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## EDITED BY

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## REVIEWED BY

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Illinois State University, United States  
Akhtar Ali,  
The Islamia University of Bahawalpur, Pakistan

## \*CORRESPONDENCE

Zaure Shagatayeva  
✉ zaureshagataeva@eclipsomail.com

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# Project-based learning via school-university collaboration: impact on general pedagogical knowledge in primary student-teachers

Assylzhan Yessimbekova<sup>1</sup>, Ainur Taurbekova<sup>1</sup>,  
Zaure Shagatayeva<sup>2\*</sup>, Nazym Zhanatbekova<sup>3</sup> and  
Nurdaulet Shakarim<sup>1</sup>

<sup>1</sup>Faculty of Pedagogy and Psychology, Zhetysu University, Taldykorgan, Kazakhstan, <sup>2</sup>Faculty of Physical Education and Art, Zhetysu University, Taldykorgan, Kazakhstan, <sup>3</sup>Faculty of Physics and Mathematics, Zhetysu University, Taldykorgan, Kazakhstan

**Background:** Service-learning, though prevalent in Western academia, remains nascent in Eurasian educational contexts. This study probes the pedagogical efficacy of a school-university partnership initiative, engaging primary education student-teachers as teaching assistants in elementary settings. Existing scholarship highlights service-learning's capacity to bridge theoretical and practical realms, bolster professional skills, and elevate self-efficacy. Yet, empirical insights into its impact on general pedagogical knowledge (GPK) and teaching self-efficacy, particularly in primary teacher education, are sparse, prompting this investigation.

**Methods:** A quasi-experimental, embedded mixed-methods design was employed, integrating qualitative reflections with quantitative data. Seventy-four undergraduate student-teachers from a primary education program were randomly assigned to a non-engaged ( $n = 37$ ) or treatment group ( $n = 37$ ). The latter participated in a service-learning intervention, collaborating with seven public schools to address specific educational challenges. Over 6–12 weeks, pre-service teachers designed and delivered supplemental instructional modules, guided by mentors. GPK and self-efficacy were assessed pre- and post-intervention using validated instruments, complemented by reflective reports.

**Results:** Quantitative analysis revealed significant GPK gains in adaptivity, structure, and assessment for the experimental group, with notable effect sizes. Teaching self-efficacy showed mixed outcomes. Reflective reports underscored the intervention's role in linking theory to practice, fostering practical skills, and deepening professional purpose. Challenges included logistical demands and resource constraints.

**Conclusion:** Project-based service-learning boosted GPK, bridging theory and practice, though its impact on self-efficacy varies. This study offers a nuanced evaluation, advancing understanding of service-learning's role in primary teacher education.

## KEYWORDS

initial teacher education, mixed methods, school-university partnership, service-learning, teaching self-efficacy

# 1 Introduction

The architecture of impactful teacher training programs persists as a central axis of educational innovation and scholarly inquiry (Wu et al., 2025). Cultivating advanced pedagogical reasoning alongside resilient professional identity in novice educators constitutes a pivotal vector for elevating the quality of K-12 education (Diab and Green, 2024). However, conventional coursework – frequently abstracted from authentic classroom dynamics – dominates much of the preparatory curriculum, potentially stifling the emergence of adaptive expertise necessary for navigating the multifaceted realities of teaching. School placements during practicum serve as transformative junctures, offering student-teachers crucial opportunities for collective reflection and experiential learning that profoundly shape their professional trajectories (Goldshaft, 2025). Over the past decade, teacher education has increasingly gravitated toward models embedded in school–university partnerships, recognizing their potential to situate learning within reciprocal, real-world contexts (Volkenhauer and Rutten, 2025).

Project-based learning, particularly when embedded in real educational settings, has gained momentum as a conduit for bridging the perennial theory–practice divide in initial teacher education (Resch et al., 2025; Ressin, 2025; Taylor et al., 2024). In parallel, service-learning frameworks have gained traction as experiential conduits, enabling pre-service teachers to engage authentically in classroom communities while simultaneously addressing tangible educational needs (Duarte et al., 2024; Jenssen and Haara, 2024). These school–university collaborations operationalize service-learning by structuring environments where student-teachers confront the complexities of instructional design, classroom management, and learner diversity firsthand (Fitzgerald et al., 2025; Gonçalves et al., 2025). As teachers-in-training hone their professional agency, they become immersed in an ongoing sequence of progress that encompasses both personal dimensions, such as beliefs and identities, and technical ones, including instructional skills (García-Lázaro et al., 2025).

Although service-learning enjoys widespread acceptance and implementation across Anglo-American, Canadian, and Australian higher education landscapes (Resch and Schritteser, 2023), it remains underdeveloped in Eurasian contexts. The present exploration interrogates the pedagogical value of a project-based service-learning initiative in which primary education student-teachers assumed structured roles as teaching assistants in elementary school settings. What follows is a review that defines the key research variables and synthesizes relevant empirical findings, setting the stage for the present investigation.

