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Effect of American-Based Professional Development Program on Acculturation Strategies of Kazakhstan Mathematics Faculty

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Abstract: The views and practices of teaching mathematics are significantly influenced by the cultural and social contexts, resulting in differences in teaching traditions among countries. Thus, when evaluating the effectiveness of professional development (PD) programs, it is crucial to consider differences in teaching traditions between PD participants and providers. There is limited research that examines PD participants' acculturation strategies in such circumstances. This case study examines the influence of the PD program that introduced current teaching traditions in American mathematics education to Kazakhstan's university mathematics faculty on their perceptions and practices of teaching discrete mathematics to aspiring mathematics teachers. The PD program focused on connecting abstract mathematical concepts to real-life applications, and integrating technology and STEM applications using inquiry-based strategies. The study findings indicate that, while PD enhanced faculty knowledge and attitudes toward technology integration, it did not significantly alter their views on teaching practices. A traditional teacher-centered approach persisted even when technology was incorporated, highlighting the deeply ingrained nature of educational traditions and their resilience to change. This underscores the importance of considering the cultural context and addressing deeply held beliefs in professional development initiatives, especially when aiming for substantial shifts in teaching practices.

Keywords: international cooperation; professional development; acculturation strategies; reformed teaching; technological pedagogical content knowledge (TPACK)

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1. Introduction

Although mathematics has often been viewed as a universal subject, mathematicians and mathematics educators from different cultures hold very distinct views on how mathematics should be taught. Due to historical and cultural factors, mathematics is a subject that contributes to individuals' development in many aspects beyond academic purposes [1]. Thus, differences in social and cultural contexts may lead to variations in mathematics education traditions. In this study, *mathematics education tradition* of a group refers to the shared dominant values and expectations of mathematics education, shaped by the cultural, historical, and environmental contexts of a certain society [2]. Comparative studies worldwide have highlighted the diversity of educational traditions, revealing how these traditions influence teaching practices across different cultures. For example, the current dominant education tradition in the United States advocates for enjoyable, personalized, and intrinsically motivated learning experiences that promote student-centered learning, with a strong emphasis on the meaning of mathematics and the process of doing mathematics and understanding concepts before memorization and internalization [1,3]. In contrast, education traditions in most East Asian countries value hard work, perseverance, the role model of teachers, and extrinsic motivation. Thus, teaching traditions promote centralized instruction, prioritizing fundamental mathematics content and essential procedures or skills that rely heavily on memorization, drills, and rote learning [3]. While much research has compared Western and Eastern mathematics education traditions focused on East Asian countries such as China and Japan, little research has explored education traditions in Central Asian countries, which have unique blends of cultural and historical influences.

Kazakhstan is an especially interesting case because its education system has been undergoing significant transformations since its independence from the Soviet Union in 1991, including efforts to align with Western educational standards [4]. In higher education, faculty members are increasingly expected to modernize their teaching practices to meet these new standards. One way this is being addressed is through professional development (PD) programs, mostly offered by experts from Western countries, that introduce faculty to new teaching traditions. When faculty members participate in PD, they are exposed to teaching methods and educational philosophies that are often different from the traditions they have experienced. According to Berry [5], the process of psychological and social adaptation to a new educational tradition can be viewed as acculturation. Thus, faculty must navigate the tension between maintaining their heritage teaching traditions and adopting new ones, creating various acculturation strategies [6].

Given Kazakhstan's unique educational and cultural context, the purpose of this study was to examine the acculturation strategies in perceptions and teaching practices of two Kazakhstan's university mathematics faculty who participated in a PD program that introduced them to the current teaching traditions of American mathematics education.

2. Background

Alan Bishop [7] highlights the substantial influences of social, cultural, and historical factors on mathematics education tradition in various countries. Since the early ninth century, Central Asian countries have been influenced by Islamic culture, which caused their mathematics education tradition to reflect characteristics akin to the ancient Chinese mathematics education tradition [8]. The latter influence of the Union of Soviet Socialist Republics (USSR) contributed to shaping the teaching traditions of mathematics with a focus on lectures and exercises [3,9,10]. In recent decades, as Central Asian countries became independent, they have experienced significant transformations, which set their social and educational goals apart from other countries. Consequently, it is imperative to examine Central Asian mathematics education traditions independently, as they are distinct from those in other Asian countries.

Since Kazakhstan became independent from the USSR in 1991, it has undergone significant societal reforms, moving away from Sovietized structures, including the transformation of its political, economic, and educational systems to more flexible and autonomous [4]. Higher education reform is a critical component of these transitions, and the Kazakhstan government enforces the reform by changing its curricula, pedagogy, institutional structure, and laws [11]. Kazakhstan has aimed to align its educational system with international standards, including but not limited to increasing financial support for education programs, popularizing the use of the Internet and technology in schools, and developing programs to improve the quality of teachers [12]. Furthermore, after becoming a signatory to the Bologna Press in 2010, Kazakhstan has driven its higher education system toward a Western structure and standards of education [4,8].

However, aligning with these international standards requires not only systemic reforms, but also significant efforts in faculty development. Kazakhstan's educators must acquire new skills and adapt to modern teaching practices to effectively support students during this transitional period [12–14]. To facilitate this transition, various programs have been initiated, including partnerships with international institutions to bring in Western experts to provide PD aimed at both schoolteachers and university faculty, exposing Kazakhstan's educators to new teaching traditions and methodologies, which are often very different from their own. This case study is part of a project funded by the American Council for International Education in collaboration with the Ministry of Education of Kazakhstan to provide a PD based on dominant American teaching traditions for Kazakhstan's university mathematics teacher educators.

3. Theoretical Framework

This study is framed by merging two theoretical frameworks, The Framework for Studying the Effects of PD [15] and the modified Acculturation Strategies Framework [16], to explore faculty acculturation strategies in terms of perceptions and teaching practices.

