Journal of Contemporary Educational Research, 2025, Volume 9, Issue 8
http://ojs.bbwpublisher.com/index.php/JCER
ISSN Online: 2208-8474
ISSN Print: 2208-8466

A Study of a KUD-BOPPPS Teaching Model for Advanced Mathematics Courses at a Chinese University for International Students

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Abstract: International student enrollment has rapidly grown in China, positioning transnational education as a significant component of the country's higher education system. So our study investigates an innovative teaching approach that combines the Knowing-Understanding-Doing (KUD) framework with the BOPPPS pedagogical model (which includes the Bridge-in, Objective, Pre-assessment, Participatory Learning, Post-assessment, and Summary components), with specific application to undergraduate mathematics teaching for international students at a Chinese university. Taking Calculus 1 as a case study, our study evaluates the implementation efficacy of this integrated approach. The findings offer valuable insights for those seeking to enhance the quality and effectiveness of their teaching methodologies in culturally diverse undergraduate mathematics classrooms.

Keywords: KUD-BOPPPS; Advanced mathematics courses; International students in China

Online publication: 17th September 2025

1. Introduction

The number of international students' enrollment in China has markedly increased in recent decades. Among international student destinations worldwide, China ranked third in 2021 with 440,000 international students, according to the "Brief Statistics on International Students in China" report by the Ministry of Education. As a result, transnational education plays an increasingly critical role in its educational system and contributes to cross-cultural awareness.

In spite of this, international students' transition into Chinese academic settings could be challenging. This is especially true when it comes to a variety of pedagogical approaches and establishing meaningful social connections with peers from diverse cultural backgrounds [1]. Aspects of international student learning experiences have been explored in the existing literature. Key areas of investigation include determinants

of successful acculturation [2], psychological stressors linked to mental well-being [3], barriers to academic achievement [4–6], and so on. A comprehensive understanding of academic adaptation processes among international students is crucial for those seeking to enhance support mechanisms during the initial phase of university-level mathematics instruction.

There have been many studies examining international students' learning experiences at Chinese universities, such as the studies [7–11]. In particular, the study analyzes contemporary pedagogical practices in advanced mathematics education [12]. It focuses on exploring innovative instructional models and methodologies tailored for international students within the digital learning environment characteristic of the "Internet Plus" era. The study indicates that numerous factors stimulate students' mathematical performance, including curriculum factors and other non-curricular factors, such as parental expectations and the duration of private tutoring classes [13]. While the study suggests that integrating KOGNITY not only enhances students' problem-solving and abstract reasoning skills but also significantly outperforms traditional methods, limitations such as non-randomized sampling, contextual variables, and the absence of long-term retention data are acknowledged [14]. Despite this, there are still many gaps in the current literature [15,16]. Few studies have examined the learning experiences of students in the context of mathematics in Chinese universities [17]. In addition, the shift from secondary to university-level mathematics often necessitates substantial adjustment for international students. Thorough study of international students' mathematics learning experiences is thus essential for universities aiming to provide effective academic support during their initial year of mathematics education.

This study explores an innovative pedagogical framework that integrates the BOPPPS teaching model with the knowing-understanding-doing (KUD) strategy. It redesigns the calculus 1 curriculum for international learners at a Chinese applied university. Focusing specifically on first-year calculus 1 instruction, the research investigates the implementation of this KUD-BOPPPS approach while accounting for international student populations' unique academic and cultural characteristics. This curricular innovation aims to enhance student engagement and optimize learning outcomes through systematic instructional restructuring.

Our study proposes an innovative pedagogical framework that integrates the BOPPPS teaching model with the knowing-understanding-doing (KUD) strategy. It redesigns the Calculus 1 curriculum for international learners at a Chinese applied university. Focusing specifically on first-year calculus 1 teaching, the study investigates the implementation of this KUD-BOPPPS approach while accounting for international students' academic and cultural characteristics and the particular properties of advanced mathematics. This curriculum innovation aims to enhance student engagement and optimize learning outcomes through systematic instructional restructuring.

2. Theoretical frameworks and models

2.1. An overview of the Knowing-understanding-doing teaching method

Originally conceptualized by Tomlinson [18], the knowing-understanding-doing (KUD) framework restructures teaching dynamics and provides learners with diverse options for acquiring information, constructing conceptual understanding, and demonstrating knowledge acquired. This approach represents a contemporary constructionist pedagogical strategy that adopts a learner-centered philosophy emphasizing individual differentiation and addressing diverse student needs, preferences, and learning dispositions. The methodology incorporates a structured sequence of teaching procedures designed to transform passive learners into active participants, while the teacher assumes a facilitative role. Key implementation features include: organizing

students into collaborative learning teams, employing visual representations to introduce concepts initially, followed by distributing concept-based learning activities aimed at fostering deep conceptual understanding among participants.