## 2 Literature review

### 2.1 Project-based learning and service-learning

Project-based learning is a teaching method implying educators guiding students through an iterative problem-solving journey (spanning from identifying real-world issues and formulating action plans to testing these solutions in practical settings and reflecting upon the outcomes) applied to the design and completion of a student

project (Alexandersen et al., 2025). Service-learning can be conceptualized as a distinct form of project-based learning, one where the project is intentionally designed to address identified community needs (Liao et al., 2025). While it shares the core tenets of authentic, learner-centered experiences with project-based learning, its unique emphasis lies in integrating meaningful community service with instruction and reflection to enrich the learning experience, teach civic responsibility, and strengthen communities (Choi et al., 2025; D'Elia et al., 2025). Contrasting distinctly with traditional didactic methods, project-based learning emphasizes authentic, learner-centered experiences, cultivating teamwork, self-assessment, and audience-oriented presentation of results (Li et al., 2025; Pitot et al., 2024).

Closely aligned with this constructivist ethos, service-learning integrates formal curricular objectives with meaningful community engagement, addressing genuine societal issues (Pérez-Baena et al., 2025). Originating from John Dewey's constructivist experiential learning theory, service-learning is supposed to facilitate holistic learning through actively linking students' actions with their consequences (Diez-Ojeda et al., 2025). This method seeks not merely academic enrichment but also civic empowerment, nurturing student-teachers' abilities to contribute meaningfully to societal transformation (Tiippana et al., 2024).

One distinguishing feature of service-learning is its requirement for pre-service teachers to engage actively with community partners, peers, and service beneficiaries, receiving their feedback and thus moving beyond theoretical classroom knowledge into authentic interaction (Adarlo and Pelias, 2021). Service-learning offers student-teachers opportunities not only to apply theoretical knowledge practically but also to engage in critical reflection, fostering deeper understanding and promoting subsequent application of experiences (Lin et al., 2025; Ramón-Jerónimo et al., 2025).

Empirical studies across various professional training contexts have documented tangible benefits of service-learning. For instance, a descriptive case study (Jessani et al., 2025) integrated a community service-learning program into undergraduate dental curriculum to train students in addressing the oral health needs of equity-deserving populations through experiential learning. The undergraduates ultimately reported high satisfaction and strengthened community ties. However, within primary teacher education specifically, service-learning research remains sparse. A mixed methods study (Piestrzynski and Williams, 2024) embedded a service-learning component into a literacy methods course for pre-service elementary teachers. The intervention advanced student-teachers' ability to apply course content in classroom settings, deepening their understanding of literacy assessment and instruction. It elevated critical reflection, enabling them to identify personal strengths and areas for growth, while increasing their awareness of diverse student needs and community engagement.

Similarly, service-learning project (Blanco et al., 2022) integrated a mathematical stimulus program into the training of prospective primary teachers, combining classroom-based learning with community service to support adolescents at risk of social exclusion. The intervention revealed significant gaps in teachers' common and specialized mathematical knowledge, with many struggling to apply concepts deeply or move beyond traditional teaching methods. Despite these challenges, the program built greater awareness of inclusive practices and

highlighted the value of interdisciplinary activities in bolstering motivation and attitudes toward mathematics teaching. These studies collectively illustrate not only the promise of service-learning in honing practical teaching competencies but also the complexities inherent in bridging theoretical knowledge and classroom applications.

## 2.2 General pedagogical knowledge and teaching self-efficacy

Central to evaluating the effectiveness of teacher preparation interventions, such as service-learning, is the construct of general pedagogical knowledge (GPK). GPK encompasses broad instructional principles and classroom management strategies applicable across diverse teaching contexts, transcending specific content areas (Getenet, 2025). Later conceptualizations defined GPK as a latent cognitive disposition tied to four instruction-related dimensions encompassing the abilities to: (1) handle heterogeneous classrooms ('adaptivity'); (2) design, structure, and analyze lessons ('structure'); (3) foster student engagement and oversee classroom processes ('classroom management/motivation'); and (4) gauge learner performance ('assessment') (Nehls et al., 2020). Recognized as a critical competency developed throughout teacher education, GPK significantly influences student academic growth and motivational outcomes (Heine et al., 2024; Weyers et al., 2024). Moreover, GPK was found to be a precursor to pre-service teachers' situation-specific pedagogical adaptivity skills, as demonstrated in their written lesson plans (König et al., 2020).

Upon reviewing related literature, it can be concluded, consistent with past research (Leijen et al., 2022), that GPK remains underevaluated, overshadowed by narrower, subject-specific discussions. Even more pronounced is the scarcity of studies into how service-learning specifically impacts teaching-related performance variables like GPK. Although service-learning has been established as beneficial for students' personal and social growth, detailed insights into its direct effects on teaching-related performance outcomes, such as GPK, remain critically lacking, particularly relative to more conventional instructional contexts (Pinto and Costa-Ramallo, 2023).

Teaching self-efficacy – termed as educators' "belief in their abilities to successfully perform teaching-specific tasks" (Täschner et al., 2025) – is another pivotal yet insufficiently investigated outcome within service-learning contexts. One exception is the longitudinal quasi-experimental study (Gutzweiler et al., 2022), which revealed significant increases in general and teaching-specific self-efficacy among student-teachers who had implemented a service learning-based mental health prevention seminar in primary and secondary school settings. The study identified feedback processes as instrumental in these improvements.

Reflection, a key process in the service-learning cycle, encourages student-teachers to consider their evolving understanding of community needs and their personal contributions to positive change, thereby strengthening their belief in their ability to make a difference (Winterbottom and Mazzocco, 2015). The significance of teaching self-efficacy is further underscored by its effect on teacher behavior and student outcomes. Teachers who doubt their own abilities may avoid teaching certain topics or skip activities that involve problem-solving. Conversely, high self-efficacy educators are typically more

supportive and less critical when learners struggle, confident that their teaching can revamp student achievement (Naidoo and Naidoo, 2023).