The framework for Studying the Effects of PD (SEPD) [15] "represents interactive, non-recursive relationships between the critical features of professional development, teacher knowledge and beliefs, classroom practice, and student outcomes" (p. 184). In this study, the authors focus specifically on examining how PD influences participants' perceptions and teaching practices. The SEPD framework suggests that PD has a sequence of impacts starting with PD experience, followed by knowledge and skill enhancement, changes in attitudes and beliefs, implementation of newly acquired practices, and, finally, improvements in instruction and student achievements. This framework identifies five core features of effective PD: content focus, active learning, coherence, duration, and collective participation. It also suggests that these features should be measured to assess the PD's impact on changes in participants' perceptions, changes in practices, and changes in students' achievement [15] (Figure 1).

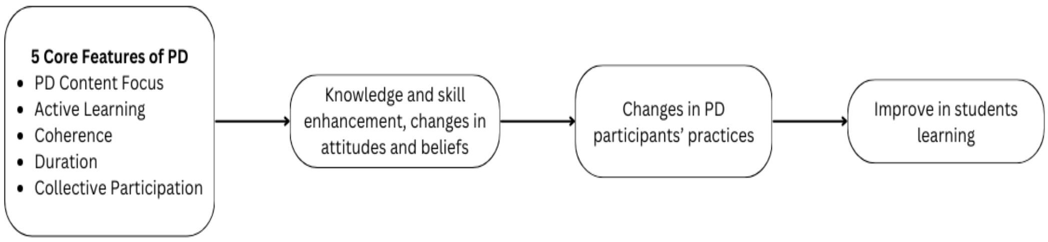

Figure 1. Framework for studying the effects of PD.

While the PD framework takes into account the teaching and learning contexts, which could include teacher and student knowledge and attitude, and environmental factors such as type of university (e.g., public or private) and geographic region (e.g., rural or urban), it does not account for the potential influence of education traditions of participants and PD providers. Therefore, in this study, the authors consider education tradition to be separate from the context of teaching and learning. When different education traditions intersect, the reactions of participants can be complex. Understanding the potential influences of Western education tradition on Kazakhstan faculty experience in the PD is a central focus of this study.

The Framework of Acculturation [16] explains the effects that occur when two groups from different cultures come into continuous first-hand contact, which can manifest at both cultural/group and psychological/individual levels (Figure 2).

At the cultural level, acculturation results in "cultural changes in both groups and in the emerging ethnocultural groups during the process" [16] (p. 14). The changes can be observed as "minor or substantial and range from being easily accomplished to being a source of major cultural disruption" [16] (p. 15). At the individual level, individual identity, values, attitudes, and behaviors are influenced by acculturation at the moment of cultural contact. Because of the vast differences among individuals (even within the same group or society) under the same cultural contact experiences, it is important to explore individuals' acculturation experiences [6].

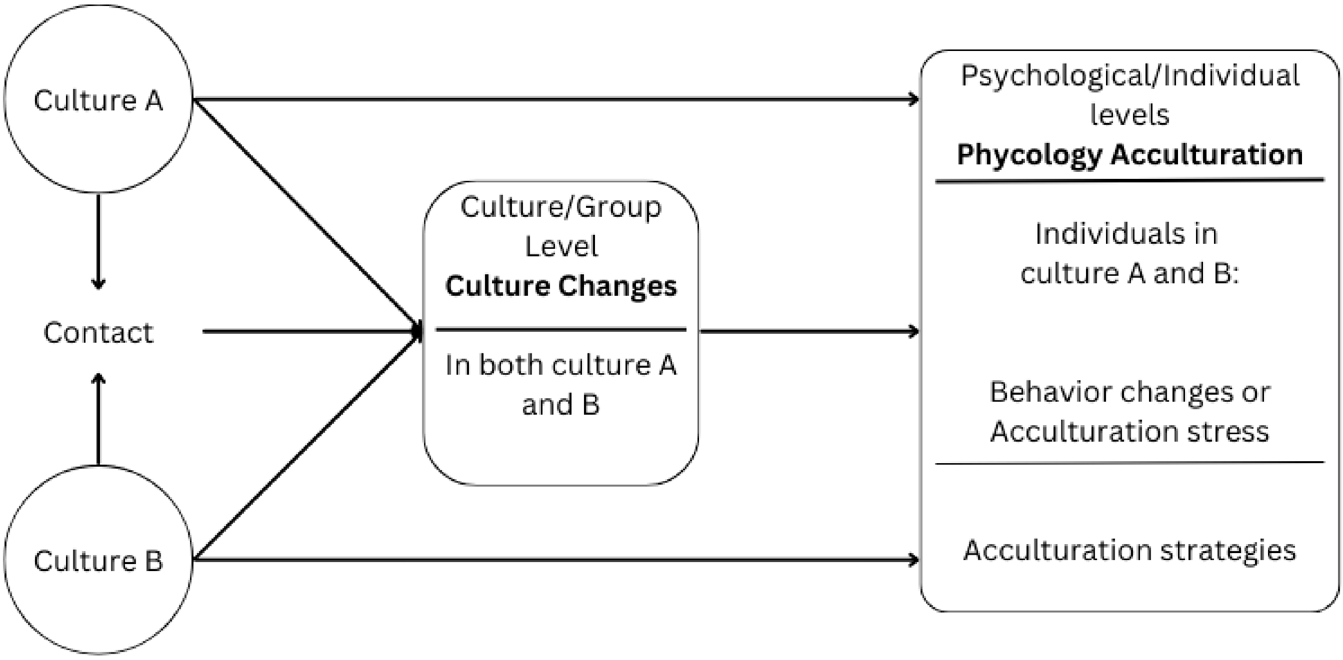

Figure 2. Framework for conceptualizing acculturation components and relationships.

In this study, the authors focus on individual faculty experiences during PD to provide insights into how differences in education traditions affected faculty acculturation in the short term. The short-term outcomes of acculturation can be observed as behavior changes or acculturation stress (such as uncertainty, anxiety, and depression) and acculturation strategies to indicate how individuals intend to enact acculturation [16]. The authors adapted the acculturation framework to examine individual faculty acculturation strategies in perception and teaching practice. The acculturation strategies are distinguished based on individuals' preferences for maintaining their heritage culture and their engagement with other cultures [6] (Figure 3).