The KUD approach comprises three distinct cognitive phases. The initial phase (K) focuses on foundational knowledge acquisition, requiring learners to knowledge essential terminology, core concepts, factual information, and fundamental definitions within a given subject area [19]. This knowledge base serves as a crucial prerequisite for transforming learners from passive recipients into engaged participants, while simultaneously establishing a platform for scholarly inquiry and knowledge expansion. The second phase (U) emphasizes in-depth understanding, wherein students must comprehend the underlying principles, theoretical generalizations, and disciplinary rules within their field of study. This stage is particularly critical as it enables the development of higher-order cognitive skills, including application, analysis, synthesis, and evaluation - capacities that remain inaccessible without substantial conceptual mastery. The final phase (D) represents the application phase, wherein learners operationalize acquired knowledge and comprehension through novel educational contexts. This implementation stage necessitates communicative competencies, cognitive processing, and strategic planning [20].

2.2. An overview of the BOPPPS teaching model

The BOPPPS teaching model, originally conceived by Douglas Kerr and his team, has gained international recognition and has been implemented across educational institutions in over 30 Western nations [21]. In recent years, this pedagogical approach has been adopted within Chinese universities, demonstrating significant applicability to collegiate teaching environments [22]. This model is characterized by its learner-centered philosophy, advocating instructional strategies tailored to diverse learning populations. It underscores the importance of student engagement, bidirectional teacher-learner communication, and instructional coherence. Structurally, the BOPPPS model includes six sequential phases: (1) bridge-in (B), which establishes contextual relevance; (2) objective (O), clarifying learning outcomes; (3) pre-assessment (P), diagnosing prior knowledge; (4) participatory learning (P), facilitating active knowledge construction; (5) post-assessment (P), evaluating comprehension; and (6) summary (S), consolidating key concepts. These interconnected elements collectively form a cohesive pedagogical system, enabling teachers to systematically organize and deliver instructional content. Participatory learning cultivates learners' capacity to apply theoretical knowledge to practice. Such engagement not only enhances learners' intrinsic motivation but also facilitates the identification and remediation of knowledge gaps, thereby optimizing overall learning outcomes.

3. Studying advanced mathematics courses as an international student at a Chinese university

Discursive formulations of knowledge in socioculturally situated learning environments, particularly mathematics classrooms, actively shape and transform institutional frameworks. The findings of empirical studies indicate that pedagogical approaches in formal and collaborative learning environments are influenced by collectively endorsed values, which affect students' mathematical identities [23]. Consequently, students' engagement in instructional activities is mediated by their subjective understanding of these socio-mathematical conventions. International students, in particular, may encounter substantial socio-cultural adaptation challenges when navigating unfamiliar academic environments.

Comparative pedagogical research has consistently identified significant variations in teaching approaches

across global mathematics classrooms. In particular, instructional practices in Chinese universities are deeply embedded in the Confucian traditions, which position teachers as authoritative figures and subject-matter experts [24]. This pedagogical orientation often differs markedly from the methodologies that dominate Western or other educational systems [25].

Existing studies have demonstrated that mathematical learning is multifaceted in international education contexts. To investigate the diverse variables affecting international students' mathematical development, our study was conducted within the institutional framework of a Chinese university establishment, with a particular focus on analyzing the localized implementation of the academic program. As a provincial university, it has cultivated distinctive international and regional attributes.

A majority of our university international students come from Asian and African countries, with a wide range of cultural and educational backgrounds. Many of them are native English speakers, while their foundational mathematical competencies often lag behind their Chinese counterparts. This is partly attributed to differing academic trajectories--particularly the absence of standardized national examinations and their associated rigorous test preparation culture. Conventional teaching mechanisms employed by domestic students, including teacher-centered teaching, uniform assignments, attendance-based grading, and high-stakes examinations, prove inadequate at accurately gauging international students' academic progress. This disparity underscores the imperative to develop a more equitable, multidimensional evaluation framework that accounts for diverse learning backgrounds.

4. A case study on KUD-BOPPPS teaching model for international students

Our study employs an integrated KUD-BOPPPS teaching model to examine the enhancement of advanced mathematics teaching for international learners within a Chinese local university context. The synthesized pedagogical approach capitalizes on the complementary strengths of both methodologies: while KUD emphasizes conceptual mastery through structured learning objectives, BOPPPS provides a systematic lesson design template. Significantly, both paradigms converge on fundamental learner-centered principles, including: (1) Prioritizing student agency in the learning process, (2) Facilitating active classroom engagement, (3) Implementing formative assessment mechanisms.