Examining service-learning through the lenses of pedagogical knowledge and self-efficacy reveals a compelling yet incomplete narrative. While existing research consistently underscores service-learning's potential benefits in bridging theory and practice, enhancing professional competencies, and augmenting self-efficacy, the empirical landscape remains fragmented, especially concerning primary teacher education as most authors there evaluate the success of this practice based on its effects on the educational improvement of instruction recipients (Chiva-Bartoll et al., 2020; Merritt et al., 2024; Scott and Graham, 2015). The scarcity of rigorous, controlled investigations into the impacts of service-learning on GPK and teaching self-efficacy represents a remarkable academic gap, which is addressed in the present exploration. The latter was guided by the following research questions:

RQ1. Is there a significant difference in the change of pedagogical knowledge between student-teachers participating in service-learning and business-as-usual counterparts?

RQ2. Is there a significant difference in the change of teaching self-efficacy between student-teachers participating in service-learning and business-as-usual counterparts?

To potentially contextualize what occurred quantitatively by pre-service teachers' reflection on the project, an additional question was formulated:

RQ3. What are student-teachers' perceptions of their experience within the project, particularly regarding its effectiveness and areas needing improvement?

By answering these questions, the study intends to amend the body of knowledge on teacher education practices, mining revelations into how structured, collaborative, and reflective learning experiences can foster the adroitness of teachers-in-training.

## 3 Materials and methods

### 3.1 Design and sample

This quasi-experimental study adopted the embedded mixed-methods design where qualitative data was collected to try to explain the numerical data collected simultaneously. A total of 74 undergraduate students from the primary teacher education program at the first author's university, enrolled in the academic year 2024/2025, participated in this study. These conveniently recruited students were randomly divided into an experimental group ( $n = 37$ ) and a comparison group ( $n = 37$ ), with the latter following the standardized educational framework of the institution, with practicums of 4–10 weeks in the 3rd and 4th years. This traditional model primarily consists of university-based coursework focused on foundational theories of pedagogy and psychology, with practical experience confined to block practicums where student-teachers typically observe lessons and deliver a limited number of pre-planned classes under

direct supervision. The experimental group additionally engaged in the project-based intervention (see section 3.2).

Table 1 outlines the demographic and academic profiles of participants in both the service-learning and comparison groups. The individuals took part voluntarily and received a consent form prior to the intervention inception. This document clarified the research aim and claimed confidentiality of personal data. The protocol adhered to institutional ethical standards and received approval from the university's ethics review board.

## 3.2 Intervention

This study employed a tailored, project-based intervention adapted from the Partner School Programme (Resch et al., 2024) while integrating service-learning principles into teacher training. The intervention was designed to immerse primary education student-teachers in authentic classroom settings and simultaneously address pressing educational needs identified by partner schools. The intervention commenced in late September 2024, aligning with the start of the practicum period. Given the variability in project scope and student involvement, the intervention effectively constituted the practicum for most participants, with some cases extending beyond the formal practicum duration – a structure approved by the dean's office. For others, the intervention was partially embedded within their practicum. Departing from the original reactive model – where university teams responded to school-initiated requests – our approach adopted a proactive alignment strategy. While the standard practicum relies on a placement office matching students to available host teachers, this project involved the research team directly collaborating with school leadership to identify a specific educational challenge and then co-design a project brief to address it. Through existing professional networks, seven public schools experiencing educational challenges at the elementary level were identified and recruited, ensuring a close alignment between school needs and the educational objectives of the teacher preparation program, moving

beyond the more general goal of gaining teaching experience that defines the conventional practicum.

Throughout the intervention, university supervisors maintained their traditional supervisory support role, ensuring that the project aligns with educational goals and standards, while school-based mentors took on expanded collaborative roles as co-designers and co-implementers of the projects. This dual mentorship model ensured academic rigor while maximizing authentic workplace learning. In collaboration with each school's principal and teaching staff, the research team co-designed school-specific project briefs, which encapsulated focal school issues, expected outcomes, and delineated roles and tangible deliverables for each student-teacher team. The briefs were developed via a structured, two-stage process: (1) an initial needs assessment meeting with school leadership and a walkthrough of the current challenges (e.g., classroom management issues, curricular gaps, or resource limitations), and (2) a review of the relevant literature and best practices in teacher education and school improvement. This evidence-based approach ensured that the intervention strategies were both practical and feasible in real-world contexts.

Once project briefs were finalized, the 37 primary education student-teachers randomly assigned into seven teams were introduced to their respective schools' challenges. Their participation was framed under a service-learning model, emphasizing active learning and continuous feedback. Student-teachers assumed roles as teaching assistants and educational partners, engaging in activities such as designing and co-delivering supplemental instructional modules (e.g., literacy or numeracy workshops), facilitating small-group work, and developing formative assessment tools.