This study adapts Berry's definitions of acculturation strategies in the context of faculty PD (Table 1). Since teachers must employ some form of pedagogy, it is inevitable that they will draw on either their traditional methods or newly introduced approaches. Therefore, the *marginalization* strategy used in the original framework is not applicable in an educational context; therefore, it was removed from this study framework.

As Kazakhstan faculty participated in PD, the authors examined whether they were affected by both their perceptions and teaching practices. The variations in cultural and social contexts influence perceptions of mathematics and its pedagogy, which in turn result in differences in how courses are implemented [17]. To explore faculty acculturation strategies, this study considers the teaching traditions that include teaching methodologies, teaching objectives, assessment practices, organizational structures, and cultural norms in the classroom.

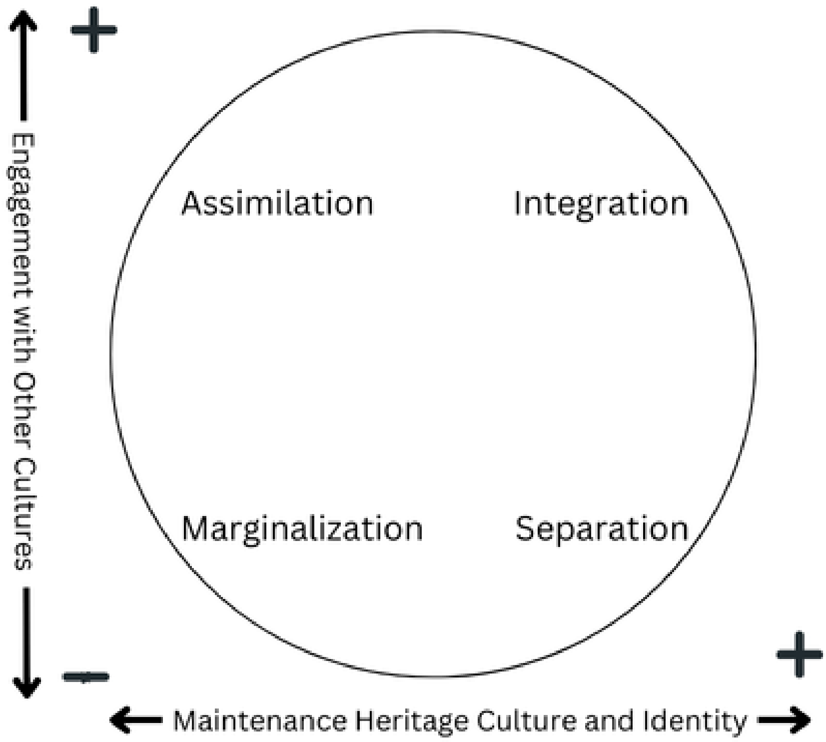

Figure 3. Four acculturation strategies for small groups and their individual members.

Table 1. Definitions of acculturation strategies.

Strategies	Original Definition	Definition of Education Tradition
Assimilation	Individuals do not wish to maintain their cultural identity and seek daily interaction with other cultures	Instructors do not wish to maintain their traditional pedagogical practices and seek daily implementation of pedagogical practices from another educational tradition
Separation	Individuals place a value on holding on to their original culture and, at the same time, wish to avoid interaction with others	Instructors place value on their traditional pedagogical practices and, at the same time, wish to avoid the implementation of new pedagogical practices from another education tradition
Integration	Individuals have an interest in both maintaining one's original culture and having daily interactions with other groups; there is some degree of cultural integrity maintained, while at the same time, the individual seeks to participate as an integral part of the larger society	Instructors, to some degree, maintain their traditional pedagogical practices and, at the same time, seek to implement some pedagogical practices from another educational tradition

The study framework considers education tradition as a factor that can influence the outcomes of PD since perceptions and behaviors of educators participating in PD are shaped not only by PD features but also by their acculturation strategies. While PD features influence faculty perceptions and behaviors, their decisions to preserve heritage educational beliefs and practices and/or engage with new educational practices from Western traditions also shape the impact of the PD. In the short term, faculty behaviors may reflect varying degrees of retention of heritage traditions and the adoption of Western traditions, leading to one of three possible acculturation strategies: separation, integration, or assimilation (Figure 4).

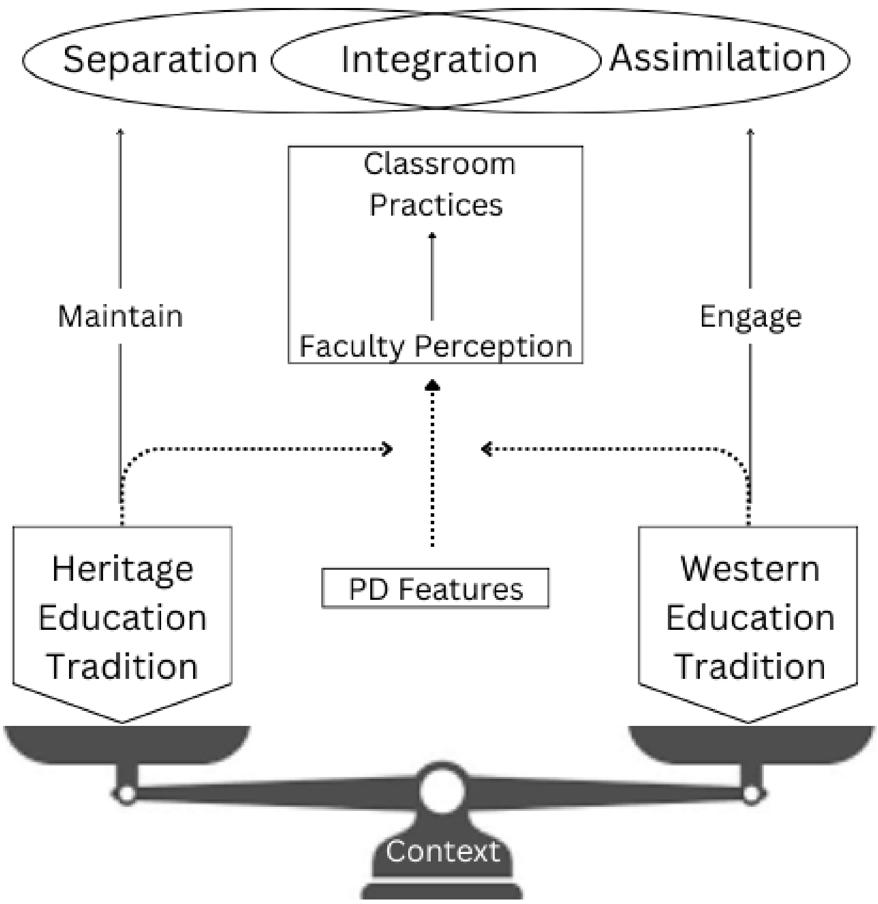

Figure 4. Theoretical framework of the study.

