3.35, indicating moderate engagement but not a high level of excitement or satisfaction. They reported significant challenges (D1 to D6), particularly in creating blueprints and performing item analyses, with these tasks averaging 4.0 on a 5-point scale. Tasks involving advanced calculations, such as KR-20 reliability coefficients, were also rated as challenging, with an average score of 3.8. Only 55% reported significant improvement in designing valid and reliable assessment tools, and distractor analysis scored an average of 3.7, reflecting minimal gains. The CBA course's impact on their understanding of assessment techniques (E1 to E4) were somewhat neutral or moderate. For example, the knowledge they gained about designing valid and reliable assessment tools (E2) was rated 3.35 on average, indicating some areas of improvement. For the CBA course perception (F1 to F3), this cluster expressed minimal confidence in designing reliable and valid instruments, with only 40% feeling "somewhat confident." Preparation for real-world applications was rated as "poor" by 30% of the group, and skill transferability was seen as limited. For each assessment criteria used during the CBA course, they rated the clarity of assessment criteria as "somewhat clear," with 58% agreeing. Motivation through criteria was seen as limited, with 45% finding it "somewhat effective." With an overall satisfaction of 3.81, cluster 0 represents students who were somewhat neutral or dissatisfied with certain aspects of the course.

Cluster 1. Moderately satisfied

This cluster has moderately high scores in many areas but does not reach the highest levels. Their overall satisfaction is 4.45, indicating a good experience. They seem to have found the course moderately effective in areas like feedback and understanding assessment techniques. This group has an average age of 20.74 years, similar to cluster 0, and shows typical young participants. They rated course design aspects moderately well. For example, they rated how well the course objectives aligned with their expectations (B1) at about 4.23, showing a better alignment compared to cluster 0. Their ratings for PjBL (C1 to C4) were somewhat higher, particularly for engagement (C1 = 4.15) and task ownership (C4 = 4.15). This indicates they were more engaged with the PjBL approach compared to cluster 0. This cluster exhibited moderate task difficulty (D1 to D4), with advanced tasks like item analysis and KR-20 calculations rated around 3.5. Students found blueprint creation less challenging, with an average score of 3.2 (note that the highest level of challenge was rated 5, and the lowest level of challenge was rated 1). Their ratings for understanding assessment-related concepts (E1 to E4) show a moderate impact. They reported a relatively positive view on their ability to design valid assessment tools (E2 = 4.26), but less so regarding reliability and validity coefficients (E4 = 3.94). For the CBA perception (F1 to F3), cluster 1 exhibited moderate confidence in designing valid and reliable instruments after completing this course, with 60% feeling "somewhat confident." After CBA course the skill transferability to other academic or professional contexts was rated as "moderately transferable" by the majority. This group rated the assessment criteria used in the CBA course (G1 to G5) as "somewhat clear," with 60% agreeing. Motivation derived from these criteria was rated as "somewhat effective," reflecting a mixed perception. Cluster 1, with an overall satisfaction rating of 4.45, reflects students who had a good experience. They were satisfied with feedback (G5 = 4.44) and felt the course had a good influence on their learning outcomes. This group found the course moderately effective and enjoyable but still had some areas where improvements could be made.

Cluster 2. Highly engaged and satisfied

This group has the highest scores across most variables, especially in areas like engagement with the course (C1-C4), learning outcomes (E1-E4), and overall satisfaction (4.91). This represents students who had the most positive perceptions and found the course most effective. This group has an average age of 20.37 years, similar to the other clusters. They rated course design aspects highest across the board. They gave the highest ratings for the clarity of instructions (B2 = 4.79) and the integration of materials with project activities (B3 = 4.79). These ratings suggest that they found the course well-

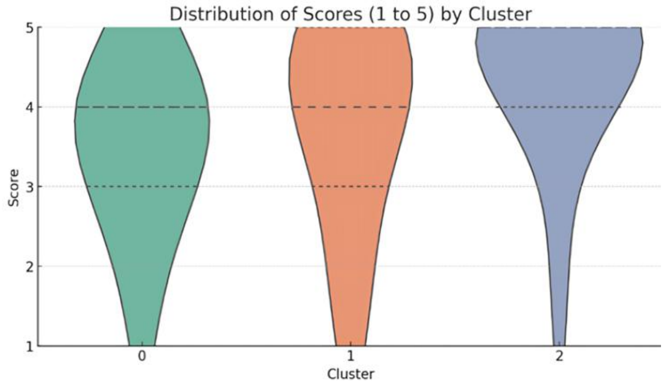

Figure 3. Distribution of scores by cluster (Source: Authors' own elaboration)