For instance, in one of the partner schools, a prevalent issue was identified in the third grade: difficulties in reading comprehension among students, particularly in understanding narrative texts. The student-teachers, alongside their faculty mentors, reviewed current literacy research and best practices in early reading instruction, ultimately crafting a project brief that focused on reading strategies for narrative comprehension. Prior to classroom engagement, the student-teachers participated in a preparatory workshop that provided guidance on service-learning best practices and effective instructional strategies for young learners. To facilitate this intensive engagement, weekly university seminar slots were repurposed as dedicated project work sessions, allowing teams to collaborate on planning and consult with their university supervisors. They adapted recommended strategies – such as guided reading, interactive read-alouds, and vocabulary mapping – into lesson modules suitable for third graders. The sessions were rehearsed and refined during peer-review meetings and feedback sessions with university supervisors to ensure age-appropriateness and clarity.

Under the guidance of their mentors and in close collaboration with classroom teachers, the student-teachers co-delivered a series of supplemental instructional modules over a six-week period. For instance, in one specific module, the student-teachers introduced a Reading Detective activity. During this activity, small groups of third-grade students read a narrative text, flagged challenging vocabulary, and worked collaboratively to infer meaning and discuss character motivations. To further engage the students, interactive questioning techniques and group discussions were employed. Throughout the intervention, student-teachers collected informal feedback from pupils, teachers, and mentors. At the project's conclusion, they

TABLE 1 Description of the research sample.

| Characteristics              | Treatment<br>(n = 37) | Control<br>(n = 37) | Total<br>(n = 74) |
|------------------------------|-----------------------|---------------------|-------------------|
| Age                          |                       |                     |                   |
| Mean (SD)                    | 19.32 (1.83)          | 19.95 (2.01)        | 19.64 (1.93)      |
| Range                        | 17–23                 | 17–23               | 17–23             |
| Gender                       |                       |                     |                   |
| Male                         | 3 (4.1%)              | 2 (2.7%)            | 5 (6.8%)          |
| Female                       | 34 (46%)              | 35 (47.3%)          | 69 (93.2%)        |
| Year of study                |                       |                     |                   |
| 1st                          | 13 (17.6%)            | 8 (10.8%)           | 21 (28.4%)        |
| 2nd                          | 10 (13.5%)            | 13 (17.6%)          | 23 (31.1%)        |
| 3rd                          | 9 (12.2%)             | 7 (9.5%)            | 16 (21.6%)        |
| 4th                          | 5 (6.8%)              | 9 (12.2%)           | 14 (18.9%)        |
| Previous teaching experience |                       |                     |                   |
| Yes                          | 13 (17.6%)            | 18 (24.3%)          | 31 (41.9%)        |
| No                           | 24 (32.4%)            | 19 (25.7%)          | 43 (58.1%)        |



reflected on the process in their individual reports. This iterative cycle of teaching, feedback, and reflection underscored the core service-learning principle: learning through active community engagement and responsive pedagogical practice.

By integrating service-learning into a project-based framework and providing clear examples of active learning initiatives, the intervention was supposed to not only enhance pre-service teacher competencies but also meaningfully address the educational needs of partner schools. The duration of participation varied from 6 to 12 weeks to account for the differing complexity and scope of the school challenges; for instance, schools facing systemic issues (e.g., high teacher turnover) required longer intervention cycles, whereas issues with a narrower focus (e.g., developing a single curricular module) were addressed over a shorter timeframe.

### 3.3 Data collection and sources

Quantitative data collection spanned 1 week before project implementation and 1 week following a team's completion of their service-learning program. The measurements were administered offline in a paper-and-pencil format at the university sampled.

The GPK was assessed using the latest version of a standardized test (König et al., 2024) comprising 30 items (free response and multiple-choice). The measure focuses on the four GPK dimensions mentioned in the section 2, i.e., dealing with heterogeneous learning groups (adaptivity in teaching), structuring lessons, motivating students as well as managing the classroom effectively, and assessing students. Following the revised Bloom's taxonomy of educational objectives, the test items require respondents to: (1) recall information stored in long-term memory to complete the tasks, (2) demonstrate deep understanding/analysis of the ideas delineated in the items, or (3) develop practical solutions to problematic classroom scenarios depicted through short vignettes (König and Pflanzl, 2016). Each respondent's score represented the average percentage of correct answers for each of the four subscales. The inventory designers reported its expected a posteriori reliability of 0.87 under the unidimensional Rasch model.

Student-teachers' beliefs in their future teaching adroitness were captured via the 13-item scale suggested by Chan et al. (2023). Respondents were tasked to evaluate each item on a range from 1 ("strongly disagree") to 5 ("strongly agree"). The questionnaire designers stated that its three constructs—efficacy for instructional strategies, classroom management, and student engagement—had high internal consistency, with alpha estimates of 0.86, 0.90, and 0.88, respectively.

Prior to the investigation, participants received an email with a brief reflection guide from an independent assistant from an unaffiliated institution. The guide, adapted from Pei et al. (2025), included four open-ended prompts: (1) "Did the project help you meet its objectives? If not, why?" (2) "What went well?" (3) "What improvements would you suggest?" and (4) "Additional remarks?" The pre-service teachers were instructed not to include any information that could disclose their identity. At the conclusion of their placement, each student-teacher submitted a reflective report (approximately 1,000 words) through Paperform. These deidentified reflective entries provided qualitative data that complemented pre-post quantitative assessments conducted as part of the study's summative evaluation.