4. Study Context

This study was part of a 1.5 year long project funded by the U.S.—Kazakhstan University Partnerships Grants Program (UPP) aims (1) to enhance teacher preparation, teaching methodology, and pre-service teacher training, to support English language teaching and learning in Kazakhstan, including STEM, and (2) to modernize content, pedagogy, and curriculum for programs of study. In this study, the project objectives were (1) to develop a college-level discrete mathematics course in English for pre-service mathematics teachers in Kazakhstan that integrated technology and STEM applications and (2) to prepare six mathematics faculty members at two Kazakhstan's universities to teach this course to future mathematics teachers at their institutions.

This discrete mathematics course was designed to help future teachers connect high school mathematics concepts to advanced mathematical ideas, thus enabling them to foster a deeper understanding of their own future classrooms. In order to achieve this, the project team developed Supplementary Materials for the discrete mathematics textbook used by the faculty to include the GeoGebra online book with interactive tasks and STEM applications, as well as an additional set of problems that used practical examples to illustrate abstract mathematical ideas. Beginning in January 2020, the project team held online meetings to develop these Supplementary Materials. The initial workshop with faculty members was held in the spring of 2020 to review the materials. Based on faculty feedback, materials were refined and distributed to the faculty. Online faculty workshops were held in the fall of 2020, and course implementation was conducted in the spring of 2021 at the two partner universities. Table 2 shows demographic information about these two institutions

Table 2. Demographics of two partner Kazakhstan universities.

	Funding	Geographic Location	Student Enrollment	National Ranking	Teacher Education National Ranking
University 1 (U1)	Private	Suburban	7400	12	Not Ranked
University 2 (U2)	Public	Urban	7000	10	3

5. Methods

A case study approach was used to address the following research questions:

1. What is the influence of PD on faculty acculturation strategies, as demonstrated by their perceptions of teaching mathematics and teaching practices?
2. How do Kazakhstan faculty members intend and enact acculturation strategies in their discrete mathematics courses?

5.1. Description of Intervention (2020–2021 PD Program)

The study included two parts. In the first part, conducted in the fall 2020 semester, mathematics faculty from two Kazakhstan universities participated in three 3 h PD sessions led by an American STEM education expert held on consecutive Saturdays (see Table 3).

Table 3. Overview of fall professional development workshops.

Schedule	Content	Assignments
Session 1	1. Discrete mathematics course philosophy 2. Overview of methodological traditions in teaching mathematics in the USA 3. Special features of the teaching approach, e.g., real-life STEM applications, investigations, and explorations with GeoGebra	Develop practical examples for each course chapter
Session 2	1. Role of technology in the discrete mathematics course 2. Review of GeoGebra book materials 3. Introduction to GeoGebra—workshop 4. Research-based foundations for effective use of technology	1. Complete the GeoGebra basic skills tutorial 2. Select and analyze a discrete mathematics activity from the GeoGebra book. Prepare presentation: a. Demonstrate activity features b. Explain how the activity will be used in teaching
Session 3	1. Integrating technology into teaching discrete mathematics: a. STEM applications b. GeoGebra explorations, 2. Development of activities with GeoGebra 3. Faculty presentations of GeoGebra activities 4. Advanced features of GeoGebra workshop	

As part of the project, faculty members were provided with access to an online GeoGebra book that had a compilation of interactive activities adapted, modified, or developed by the project team for the discrete mathematics course. The GeoGebra book activities included pre-made dynamic mathematics demonstrations and simulations, virtual labs, and STEM application problems.

During the spring 2021 semester, faculty members were expected to integrate technology and implement pedagogical practices introduced in the PD workshops in their discrete mathematics courses. The second part of PD included monthly meetings to discuss their teaching, share their experiences, and provide faculty with support, as necessary. During these meetings, each faculty member demonstrated one of their lessons to others through micro-teaching.

5.2. Participants

For this case study, we selected two mathematics faculty members from each university. Both faculty members hold a master's degree in mathematics; Faculty 1 (F1) has seven years, and Faculty 2 (F2) has 10 years of university teaching experience.

During the study, F1 taught a lecture portion of the discrete mathematics course to 38 students at U1. The lectures were scheduled once per week for fifty minutes. F2 taught both the lecture and practice portions of the discrete mathematics course for five weeks to 16 students at U2. The lectures were scheduled twice a week for fifty minutes, and the practice seminars were scheduled once a week for fifty minutes. Both faculty taught in English.

5.3. Data Collection and Analysis

The data used for this case study included videos of two semi-structured individual faculty interviews as well as videos and lesson plans of three taught lessons, each selected by the respective faculty.

Faculty semi-structured individual interviews (F-SII) were conducted via Zoom immediately after participating in the fall PD and after teaching the course. The interview protocol was modified from the Contextualize to Learn (C2L) faculty interview protocol [18], and included seven open-ended questions about faculty attitudes and perceptions of their PD experiences, provided materials, and intended or enacted teaching.

The video recordings of the semi-structured individual interviews were transcribed, and the transcripts were analyzed using thematic analysis methodology. Based on these emergent themes, the authors identified faculty acculturation strategies in their perceptions of teaching mathematics and their teaching practices. The acculturation strategies codebook included two categories (PD Features and Education Traditions) with five codes per category that were developed based on the theoretical framework (Table 4).