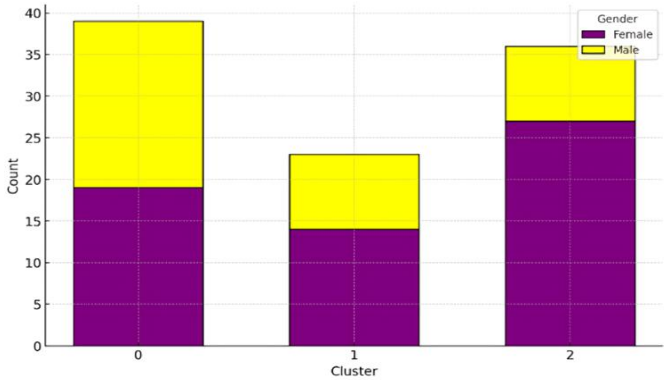

Figure 4. Gender distribution in each cluster (Source: Authors' own elaboration)

organized and the materials highly relevant to the projects. Cluster 2 also gave very high ratings for PjBL (C1 to C4), such as task ownership (C4 = 4.79) and balancing process tasks with final product quality (C3 = 4.75). This indicates strong engagement and involvement in the course's learning approach. Cluster 2 found PjBL tasks more manageable, with difficulty ratings averaging below 3.2 for most items. Students excelled in blueprint creation and distractor analysis, indicating they were better prepared or more confident in these tasks. This group showed the highest ratings for learning outcomes, especially for understanding Bloom's revised taxonomy (E1 = 4.93) and designing valid assessment tools (E2 = 4.77). They perceived significant improvements in their ability to apply assessment techniques after the course. With an overall satisfaction rating of 4.91, this cluster represents the most highly engaged and satisfied students. For assessment criteria used in the CBA course, cluster 2 showed high confidence, with 75% feeling "very confident" in their ability to design reliable instruments. This group also believed strongly in the transferability of skills, with 80% rating them as "highly transferable." This group found the assessment criteria highly clear and effective. About 85% agreed the criteria were "very clear," and motivation was rated as "highly effective" by 78%. This group also strongly agreed that the criteria made evaluations fair and transparent. They rated aspects like feedback effectiveness (G5 = 4.82) and course relevance to real-world contexts (F2 = 4.19) very highly. In short, this group was very pleased with the course, found it highly relevant, and benefited the most from the learning experience.

Distribution of Survey Scores

The distribution of scores (1 to 5) across the three clusters is shown in **Figure 3**.

Cluster 0 exhibits a balanced distribution with a slight concentration in higher satisfaction scores, particularly at 4. Approximately 5.5% of the students scored 1, while 10.6% scored 2. A larger portion, 25.9%, provided a score of 3, and 40.2% of the students reached a score of 4, which is the dominant score in this cluster. Around 14.6% indicated a maximum score of 5. Cluster 1 reflects a mixed performance, but with higher satisfaction scores, particularly scores 4 and 5. About 7.4% of students scored 1, while 11% scored 2, and 13.7% scored 3. The most notable trends are the 30.7% of students scoring 4 and 33.9% achieving the maximum score of 5. This indicates that the majority of students in cluster 1 are mostly satisfied with the course, with over 60% scoring in the top two categories. Cluster 2 stands out with a very strong dominance of the maximum score, 5. Only 2.5% of students scored 1, and 4.9% scored 2. A small portion, 4.4%, showed a score of 3, while 22.9% scored 4. The most remarkable feature of this cluster is that 62.3% of the students provided the maximum score of 5, indicating exceptional performance. Cluster 2 clearly represents the top-performing students, with a significant majority reaching the highest score.

The Distribution of Variables into Clusters

Gender distribution in each cluster

The graph in **Figure 4** shows the gender distribution within each cluster. It presents how males and females are distributed across the three clusters.