## 3.4 Data analysis

### 3.4.1 Quantitative analysis

The collected quantitative data were subjected to the Grubbs' test to assess outliers, with no extreme values detected. Then descriptive statistics (mean [M] and standard deviation [SD]) were computed. It was followed by multivariate analysis of covariance (MANCOVA) to test for overall multivariate differences across the response variables while protecting against Type I error inflation due to multiple comparisons. The analysis proceeded with a series of repeated measures analyses of covariance (RM ANCOVAs), with pre-existing scores serving as covariates. Data normality and homogeneity of variance were tested using Shapiro–Wilk and Levene's tests. For significant Shapiro–Wilk results, aligned rank transformation analysis of variance (ART ANOVA) replaced RM ANCOVA. Effect sizes were calculated via partial eta squared ( $\eta^2p$ ), categorized as small ( $<0.06$ ), medium ( $0.06–0.13$ ), or large ( $\geq 0.14$ ).  $p$ -value below 0.05 indicated statistical significance.

### 3.4.2 Qualitative analysis

To ensure anonymity, a blinded research assistant de-identified student reflection entries, assigned participant codes (P1–P37), compiled the data into a single document, and shared it with two trained coders. Thematic analysis followed a hybrid deductive-inductive approach (Wallace and Harvey, 2024): coders first organized data using a predefined scheme before inductively refining themes through reflective coding. Discrepancies were discussed to reach a consensus, and illustrative quotes were selected to substantiate findings. Originally expressed in Russian, the reflections are presented here translated into English for presentation purpose.

## 4 Results

### 4.1 Quantitative findings

Shapiro–Wilk tests revealed that post-test scores for adaptivity ( $W = 0.951$ ,  $p = 0.005$ ), structure ( $W = 0.928$ ,  $p = 0.001$ ), classroom management/motivation ( $W = 0.947$ ,  $p = 0.004$ ), assessment ( $W = 0.954$ ,  $p = 0.009$ ), and management ( $W = 0.947$ ,  $p = 0.004$ ) violated normality assumptions. In contrast, instruction ( $W = 0.983$ ,  $p = 0.422$ ) and engagement ( $W = 0.981$ ,  $p = 0.319$ ) were normally distributed, necessitating ART ANOVA.

Descriptive statistics for baseline and post-intervention scores across GPK and teaching self-efficacy dimensions are listed in Table 2. The experimental group generally exhibited higher post-test means across most GPK subscales, with notable improvements in assessment ( $M = 72.97$ ,  $SD = 10.42$ ) compared to the comparison group ( $M = 47.37$ ,  $SD = 16.96$ ). Teaching self-efficacy dimensions showed mixed patterns, with the control group slightly outperforming the service-learning group in instruction and engagement post-tests.

As for MANCOVA, the results revealed a significant multivariate effect for group membership (Wilks'  $\Lambda = 0.329$ ,  $F[7, 59] = 17.187$ ,  $p = 0.001$ ), indicating substantial differences between the experimental and control groups across the combined response variables. Among the covariates, baseline perceived efficacy for instructional strategies (Wilks'  $\Lambda = 0.749$ ,  $F[7, 59] = 2.819$ ,  $p = 0.013$ ) and performance-based adaptivity (Wilks'  $\Lambda = 0.794$ ,  $F[7, 59] = 2.192$ ,  $p = 0.048$ ) yielded

TABLE 2 Descriptive statistics for pre-test and post-test scores by group.

| Variable                             | Group     | Pre-test mean (SD) | Post-test mean (SD) |
|--------------------------------------|-----------|--------------------|---------------------|
| <b>General pedagogical knowledge</b> |           |                    |                     |
| Adaptivity                           | Control   | 29.05 (15.88)      | 38.51 (19.85)       |
|                                      | Treatment | 36.49 (19.18)      | 56.42 (10.47)       |
| Structure                            | Control   | 24.86 (11.93)      | 27.03 (14.31)       |
|                                      | Treatment | 28.65 (13.78)      | 44.86 (19.67)       |
| Classroom management/ motivation     | Control   | 3.29 (0.81)        | 3.24 (0.93)         |
|                                      | Treatment | 3.11 (0.95)        | 3.85 (0.93)         |
| Assessment                           | Control   | 41.55 (16.94)      | 47.37 (16.96)       |
|                                      | Treatment | 59.46 (17.28)      | 72.97 (10.42)       |
| <b>Teaching self-efficacy</b>        |           |                    |                     |
| Instruction                          | Control   | 4.06 (0.69)        | 4.34 (0.41)         |
|                                      | Treatment | 3.22 (0.67)        | 3.86 (0.65)         |
| Management                           | Control   | 3.69 (0.65)        | 3.95 (0.61)         |
|                                      | Treatment | 3.40 (0.85)        | 4.25 (0.63)         |
| Engagement                           | Control   | 3.29 (0.70)        | 3.74 (0.67)         |
|                                      | Treatment | 3.76 (0.81)        | 3.34 (0.75)         |

statistically discernible multivariate effects, suggesting their influence on post-evaluation outcomes. Other covariates had non-significant multivariate effects ( $p > 0.05$ ). These findings are summarized in Table 3.

Results of RM ANCOVAs and non-parametric analyses are detailed in Table 4. For adaptivity, there was a statistically detectable group effect ( $F[1, 72] = 24.80, p = 0.001, \eta^2p = 0.26$ ), favoring the project group. Similarly, the structure facet showed a significant group effect ( $F[1, 72] = 24.226, p = 0.001, \eta^2p = 0.25$ ), with the experimental group outperforming the counterparts. The assessment dimension also demonstrated a remarkable effect ( $F[1, 72] = 77.176, p = 0.001, \eta^2p = 0.52$ ), strongly favoring the treatment group. The domain covering classroom management and motivation exerted an insignificant effect ( $F[1, 72] = 2.394, p = 0.126, \eta^2p = 0.03$ ).