The validity of the codebook was checked through (1) an expert review of the codebook for clarity and comprehensiveness, and (2) inter-coder reliability and codebook refinement, which led to 82% agreement of codes under the PD Features category and 89% agreement of codes under the Education Tradition category.

Faculty lesson plans and corresponding videos of taught lessons were analyzed using the Reform Teaching Observation Protocol (RTOP) developed by the Arizona Collaborative for Excellence in the Preparation of Teachers Program to assess the extent to which mathematics classrooms have transitioned from traditional didactic practice to student-centered active learning [19]. The protocol uses a 5-point Likert scale and includes 25 items in three subscales: Lesson Design and Implementation (five items), Content (ten items), and Classroom Culture (ten items). Items are rated based on the degree to which they are characteristic in the lesson on a scale of 0 (not observed) to 4 (very descriptive). According to Treagust et al. [20], the range of 0–25 represents teacher-centered instruction, 26–50 represents transitional instruction, 51–75 represents student-centered instruction, and 76–100 represents highly reformed instruction. Higher RTOP scores indicate that faculty members are more engaged with reformed teaching traditions, demonstrating active and student-centered practices. Conversely, lower RTOP scores suggest that faculty members rely more on traditional teaching methods, maintaining familiar, teacher-centered approaches.

While watching the videos of the taught lesson, detailed field notes were taken, carefully observing and documenting key events, interactions, and behaviors, specifically focusing on the types, frequency, and placement of teaching practices within each lesson.

Table 4. Acculturation strategies codebook.

Codes	Definitions	Example
PD Features		
Content Focus	Faculty perceptions of the PD materials (e.g., supplementary textbook, GeoGebra tutorials and book, and presentations).	I think the most valuable thing [about the PD] was about the GeoGebra
Active Learning	Faculty perceptions about their learning opportunities during PD	Maybe if we can do more practice, I think it will be better.
Coherence	Faculty perceptions about the relevance of PD to their teaching	I think it is also my field. So I'm very happy to be in this workshop.
Duration	Faculty perceptions about the length of the PD program	It is not enough time
Collective Participation	Faculty perceptions about their experience of PD with work peers	I asked some things that we had . . . in our workshop from them [peers]
Education Traditions		
Teaching Methodology	Teaching strategies and techniques to deliver mathematics content and facilitate students' learning.	I used GeoGebra as a demonstration, for demonstration examples of theories
Teaching Objectives	The knowledge and skills faculty expects students to learn from the lesson.	They have to memorize that formula, and they have to calculate it by hand
Assessment Practice	The methods faculty use to assess students' learning.	I had to check their solutions by hand, but if we had some technologies which help to do that for us, it would be very delightful.
Organizational Structure	Classroom management. How lessons are structured, including how student work is organized.	I never think that each student can also use their own computer in the same lecture.
Culture Norms	Unwritten rules that guide faculty-student relationships and behaviors in the classroom.	Generally in lectures, we will just . . . teach by presentation.

In addition, the TPACK Levels Rubric developed by Lyublinskaya and Tournaki [21] was used to score lesson videos in order to evaluate the effectiveness of the integration of instructional technology. The rubric assesses the level of Technological Pedagogical Content Knowledge (TPACK) [Recognizing (1), Accepting (2), Adapting (3), Exploring (4), and Advancing (5)] across the four components of TPACK: (1) An overarching conception of what it means to teach a particular subject with technology, (2) Knowledge of instructional strategies and representations for teaching particular topics, (3) Knowledge of students' understandings, thinking, and learning in the subject, and (4) Knowledge of curriculum and curriculum materials in the content area. Higher TPACK levels indicate that technology was effectively incorporated into teaching, demonstrating the faculty's engagement with new teaching traditions. In contrast, lower TPACK levels suggest that faculty integrated technology in ways that maintained traditional teacher-centered instructional methods.

The RTOP and TPACK scores, along with field notes, were used to identify faculty acculturation strategies in their teaching practices.

6. Results

In this section, we describe the key findings from both faculty interviews and video recordings of the lectures.

6.1. Findings from Faculty Interviews

The analysis of faculty interviews before and after teaching the discrete mathematics course resulted in several emerging themes that illustrated the influence (or lack of influence) of PD on faculty attitudes toward GeoGebra and STEM applications in discrete mathematics courses, their views on the role of technology in teaching and learning, and their perceptions of peer collaboration in professional development.

6.1.1. Theme 1: Faculty Recognized the Relevance of the GeoGebra Book for Teaching Discrete Mathematics, Felt Prepared to Use GeoGebra Materials in Teaching, and Developed Positive Attitudes Toward GeoGebra

Both participants had heard about GeoGebra before this project, but they had not previously recognized its value. "[GeoGebra] . . . wasn't something new for me. . . . when I first saw it. . . GeoGebra was not so good" (F1, 1st interview). After participating in the PD, they recognized GeoGebra as a valuable teaching tool and identified learning how to use GeoGebra as the most significant takeaway from the PD: "[I can use GeoGebra] not only in the discrete [math], I think, in other fields also, you can use that." (F1, 1st interview). Similarly, F2 noted after the PD, "I think the most valuable thing was [learning] about the GeoGebra, . . . I [got] something new for myself" (F2, 1st interview). Through PD, both faculty members began to see how GeoGebra could be meaningfully incorporated into their teaching, and this exposure prompted them to rethink their teaching practices. "As I'm a classic mathematician, I like to show the theorems, how to solve the examples, how to prove the theorems by handwriting, it was more trustworthy. But now I think GeoGebra will [also] be better at explaining [the theorems]" (F1, interview 1).

The PD focus on GeoGebra not only shifted faculty attitudes toward GeoGebra, but also helped them feel prepared to use it in teaching discrete mathematics: "I feel comfortable [using GeoGebra]. Because. . . during the [PD] sessions. . . GeoGebra . . . was clear for me. Also, I can find sources where I can learn" (F1, 1st interview). As both faculty members developed positive attitudes toward teaching with PD-provided materials, especially the GeoGebra book supplement, it was not surprising that they expressed interest in using the GeoGebra book in their courses: "In practice time. . . I hope there will be [use of GeoGebra]. Maybe as we [introduce] a theorem, we will also show [it] with GeoGebra" (F1, 1st interview). "I can use . . . GeoGebra, as a tool to . . . show some mathematics . . . ideas [to] students" (F2, 1st interview).