There are 19, 14, and 27 female students and 20, 9, 9 male students, respectively in each cluster. Cluster 0 have a relatively even distribution between males and females, though there are slightly more females than males. In cluster 1, there are a higher proportion of females compared to males. Cluster 2 has the highest satisfaction, also shows a more unbalanced gender distribution. There doesn't seem to be a strong gender-based difference in satisfaction across clusters. However, there is a slight tendency for more females to appear in cluster 1, where satisfaction is moderate, and cluster 2, where satisfaction is high. This is an indication that female students benefited the most from the CBA course.

Experience with assessment techniques in each cluster

The stacked area plot in **Figure 5** illustrates the distribution of experience with assessment techniques

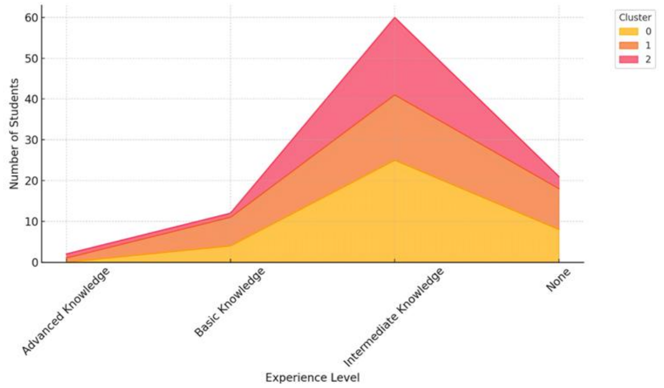

Figure 5. Experience with assessment techniques in each cluster (Source: Authors' own elaboration)

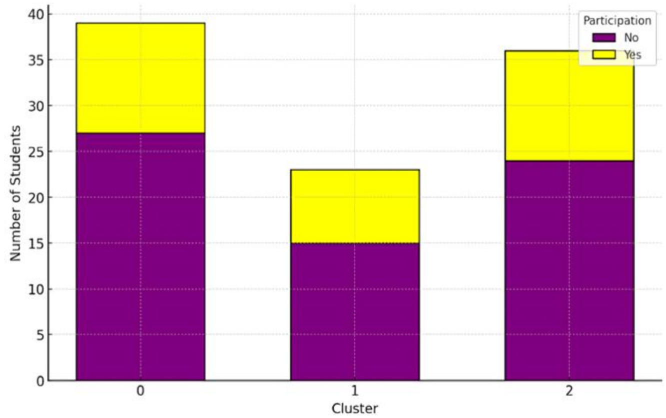

Figure 6. Participation in a PjBL course across clusters (Source: Authors' own elaboration)

(advanced knowledge, intermediate knowledge, basic knowledge, and none) across clusters.

There were 0, 26, 4, and 9; 1, 18, 2, and 3; 2, 16, 9, and 9 students in the advanced knowledge, intermediate knowledge, basic knowledge, and no knowledge levels of the clusters, respectively. Cluster 0 predominantly consists of students with "intermediate knowledge" (67.57%), followed by "none" (21.62%) and a smaller proportion with "basic knowledge" (10.81%). No students in this cluster reported "advanced knowledge." Cluster 1 has a mix of "intermediate knowledge" (47.06%) and "none" (29.41%), with "basic knowledge" accounting for 20.59% and a small percentage (2.94%) reporting "advanced knowledge." Cluster 2 is heavily composed of "intermediate knowledge" students (79.17%), with a smaller percentage having "none" (12.50%) and "basic knowledge" (4.17%). Only 4.17% of students in this cluster reported "advanced knowledge."

Participation in a PjBL Course

Figure 6 illustrates the distribution of students who have previously participated in a PjBL course across the three clusters. Each segment represents the proportion of students in a cluster who participated ("yes") or did not participate ("no") in a PjBL course.

There were 12 and 27, 8 and 15, 12 and 24 students, respectively for "yes" and "no" in each cluster. Cluster 0 has a higher proportion of students who have not participated in a PjBL course compared to those who have participated. In cluster 1, the distribution between students who have and have not participated in a PjBL course is more balanced. Cluster 2 shows a noticeable higher proportion of students who have participated in a PjBL course.

DISCUSSION

Cluster Analysis and Satisfaction Levels

The three clusters–"less engaged or satisfied," "moderately satisfied," and "highly engaged and satisfied"–highlight distinct patterns in student engagement and learning experiences. Cluster 2's high satisfaction levels, supported by clear course design and aligned tasks, reflect Lewis' (2021) findings, which advocates starting with clear, measurable outcomes. This alignment likely enabled students to connect theoretical learning with practical tasks effectively, improving deeper engagement. Biggs and Tang's (2011) concept of constructive alignment further explain how the integration of objectives, tasks, and assessments likely benefited cluster 2 students.