Regarding teaching self-efficacy, a statistically notable group effect was observed for the instructional capacity ( $F[1, 72] = 15.79, p = 0.001, \eta^2p = 0.18$ ) in favor of the reference group. Meanwhile, the classroom management factor had a negligible group effect ( $F[1, 72] = 0.023, p = 0.880, \eta^2p = 0.01$ ), suggesting comparable self-efficacy in this competency across groups. The student engagement dimension revealed a significant effect ( $F[1, 72] = 6.373, p = 0.014, \eta^2p = 0.08$ ), favoring the control group.

## 4.2 Qualitative findings

The qualitative data, derived from student-teachers' reflective reports, offered rich insights into their perceptions of the project-based learning experience via school-university collaboration, its effectiveness in fostering general pedagogical knowledge, and areas identified for improvement. Analysis of these deidentified reflections ( $N = 37$ ) revealed four prominent themes regarding their experiences. Table 5 illustrates these overarching themes, the corresponding

TABLE 3 MANCOVA results.

| Effect                                    | Wilks' $\Lambda$ | $F$    | $p$   |
|-------------------------------------------|------------------|--------|-------|
| Group                                     | 0.329            | 17.187 | 0.001 |
| Adaptivity pre-test                       | 0.794            | 2.192  | 0.048 |
| Structure pre-test                        | 0.798            | 2.128  | 0.054 |
| Classroom management/ motivation pre-test | 0.951            | 0.434  | 0.877 |
| Assessment pre-test                       | 0.842            | 1.578  | 0.160 |
| Instruction pre-test                      | 0.749            | 2.819  | 0.013 |
| Management pre-test                       | 0.962            | 0.334  | 0.935 |
| Engagement pre-test                       | 0.896            | 0.983  | 0.453 |

TABLE 4 RM ANCOVA and ART ANOVA results.

| Variable                             | Test type | $F$    | $p$   | n2p  | Favored group |
|--------------------------------------|-----------|--------|-------|------|---------------|
| <b>General pedagogical knowledge</b> |           |        |       |      |               |
| Adaptivity                           | ART ANOVA | 24.80  | 0.001 | 0.26 | Treatment     |
| Structure                            | ART ANOVA | 24.226 | 0.001 | 0.25 | Treatment     |
| Classroom management/ motivation     | ART ANOVA | 2.394  | 0.126 | 0.03 | –             |
| Assessment                           | ART ANOVA | 77.176 | 0.001 | 0.52 | Treatment     |
| <b>Teaching self-efficacy</b>        |           |        |       |      |               |
| Instruction                          | RM ANCOVA | 15.79  | 0.001 | 0.18 | Control       |
| Management                           | ART ANOVA | 0.023  | 0.880 | 0.01 | –             |
| Engagement                           | RM ANCOVA | 6.373  | 0.014 | 0.08 | Control       |

reflective prompts that elicited these insights, the manifestations of their experiences and perceptions, and illustrative student voices.

Overall, student-teachers emphasized how the project-based intervention served as a vital conduit between abstract pedagogical theories learned at the university and the dynamic realities of primary school classrooms. Participants reported that the experience allowed them to witness and apply concepts that had previously seemed theoretical, thereby solidifying their understanding and boosting their confidence. For instance, one participant described a “lightbulb moment” when the theoretical concept of scaffolding became clear while helping a student learn to read (P12). The opportunity to engage directly with pupils and address real educational needs was frequently cited as a powerful learning catalyst.

Many reflections highlighted “aha!” moments where theoretical constructs became clear through practical application. The direct involvement in addressing school-identified needs, as outlined in the project briefs, was perceived as highly effective in meeting learning objectives.

TABLE 5 Student-teacher reflections on the project-based learning experience.