After teaching the course, both faculty members continued to recognize the value of GeoGebra. F2 reflected, "The most useful, significant part, I think, was using GeoGebra in the course of discrete mathematics" (F2, 2nd interview). After teaching the course, both faculty members confirmed that GeoGebra was useful in presenting abstract concepts. In his second interview, F2 stated that he used all activities from the GeoGebra book supplement for topics such as sets, combinatorics, functions, and graph theory.

6.1.2. Theme 2: Faculty Recognized the Value of STEM Applications in Discrete Mathematics but Found It Challenging to Integrate Them in Teaching Discrete Mathematics Course

The focus of PD on STEM applications helped the faculty to see that these applications can be useful in teaching discrete mathematics. In their initial interviews, both faculty members mentioned that they had never considered using STEM applications in teaching, as evident from his statement, "Before this workshop I just heard about STEM, not totally researched it, totally used it. I knew that STEM is a mixed education with chemistry, physics, with real life examples, using especially technology. So before, STEM for me was integrating other lessons." (F1, 1st interview). F2 made a similar statement: "I have never seen . . . STEM application in teaching discrete mathematics . . . I think it would be very interesting for students [to see] how discrete mathematics [is] connected with science and with everyday life" (F2, 1st interview).

After PD "I think it will be better for students to understand [discrete mathematics] with [STEM] applications, especially with real life examples" (F1, 1st interview). Both faculty members recognized the value of integrating STEM applications in their teaching of discrete mathematics: "I think about STEM, technology, about how to connect theoretical subjects with real life, with science. Also, how it could be used in real life, in science" (F2, 1st interview). After teaching the course, they continued to hold positive attitudes toward using STEM applications in discrete mathematics. F1 explicitly stated that STEM applications improved the course, and F2 emphasized the importance of considering connections between discrete mathematics problems and their applications in other disciplines. However, after teaching both faculty members stated that the integration of STEM applications into discrete mathematics courses was challenging. "STEM application. . . It's challenging because maybe I don't have a lot of knowledge about STEM" (F1, 2nd interview).

6.1.3. Theme 3: Faculty Viewed Technology Primarily as Means for Their Own Demonstrations or Student Practice

The PD focus on effective teaching strategies with technology did not influence the faculty approach to teaching, which remained mostly teacher-centered, focusing on the delivery of knowledge in lectures and practice problem-solving in seminars.

This is evidenced by the way F1 described the structure of the discrete mathematics course: "[In lecture] we will try to explain the theorems, how to prove it. . . .[In] seminars, . . . we'll do the practice materials" (F1, 1st interview). Thus, both faculty members planned to use interactive tasks in the GeoGebra book only to enhance their own lecturing or provide problems for student practice. During the first interview, F1 talked about presenting course content using new examples from the GeoGebra book he had learned during PD. Using technology in the discrete mathematics course was a new idea for F2: "Before I didn't think . . . actually that I can use computers in teaching . . . discrete mathematics" (1st interview). In addition to that, F2 planned to have students use GeoGebra tasks for practice and drills, which was a significant change in his perception of technology use in the classroom: "I never think that each student can also use [their] own computer in the same lecture, for example, to make some tasks which are given by me, for example. . . . So, it's good thing for us how we can use their computers to teach them" (F2, 1st interview).

After teaching the course, F1 explained that he had taught the course using lectures, and presented definitions and theorems before demonstrating problem-solving techniques using examples. He incorporated the GeoGebra book into his teaching for demonstrations and students' practice: "I asked questions from [GeoGebra book], that was the only [time] they used [it]" (F1, 2nd interview). Similarly, F2 acknowledged the advantages of integrating technology into his instruction: "Everything is dynamic; students can see how links or edges, for example, connect to vertices and so on. We can make our lessons more interesting" (F2, 2nd interview). F2 further described a specific example in which students used a GeoGebra applet to find the shortest path, and he demonstrated a solution using the same applet.

6.1.4. Theme 4: Faculty Appreciated the Opportunity to Learn from and with Their Peers During Professional Development

The collaborative nature of the PD, bringing together faculty members from the two universities, was beneficial for both participants. For example, F1 suggested that this collaborative experience during PD will support team planning and preparation for integrating new materials into discrete mathematics courses. "We are thinking about that with our team" (F1, 1st interview). Similarly, F2 emphasized the value of learning new ideas for teaching discrete mathematics from his peers: “There were some presentations in the last workshop. . .my colleagues from. . .other university and from my university, showing some useful examples in GeoGebra” (1st interview).

In summary, the analysis of faculty interviews indicated that PD led to faculty’s positive attitudes toward GeoGebra as a relevant tool for teaching discrete mathematics, along with their readiness to integrate it into their practice. However, they found it challenging to incorporate STEM applications and shift their views of technology beyond mere faculty demonstrations or student practice tools. The positive experience of collaborative learning during professional development underscores its potential to facilitate the continued growth of faculty members in these areas.

6.2. Findings from Video Recordings of Lectures

The RTOP and TPACK total scores for the three lessons taught by each faculty member are presented in Table 5.

Table 5. RTOP and TPACK scores of taught lessons.

Faculty		Lesson 1	Lesson 2	Lesson 3
F1	RTOP	22	22	21
		(Traditional)	(Traditional)	(Traditional)
	TPACK	1.0	1.0	1.0
		(Recognizing)	(Recognizing)	(Recognizing)
F2	RTOP	18	25	17
		(Traditional)	(Traditional)	(Traditional)
	TPACK	2.0	3.0	2.0
		(Accepting)	(Adapting)	(Accepting)

F1 taught only lectures and all followed the same sequence. Each lecture started with the presentation of theoretical material that was heavily proof-oriented. The presentation was followed by several worked examples of problems that demonstrated the application of the introduced theorems and proofs. Students were then assigned similar problems to complete independently. F1 made minimal connections between discrete mathematics topics and students’ real-life experiences or other disciplines; such a connection was observed only once. After students presented solutions for converting a sequence from explicit to recursive form, F1 remarked, “Explicit [form] is easy to find a value, but recursive [form] is better for use in programming” (2nd lesson).