4.1. Experimental subject

As a fundamental requirement across STEM disciplines (Science, Technology, Engineering, and Mathematics) and medical fields, calculus serves as a cornerstone of undergraduate education. This foundational mathematics course develops essential competencies in two critical dimensions: establishing rigorous theoretical mathematical proficiency and fostering innovative problem-solving capacities. These acquired skills create vital scaffolding for advanced disciplinary coursework in students' respective majors. Beyond its immediate academic utility, calculus education cultivates systematic scientific reasoning and analytical capabilities. This pedagogical function holds particular significance in higher education, where it contributes uniquely to the development of interdisciplinary cognitive skills essential for professional formation across diverse fields. As a foundational mathematics course typically delivered in the freshman year, calculus competes with multiple disciplinary requirements for students' limited study time. Such conditions underscore the urgent need for pedagogical innovation in calculus instruction.

4.2. Participants

This study involved 126 undergraduate participants enrolled in Calculus 1 during the first semester of 2023-2024, 2024-2025 academic years at Zhejiang University of Science and Technology (Zhejiang Province, China). The participants came from four distinct engineering disciplines: Data Science and Big Data Technology, Robotics Engineering, Food Science and Engineering, and Civil Engineering.

4.3. KUD-BOPPPS design for teaching

Teaching design serves as a fundamental framework guiding teachers in the systematic preparation and implementation of teaching activities. As a structured planning process, it requires teachers to comprehensively organize instructional content, methodologies, and assessment strategies in alignment with prescribed curricular objectives. The efficacy of classroom instruction is largely contingent upon the quality of this preparatory design phase.

The design can be sequentially structured into three distinct phases based on chronological sequencing: K-phase, U-phase, and D-phase stages. Our study presents an integrated teaching-learning framework that merges the fundamental components of the BOPPPS model with the characteristics of the KUD approach.

4.3.1. K-phase

The K-phase component of our teaching design fundamentally differs from conventional preparatory lessons by demanding a more in-depth level of knowledge transfer. This enhanced expectation requires more rigorous teaching planning from teachers, who must address two critical dimensions of task design: tailoring learning activities to students' cognitive capabilities, and setting quantifiable assessment criteria to effectively assess learning progress. During these phases, teachers play a supportive role by offering targeted scaffolding, systematically documenting students' conceptual difficulties, and providing timely, formative feedback, which is to supports knowledge acquisition.

4.3.2. U-phase

Effective teaching design should make careful consideration of bridge-in activities to establish meaningful cognitive connections between learners and course content. These transitional components serve dual teaching purposes: to enhance student engagement in preparatory learning and to support more efficient task completion. The bridge-in process could take multiple forms, such as game-based activities, problem-solving scenarios, and cognitive conflict situations. Teachers could employ various strategies such as creating content-relevant contexts, drawing upon students' prior knowledge, or posing thought-provoking questions to stimulate interest. Furthermore, K-phase task design should incorporate the following essential elements based on instructional objectives and identified student difficulties:

(1) Alignment between task requirements and specified learning outcomes, ensuring comprehensive coverage of key concepts.
(2) Detailed and unambiguous task descriptions to eliminate potential confusion.
(3) Incorporation of engaging elements to maintain learner motivation.
(4) Provision of appropriate scaffolding resources to support task completion.

In addition, teachers facilitate participatory learning engagements centered on planned teaching tasks. This enables students to simultaneously reinforce existing knowledge constructs while gaining novel understandings. In a collaborative group setting, each team examines a designated difficult topic. The teachers could help by maintaining dialogue direction and offering differentiated instructional support. During subsequent plenary

discussions, the teacher synthesizes prevalent conceptual difficulties across groups. The teacher aligns these with predefined learning outcomes and delivers targeted consolidation to enhance comprehensive content mastery.

4.3.2. D-phase

Teachers may strategically schedule D-phase evaluations based on contextual requirements, implementing them following in-class activities or during subsequent independent study periods. These assessments serve dual purposes: monitoring students' developmental progress after formal teaching and evaluating knowledge gain through diverse methods, including interdisciplinary exercises, standardized evaluations, and competitive learning formats. The assessment design should incorporate two critical aspects: (1) measurement of objective outcomes and (2) evaluation of applied problem-solving competencies, potentially including the development of actionable implementation plans. Furthermore, the teacher may develop extended-learning materials to support continued knowledge exploration beyond formal instructional periods, supporting progressive intellectual development.