| Main themes                                               | Manifestation of experience and perceptions                                                                                                                                  | Student voices                                                                                                                                                                                                                                                                                      |
|-----------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Bridging theory with authentic practice                   | Articulation of the practical relevance of theoretical knowledge acquired during university studies.                                                                         | "I'd read about Vygotsky and scaffolding, but seeing it work when a shy second-grader finally started sounding out words with my help during our reading group – that was like a lightbulb moment! The project definitely helped me see how theory works in the real world." (P12)                  |
|                                                           | Enhanced understanding of pedagogical concepts through direct application in diverse classroom settings.                                                                     | "All those university lectures on math anxiety... then you are in a classroom with kids genuinely scared of numbers. Designing those math games to made it fun, and seeing them actually enjoy it made the theory real. This wasn't just another assignment; it was what teaching feels like." (P5) |
|                                                           | Increased confidence stemming from successful implementation of learned strategies and observing tangible student engagement.                                                | "It was incredibly effective. We were not just talking about curriculum gaps; we were actively working with class teachers to develop resources for that geography unit on local environments. Seeing the kids use what we made was proof the objectives were met." (P21)                           |
| Development of core teaching competencies                 | Acquisition and refinement of practical teaching skills, including lesson planning, instructional delivery, differentiation, formative assessment, and classroom management. | "Before this project, I would panic if students did not respond as expected. Now I see those moments as opportunities to pivot and try something new. That mental shift has transformed my teaching confidence." (P19)                                                                              |
|                                                           | Improved collaborative abilities through co-planning and co-teaching with experienced teachers and peers.                                                                    | "Figuring out how to explain fractions using local market examples for the 4th graders... that was a challenge, but so rewarding when they got it." (P32)                                                                                                                                           |
|                                                           | Growing self-efficacy as educators through active participation and positive reinforcement in authentic school environments.                                                 | "The best part was actually doing it. Not just observing. Designing those literacy rotation stations and then leading them made me feel much more prepared to run a small group now." (P9)                                                                                                          |
| Experiencing the impact and realities of service-learning | A heightened sense of professional purpose and an understanding of teaching as a service to the community.                                                                   | "Seeing those kids in the geography club actually get excited about mapping our local area... it made me feel like I was doing something truly useful, not just learning to be a teacher. It was about giving back to the school community." (P14)                                                  |
|                                                           | Deepened empathy and insight into the diverse needs of pupils and the complex operational realities of schools.                                                              | "Some days were tough, but the thank you from a parent whose child finally understood long division? Priceless. This project showed me the real heart of teaching and how much impact we can have." (P26)                                                                                           |
| Reflections on challenges and program amendment           | Significant personal and professional satisfaction derived from making a tangible contribution to partner schools and witnessing student progress.                           | "It wasn't just about us learning; it was about helping the school. When the principal said our numeracy workshops really helped their Year 3s catch up, that felt huge. Like we actually contributed something meaningful." (P11)                                                                  |
|                                                           | Identification of logistical complexities, such as time management between university requirements and intensive school engagement, or resource limitations within schools.  | "Juggling our university coursework with the school placement was a killer during the 10-week project. Maybe a bit more protected time for the project weeks, or more integration with other course assessments?" (P3)                                                                              |
|                                                           | Desire for more extensive pre-intervention preparation on specific school contexts or challenges.                                                                            | "More prep time for specific school challenges would be great. We hit the ground running with the reading intervention, which was good, but understanding the school's specific data beforehand would have helped us tailor it even better from day one." (P34)                                     |
|                                                           |                                                                                                                                                                              | "Sometimes the lines blurred between our role and the class teacher's, especially at the start. Maybe clearer guidelines in the project brief or an initial joint meeting to set expectations for the co-teaching parts?" (P18)                                                                     |

The project was widely perceived as instrumental in developing a range of core teaching competencies. Student-teachers reported significant growth in practical skills such as lesson planning, instructional delivery, adapting materials for diverse learners, implementing formative assessment strategies, and managing classroom dynamics. The shift from passive observation to active participation was highlighted as a key element; one participant, for example, expressed feeling much more prepared to lead small groups after having the chance to design and run literacy rotation stations firsthand (P9). The collaborative nature of the projects, involving co-planning and co-teaching with experienced school mentors and peers, was particularly valued for fostering these competencies and building self-efficacy. Participants frequently described specific instances where they honed their skills, and the shift from observation to active participation was a key element in this skill development.

The service-learning component of the project resonated deeply with many student-teachers, fostering a heightened sense of professional purpose and a tangible connection to the communities they served. Reflections often conveyed an increased understanding of the multifaceted roles of teachers and the complex realities of school environments, including resource constraints and diverse student populations. One participant articulated that the project felt like doing something “truly useful” and giving back to the community, rather than simply learning to be a teacher (P14). The experience of making a discernible contribution to the partner schools and witnessing pupil progress was a source of considerable personal and professional satisfaction, especially when reinforced by positive external feedback, such as a principal acknowledging the tangible, positive impact of their numeracy workshops on pupils (P11).

The feeling of making a meaningful contribution was a recurring point. Participants also acknowledged the emotional rewards and deeper insights gained. The reciprocal nature of service-learning, where student-teachers both contributed and learned, was evident.

While the overall perception of the project was positive, student-teachers also provided constructive feedback, identifying challenges and offering suggestions for program refinement. Common themes included the logistical demands of balancing intensive school placements with university coursework, navigating resource limitations within schools, and the desire for even more targeted preparation or ongoing support. Time management emerged as a significant challenge for some, such as the difficulty of juggling university coursework with the intensive school placement (P3). Suggestions for enhanced preparation were also noted. The complexities of collaborative roles and resource availability were also highlighted as some areas for potential improvement.

## 5 Discussion

### 5.1 Principal findings

Acknowledging the frequent disconnect between conventional initial teacher education programs and the practical demands of schools and communities underscores the critical role of robust school-university partnerships (Ma and Green, 2023). Traditional teacher preparation pathways are often critiqued for their detachment from authentic classroom settings, potentially leaving novice educators ill-equipped for the complexities they encounter. This investigation

was conceived to address this gap by rigorously assessing the influence of a structured, project-based service-learning intervention on the development of pedagogical knowledge and teaching self-efficacy among primary student-teachers. Furthermore, the study sought to capture participants’ reflective insights to contextualize the quantitative outcomes and understand their lived experiences within the intervention.