Analysis of teaching according to the RTOP criteria indicated that out of the three subscales, F1 only scored high on his propositional and procedural knowledge, which represents his deep understanding of the discipline. However, the lesson design and implementation, as well as the classroom culture, reflected a traditional teacher-centered approach, so the overall scores fit in the range of traditional teaching.

An analysis of technology use in F1’s recorded lectures indicated that he mostly used Microsoft OneNote to present his lectures and to work through examples, where an interactive whiteboard was a replacement for a standard classroom whiteboard. Thus, all three lessons indicated that his TPACK was at the *Recognizing* level.

F2 taught both lectures and practice seminars, and he chose to submit two lectures (1st and 3rd lessons) and one seminar (2nd lesson). His lectures followed a similar F1 sequence, starting with content-focused presentations, followed by demonstrations of worked examples, and concluding with student practice. Compared to the lectures taught by F1, during F2's lectures, students had fewer problems to solve independently, and F2 often provided the problem solutions himself by writing them on the shared screen rather than asking students to share their solutions. However, F2 incorporated real-world elements into students' practice problems, such as using graphs to present friends' relationships (lesson 2) and finding the shortest path between real cities (lesson 3).

Based on the RTOP criteria, F2 demonstrated strong propositional knowledge; however, his scores on lesson design and implementation, procedural knowledge, and classroom culture were low, indicating that he maintained a traditional teacher-centered approach. Analysis of technology use in the lectures shows that F2 used GeoGebra materials and other instructional technology to support subject matter development. However, in the lectures, technology was only used for teacher's demonstrations. Even though the choice of tools was appropriate for the topics taught, technology just replaced non-technology materials. Moreover, students did not have the opportunity to interact with technology. Therefore, these lectures demonstrated that F2 developed TPACK at the *Accepting* level.

During the seminar, F2 provided students with practice problems to apply what they had learned during the lectures. In the submitted F2 video of the seminar, he demonstrated several different ways of providing feedback to students. For simple fact-based problems, he first projected a problem on the screen to the entire class and immediately asked students to verbally share their answers. After the students shared their answers, F2 explained the reasoning behind their answers. If students did not give an answer immediately or provided incorrect answers, F2 demonstrated how to solve the problem and explained the reasoning for the solution. For other problems that require graphing, F2 first demonstrated how to solve these problems using the Graph Online application. Then, students were assigned similar problems to solve on their own using Graph Online and submitted their answers to a group chat. F2 would then either share the students' solutions from the group chat or provide his own solutions after each practice problem.

Thus, during the seminar, F2 provided opportunities for students to engage in the lesson. He also paid attention to students' prior knowledge and provided explanations to students, which improved the classroom culture. According to the RTOP criteria, this reflects a shift toward a transitional teaching approach.

Even though F2 utilized technology (i.e., PowerPoint and Graph Online applications) to present problems and their solutions to the students, and he also expected students to utilize technology (Graph Online) to solve practice problems, students did not use technology for inquiry and exploration. As a result, the faculty TPACK during the seminar was assessed at the level of *Adapting*.

In summary, the analysis of faculty lesson plans and corresponding videos indicated that both maintained a traditional teacher-centered approach to teaching in their lectures. However, in the seminar, F2 demonstrated a shift toward a transitional teaching approach, providing more opportunities for student participation. There was also an observed difference in the way the faculty used instructional technology. F1 did not integrate interactive GeoGebra materials into his lectures, and he practically did not make any connections between mathematics and STEM applications. His lectures indicated that he was at the lowest (*Recognizing*) level of TPACK. On the contrary, F2 incorporated GeoGebra activities as alternative ways of presenting lecture topics and the online Graphing application as a practice tool for student problem solving, thus achieving *Accepting* level of TPACK during lectures and *Adapting* level of TPACK during the seminar. Neither faculty member implemented the instructional strategies emphasized during PD that promote student investigation and exploration.

7. Discussion

The results from the interviews suggest that PD positively influenced faculty knowledge and attitudes toward teaching discrete mathematics using GeoGebra. Both faculty recognized the value and high relevance of the PD materials for their course and expressed the intention to incorporate them into their teaching practices. Therefore, based on the interviews, we can conclude that both faculty members intended to follow an integrated acculturation strategy. However, the analysis of videos and lesson plans submitted by the faculty revealed differences in acculturation strategies between them. F1 maintained a traditional teacher-centered teaching approach without meaningful integration of technology or STEM applications, representing a separation acculturation strategy. On the contrary, even though F2 maintained a teacher-centered approach, he meaningfully incorporated GeoGebra book activities and STEM applications into his lectures and provided students with opportunities to use technology during the seminar, representing an integration acculturation strategy. These findings demonstrate that acculturation is an individual process that may require different times and efforts for different faculty members. At the same time, the fact that both faculty members intended to adopt integration acculturation, with F2 adapting this acculturation strategy in his teaching practice, is consistent with research showing that individuals in multicultural environments are more likely to select integration as their acculturation strategy [22,23].

PD focused on two aspects of teaching that represent commonly recognized best practices in American mathematics education traditions: integrating technology and student-centered approaches. PD positively influenced faculty attitudes toward teaching discrete mathematics using technology. Barakabitze et al. [24] highlight the importance of faculty attitudes and beliefs in integrating technology into teaching practices. Similarly, Wijaya et al. [25] identified teachers' behavioral intentions as key factors influencing the adoption of new technological teaching tools. Thus, PD achieved the goal of affecting the participants' intention to integrate technology into teaching. However, the analysis of videos submitted by the faculty indicated that only one of the participants integrated technology into their teaching. This difference may be attributed to various factors, such as a lack of specific PD-provided resources for the topics covered in the three lectures submitted by F1, insufficient technology skills to develop his own materials for these lectures, etc. According to F1's second interview, he did incorporate GeoGebra in other lectures; however, he chose not to submit them for analysis; therefore, we could not evaluate his level of TPACK in these cases. On the other hand, F2 selected videos of lessons that covered topics with readily available GeoGebra activities. These findings are consistent with studies indicating that the relevance and ease of use of technological tools are critical factors in their integration into teaching [25]. Even though a strong emphasis on student-centered teaching was made during PD, it did not lead to changes in faculty perceptions and teaching practices. Their views and approaches to teaching remained rooted in heritage/traditional education methods. This was reflected in both the interviews and the recorded lessons.