5. Implementation of the KUD-BOPPPS teaching model in the Calculus 1 course

5.1. A general overview

Given the teaching challenges in advanced mathematics courses for international students at their host university, by adopting an application-oriented approach, our study implemented the KUD-BOPPPS teaching framework to facilitate comprehensive pedagogical transformation spanning conceptual foundations, learning objectives, resource utilization, and systemic organization. The proposed design emphasizes didactic strategies that enhance student engagement. Each teaching unit is structured to promote conceptual understanding and creative problem-solving capacities through a variety of cognitive processes. Furthermore, the integration of competitive academic activities with course content is posited as a mechanism for fostering interdisciplinary knowledge integration and innovation competencies.

5.2. The process of practical teaching

Through the KUD-BOPPPS framework, significant teaching effects are demonstrated in the Calculus 1 module. This approach represents an alternative to conventional teaching paradigms by systematically guiding teaching delivery through multiple dimensions: (1) integrated curriculum design, (2) student-centered learning processes, (3) application-oriented practice settings, and (4) comprehensive assessment mechanisms. Collectively, these components establish a rigorously structured and well-organized framework for practical mathematics education.

According to the KUD-BOPPPS model, course content is broken down into a series of teaching units, with each unit's duration (approximately 15 minutes) calibrated to align with empirically established attention spans. These modular components are explicitly designed to fulfill specific KUD learning objectives. To optimize instructional efficacy, the micro-lecture framework incorporates several core principles: (1) Systematic integration of fundamental mathematical concepts and methodologies within lesson structures; (2) Implementation of inquiry-based pedagogy centered on student autonomy and problem-solving paradigms; (3) Scaffolding knowledge acquisition emphasizes cognitive progression from prior knowledge to novel concepts; (4) Strategic employment of multimedia technologies to facilitate concept visualization and complex topic decomposition.

5.3. Teaching practice

The student-centered teaching approach grounded in hands-on learning principles facilitates active student engagement through task-oriented activities and problem-solving exercises, thereby creating an authentic "learning by doing" classroom environment. When students confront requirements and associated challenges, they gradually develop cognitive patterns encompassing creative thinking, design capabilities, constructive approaches, discovery processes, collaborative skills, and problem-solving strategies. Consequently, in practical teaching settings, the implementation of the KUD-BOPPPS framework combined with inquiry-based curriculum design is strongly recommended.

5.4. Teaching reflection

This model demonstrates significant potential for fostering comprehensive student development and nurturing essential competencies. Nevertheless, practical implementation reveals certain limitations, particularly in large classes, in which ensuring adequate participation for all students poses considerable difficulties. A notable instance of this issue occurs during collaborative learning activities. In this instance, some group members may exhibit passive engagement while benefiting from their peers' contributions, compromising the objective of learning outcomes.

Implementing this methodology requires teachers to increase their professional competencies. Teachers must conduct in-depth K-stage analyses of learner characteristics and possess an in-depth understanding of course-specific requirements. Furthermore, detailed preparation for both course design and teaching approaches is imperative. The framework's effectiveness ultimately depends on teachers' capacity to adapt teaching strategies and optimize course designs. This is due to the unique interplay between subject matter characteristics and student learning profiles.

6. Conclusion

The KUD-BOPPPS teaching model is fundamentally student-centered, ensuring comprehensive student engagement and immediate feedback collection while prioritizing students' development needs. This integrative approach synergizes KUD's focus on learner autonomy with BOPPPS's systematic instructional architecture, thereby facilitating an interactive teaching context conducive to the cultivation of higher-order cognitive abilities, including analytical reasoning and applied problem-solving competencies. Using the structural foundation of the KUD-BOPPPS paradigm enables a critical reassessment of curricular content allocation, optimization of teaching sequencing, and implementation of more valid learning outcome assessment methodologies.

Our study establishes a framework for Calculus 1 pedagogy grounded in competency-based teaching objectives, aligned with institutional talent development programs. In response to identified instructional challenges in teaching international students, the proposed approach adopts a learner-centered paradigm as its foundational principle.

The teaching design of our study adopted the KUD-BOPPPS pedagogical model, which establishes systematic alignment with predefined learning objectives. This approach facilitates the implementation of an actionable KUD-BOPPPS teaching strategy that emphasizes learner characteristics and monitors the complete teaching process. Through this methodology, the study aims to establish a dynamic teaching ecosystem characterized by timely feedback mechanisms and adaptive instructional modifications.

Funding

Zhejiang Provincial First-Class Undergraduate Internationalized Course of 'Calculus 1'; Teaching Reform Project of the Research and Development Center for University Mathematics Teaching in Higher Education Institutions (Project No.: CMC20240641); Provincial-level undergraduate teaching reform projects in Zhejiang province (Project No.: JGBA2024350)

Disclosure statement

The authors declare no conflict of interest.

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