Cluster 1 represents students who had a generally positive experience but did not reach the highest levels of engagement seen in cluster 2. Their satisfaction levels indicate that while the course design and feedback were effective, certain aspects of the course may not have fully resonated with them. This group rated course alignment and task engagement as moderate, suggesting that while they found the course beneficial, the depth of their engagement was not as profound as that of cluster 2. The balanced ratings for task difficulty and satisfaction imply that cluster 1 represents a transitional group, where students benefitted from the course but still faced occasional challenges, such as mastering reliability and validity concepts. This pattern aligns with Sandvik et al. (2024), who emphasized that student perceptions of assessment play a pivotal role in engagement and motivation.

Students in cluster 0 reported challenges such as unclear instructions and complex tasks, resulting in lower satisfaction. These findings emphasize the critical role of scaffolding, as highlighted by Tucker et al. (2024), who argue that well-structured support is essential for success in PjBL. This cluster's struggles with advanced calculations, such as KR-20 reliability coefficients, indicates the importance of providing gradual exposure to complex concepts and ensuring resources are accessible. This gap aligns with research by Khuzwayo et al. (2020), who noted that scaffolding helps learners manage cognitive load and build confidence.

Perceptions of Project-Based Learning

PjBL was positively perceived by most students, with cluster 2 showing the highest engagement and satisfaction. These findings resonate with Kokotsaki et al. (2016), who emphasize that PjBL promotes critical thinking, collaboration, and problem-solving by linking theoretical knowledge to real-world applications. The high ratings for task ownership and engagement in cluster 2 highlight the effectiveness of PjBL when tasks are well-structured and relevant.

However, students in cluster 0 struggled with balancing weekly tasks and the final project. This aligns with findings by Baysura et al. (2016), who reported that insufficient scaffolding in PjBL leads to disengagement, particularly among pre-service teachers. The challenges experienced in cluster 0 highlight a critical need for more structured guidance, such as breaking tasks into smaller, manageable components and providing clear timelines. This observation is consistent with Shurin et al. (2021) emphasis on the importance of task clarity and alignment in PjBL.

Unexpectedly, cluster 1 showed moderate satisfaction despite a balanced distribution of PjBL experience. This suggests that while PjBL benefits are well-documented, they may vary depending on individual readiness, task complexity, and the quality of facilitation, aligning with Kubiatko and Vaculová's (2011) findings that effective PjBL requires careful planning and execution.

Experience With Criteria-Based Assessment Techniques

The study revealed that prior experience with assessment techniques significantly influenced satisfaction and engagement across clusters. Cluster 2 demonstrated strong performance and engagement, aligning with Syzdykbayeva et al. (2021), who found that familiarity with CBA enhances confidence and motivation. Students in this cluster excelled in tasks such as blueprint creation and item analysis, leveraging their prior "intermediate knowledge" to navigate complex tasks effectively. This success reflects Yunusa and Umar's (2021) observation that prior knowledge and alignment between tasks and learning goals significantly enhance satisfaction and perceived learning outcomes.

Cluster 1 exhibited mixed engagement and success, reflecting a balanced distribution of prior knowledge. Students in this group benefitted from some foundational experience but faced challenges with advanced tasks. This aligns with Matzakos and Kalogiannakis (2018), who found that structured support systems in distance learning mathematics programs help students with varying readiness levels succeed. The findings suggest that differentiated instruction and reflective practices, as proposed by Yildiz Durak (2020), could further support students in this cluster by fostering connections between theory and practice.

In contrast, cluster 0 struggled with advanced tasks like KR-20 reliability calculations. These difficulties mirror findings by Kuznetsova (2019), who identified a lack of alignment between student preparedness and course expectations as a significant contributor to dissatisfaction. The challenges in this cluster highlight the importance of scaffolding, as emphasized by Khuzwayo et al. (2020), to help students bridge the gap between theoretical understanding and practical application.