Research shows that the interaction between curriculum content and pedagogical approaches shapes instructional activities, producing different lesson types [17], in our case study—lectures and seminars. Kazakhstan, as a post-Soviet country, has undergone recent educational reforms but may still be influenced by Soviet-era curricula, which emphasize proof-based expositions and require students to solve a large number of problems [26]. Thus, the teaching traditions for the two types of sessions, lectures and seminars, are likely to remain the same as in the Soviet era. This was evident in F1's lectures, where students were assigned problems immediately after the presentation of the theoretical concepts. Similarly, F2 incorporated numerous work problems into his lectures. While lectures were primarily structured for content delivery, seminars were dedicated to student practice. The different purposes of the two lesson types likely contributed to the contrasting teaching approaches observed. Traditional teaching practices were maintained in lectures by both faculty members. Lectures remained teacher-centered, emphasizing the presentation of new knowledge, whereas seminars offered more opportunities for students' independent problem-solving. For example, F2 gave students opportunities to use Graph Online to solve graph theory problems after he demonstrated procedures and reasoning for solving several problems without technology. Given that both faculty members intended to use technology for drills and practice, they might not have felt the need to engage students in technology-based activities during lectures while reserving those tools for seminars. Consequently, it is more likely that students would have had the opportunity to engage with technology in a seminar rather than a lecture. This explains the varying levels of TPACK in lectures and seminars for F2.

Besides the influence of PD and the types of lessons, traditional teacher-centered approaches and limited student use of technology may also reflect Kazakhstan's educational traditions. Schmit et al.'s [17] study on the curriculum and pedagogy across six countries found that classroom interactions, activities, and the decisions underlying them tend to reflect the cultural norms and practices of each specific country. In Kazakhstan, society and the education system have only recently begun transitioning away from a centralized structure. Both faculty members have been educated in a centralized, teacher-centered educational tradition and most likely followed the same teaching approach during their careers. Research conducted in countries where pedagogy has traditionally been teacher-centered, such as those influenced by Confucian educational traditions, shows that many educators believe direct teacher-centered instruction best prepares students for success within the current system [27,28]. The shift to a student-centered classroom challenges educators' beliefs about their roles and relationships with students, often leading to feelings of losing control over both the classroom and students' learning. This anxiety and frustration are particularly pronounced in the early stages of the transition [29]. As the faculty recognized the benefits of teaching with GeoGebra and STEM applications, they may still have concerns about changing power dynamics in the classroom. During the initial stages of social transition and acculturation, faculty members may not yet believe in allowing students to take the lead in their learning. This may explain why the faculty highly valued teaching with GeoGebra and STEM applications, but retained their traditional teaching approach.

Another reason could be that the pandemic introduced unforeseen challenges, which significantly disrupted the teaching environment. Originally, PD was designed for in-person participation, but it had to shift abruptly to an online format. This change may have limited the ability of PD providers to effectively model intended pedagogical approaches. Moreover, online teaching added another layer of complexity, as the faculty sought to integrate PD materials and adopt new teaching practices. The simultaneous challenges of virtual teaching while navigating unfamiliar pedagogical practices may have been overwhelming, ultimately constraining the faculty in their ability to experiment with innovative teaching methods during this difficult time.

According to Berry's theory, acculturation is a gradual process and certain outcomes may take time to fully emerge. Hallinger and Lu's [29] successful implementation of problem-based learning at a graduate business school in Thailand initially faced a high turnover due to the pedagogy's conflict with the cultural norms of Thai universities. However, over time, these changes have become more accepted and valued, although their full integration requires sustained efforts and collaboration among various stakeholders in the education system [29]. Despite the educational reforms, the Kazakhstan higher education system still uses the same structure as it had during the time that the country was part of the Soviet Union [9]. For example, class size during lectures remains large, which can create difficulties in implementing student-centered instruction. As Kazakhstan continues to reform its education system—by restructuring, providing training, promoting autonomy, and fostering international relationships—faculty members are likely to develop a deeper understanding of classroom autonomy and further transition toward student-centered approaches [4]. While immediate changes in teaching practices may not always be evident immediately following PD, this study observed that participants developed new knowledge and demonstrated positive changes in their attitudes toward innovative teaching methods. As Kazakhstan continues to support educational reform, faculty will have more opportunities to deepen their understanding of and skills in new teaching methods, so they will be more likely to integrate these practices into their classrooms.

There are several limitations to this study. First, the two faculty members selected for this case study may not adequately represent the diversity of faculty teaching in Kazakhstan universities, so the findings of this study might not be applicable to other faculty members. Moreover, increasing the sample size might lead to new themes that were not discovered in this particular study. As the study involved only one faculty member from each university, it was difficult to assess whether institutional factors influenced the results. In addition, as the process of acculturation is individual and takes different times for different people, a longer period of time would have allowed us to see whether study participants combine new teaching approaches with traditional methods, revert to their heritage/traditional practices, or further shift toward innovative methods of teaching mathematics.

The study findings suggest that changes in teaching practice may require more than just knowledge and skills development; they also necessitate addressing deeply held beliefs and cultural norms. For PD developers, it is crucial to consider the cultural backgrounds, values, and experiences of participants within their education system when designing PD programs for educators from different educational traditions. Since acculturation is a long-term process, and ongoing reforms in transitioning countries lead to continuous changes, implementing a long-term PD program may provide greater benefits, allowing participants to learn and adapt effectively over time. Further research is needed on acculturation strategies and culturally responsive professional development models to facilitate meaningful and sustainable change in teaching practices.

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