Participation in PjBL Courses

Prior participation in PjBL courses emerged as a key factor in satisfaction. Students in cluster 2, who had greater prior exposure to PjBL, demonstrated higher confidence and engagement. This aligns with Kim et al. (2019), who found that pre-service teachers' perceptions of PjBL improved significantly after direct exposure, enhancing motivation and learning outcomes. The moderate satisfaction observed in cluster 1 aligns with Lee's (2014) findings, which highlight that students with mixed levels of prior experience benefit from courses that balance structured activities with opportunities for collaboration. These findings suggest that future iterations of the course could incorporate orientation sessions or foundational PjBL workshops to better prepare students with limited prior exposure. Conversely, the struggles of students in cluster 0, with limited prior PjBL experience, underscore the need for foundational support to facilitate their transition to PjBL methodologies. Tucker et al. (2024) emphasize that scaffolding and clear task alignment are critical for ensuring that students new to PjBL can succeed.

Assessment Clarity and Feedback

Clear assessment criteria and actionable feedback emerged as critical factors influencing satisfaction levels. Cluster 2 rated these aspects highly, supporting Andrade's (2010) assertion that transparent criteria and timely feedback foster self-regulated learning and engagement. Similarly, Mahir et al. (2021) found that clear learning materials and assessment criteria significantly enhance satisfaction in open education mathematics programs. In contrast, cluster 0 reported lower ratings, reflecting difficulties in understanding expectations and aligning their efforts with assessment criteria. Holmes (2015) emphasized that clear, continuous feedback frameworks can significantly improve student engagement and confidence, underscoring the need for more explicit guidance in future iterations of the course.

Gender Differences

Female students were more represented in the highly satisfied clusters (1 and 2), indicating a possible gendered pattern in benefiting from PjBL and CBA approaches. This trend aligns with Holmes (2015), who observed that female students often respond more positively to structured and transparent assessment frameworks. Although the gender differences were not statistically significant, the observed trend suggests that instructional strategies may interact with gender in subtle ways, warranting further investigation.

CONCLUSIONS, IMPLICATIONS, FUTURE RESEARCH, AND LIMITATIONS

This study integrated PjBL in CBA techniques course designed for future mathematics teachers. The study revealed distinct clusters of students differing in their levels of satisfaction with the CBA course. These clusters highlighted variations in engagement and learning experiences, with highly satisfied students benefiting from well-aligned tasks, actionable feedback, and prior exposure to assessment techniques and PjBL. Students with intermediate knowledge of assessment techniques and prior PjBL experience exhibited high satisfaction, indicating the significance of foundational knowledge in navigating course complexities. Conversely, those with limited prior exposure faced greater challenges, particularly with complex tasks such as reliability calculations and item analysis, indicating the need for customized support.

The findings indicate the importance of curriculum design that aligns tasks and assessments with learning outcomes, ensuring that students engage with relevant and meaningful content. Tailoring teacher preparation programs to include practical, hands-on experiences with both PjBL and CBA can build confidence and facilitate skill transferability. Reflective assignments and opportunities for self-assessment are critical for bridging the gap between theoretical knowledge and practical application. Instructional practices should emphasize regular, actionable feedback to boost student engagement and motivation. Peer mentoring and collaborative learning can support students struggling with complex tasks, fostering a more inclusive learning environment. Gender dynamics, while not statistically significant in this study, suggest potential benefits in considering how instructional strategies might address diverse learner needs.

Future studies should explore the long-term impacts of CBA and PjBL on teaching practices and student outcomes in real-world classrooms. Experimental research could identify the most effective scaffolding strategies for students with minimal prior experience in assessment techniques. The role of gender in shaping responses to PjBL and CBA should be examined further, focusing on instructional methods that address diverse learner needs. Replicating this study in different cultural and educational contexts would help determine the generalizability of these findings. Additionally, research into the integration of digital tools for simplifying complex assessment tasks, such as reliability calculations, could provide valuable insights into enhancing student engagement.

This study was conducted with a specific group of future mathematics teachers, limiting the generalizability of the findings to other disciplines or educational settings. The sample predominantly included younger students, which may not fully capture the experiences of older, non-traditional learners. Reliance on self-reported data may introduce bias, as participants might overestimate or underestimate their engagement and learning outcomes. The study did not systematically analyze specific components of tasks that posed challenges, limiting insights into how to better scaffold these tasks. Variability in instructor facilitation and project complexity was not accounted for, which may have influenced differences in cluster satisfaction levels. Finally, the study's cultural and educational context may have shaped students' perceptions of PjBL and CBA, limiting the findings' applicability to other settings.

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