The findings yielded a multifaceted picture regarding the intervention’s impact. Addressing RQ1, the results indicated that student-teachers participating in the project-based service-learning program demonstrated significantly greater positive changes in several core GPK dimensions – specifically adaptivity, structure, and assessment – compared to their counterparts in the standard program track. However, no significant difference emerged for the classroom management/motivation dimension of GPK. Concerning RQ2, the data revealed a more complex pattern for teaching self-efficacy; after controlling for pre-test scores, the comparison group exhibited significantly more favorable outcomes on self-efficacy related to instructional strategies and student engagement, while no significant group difference was detected for management self-efficacy. Responding to RQ3, qualitative analysis of student-teacher reflections illuminated predominantly positive perceptions of the service-learning experience, emphasizing its effectiveness in bridging theory and practice, fostering essential teaching competencies, and cultivating a sense of professional purpose, albeit alongside identified logistical challenges and areas needing refinement.

### 5.2 Theoretical underpinnings and relation to the field

Interpreting the quantitative results necessitates unfolding the specific competencies involved. The marked improvements in GPK for adaptivity, structure, and assessment within the experimental group suggest that the intervention’s focus on addressing real school issues through co-designed projects effectively honed participants’ abilities to differentiate instruction for diverse learners, plan coherent and objective-driven lessons, and utilize various assessment techniques meaningfully. These are complex cognitive skills requiring the application of theoretical knowledge to practical scenarios, which the project seemingly facilitated. The lack of significant change in the classroom management/motivation GPK dimension might suggest that the specific projects undertaken, or the intervention’s duration, provided insufficient focus or opportunity to deeply impact knowledge in this notoriously challenging domain, or perhaps that this knowledge base develops differently. The counterintuitive findings for self-efficacy (where the control group showed more positive trajectories for instruction and engagement efficacy) warrant careful consideration. It is plausible that confronting the authentic, often unpredictable challenges inherent in the service-learning projects tempered the experimental group’s confidence, potentially leading to a more realistic (and perhaps initially lower) self-appraisal compared to the potentially more scaffolded or predictable practicum experiences of the control group.

The qualitative findings provide rich context for these quantitative patterns. Student-teachers’ reflections painted a vibrant picture of the service-learning experience as a powerful catalyst for professional growth. Four central themes emerged: the crucial link forged between



theoretical learning and authentic classroom application; the tangible development of core teaching skills through active engagement; a profound connection to the meaning and realities of teaching through community service; and candid feedback on operational difficulties and potential program betterment. Participants consistently articulated how designing and implementing solutions for real school problems like creating literacy modules or math games transformed abstract concepts into practical, usable knowledge, thereby boosting their perceived readiness and skill set.

These qualitative insights resonate strongly with the persistent challenge highlighted in teacher education literature: a recognized gap often exists where pre-service teachers find it difficult to operationalize educational theory effectively within the constraints of real school environments, sometimes feeling inadequately prepared for the daily realities of the classroom (Andreasen, 2023; Bonar et al., 2025). The student-teachers in this study explicitly described the service-learning project as a mechanism that helped them overcome this hurdle, providing a context where pedagogical theories were not just learned but actively tested, adapted, and validated through direct application and observed impact on pupils. The discovery moments described, where theory clicked into place through practice, directly address this theory-practice divide.

Several mechanisms likely underpin these findings. The significant GPK gains can be attributed to the principles of situated learning and constructivism embedded in the intervention; knowledge was acquired and refined within the authentic context where it would be used. The collaborative nature of the projects (working with peers, university mentors, and school staff) likely facilitated knowledge co-construction and distributed cognition. Furthermore, the requirement for reflective practice encouraged metacognition and deeper processing of experiences. The unexpected self-efficacy results might be explained through social cognitive theory; while mastery experiences (successfully implementing project components) occurred, the vicarious experiences (observing experienced teachers navigate difficulties) and physiological/affective states (stress or challenge associated with complex real-world problems) encountered in the service-learning setting could have led to a more cautious self-assessment of efficacy compared to the control group. The qualitative data suggests that while challenges were acknowledged (potentially impacting efficacy scores), the overall perceived value and learning were high.

The revelations from this project-based intervention imply that integrating structured, collaborative, and reflective service-learning experiences into primary teacher education holds considerable promise for enriching specific, critical dimensions of general pedagogical knowledge. However, they also caution that such immersive experiences, while valuable for skill development, may present challenges that temper immediate gains in teaching self-efficacy, particularly concerning instructional strategies and student engagement. This suggests that teacher education programs employing similar models must be intentional not only about fostering knowledge and skills but also about providing robust support systems to help student-teachers navigate the complexities and potential confidence fluctuations inherent in authentic practice.

Comparing these results with prior research reveals both convergence and divergence. The heightened self-efficacy observed in service-learning participants by Asenjo et al. (2021) and Gutzweiler et al. (2022) contrasts with the nuanced self-efficacy findings here,

where the control group fared better on some dimensions. This discrepancy might stem from differences in the participant populations (primary education vs. psychology undergraduates), the specific nature and intensity of the service-learning tasks, the comparison groups employed (volunteering or standard curriculum vs. standard practicum), or the measurement instruments used. Nonetheless, the current study's qualitative findings strongly align with Piestrzynski and Williams (2024), who similarly found that service-learning prompted theory-practice integration, bolstered pedagogical knowledge (akin to the GPK gains seen here), and fostered reflection and awareness of student needs. The present study extends these insights through its quasi-experimental design and specific focus on GPK domains.

## 5.3 Contributions, limitations, and future directions

This investigation offers distinct contributions to the field. Theoretically, it provides rare quasi-experimental evidence examining the causal impact of project-based service-learning on GPK within primary teacher education, moving beyond correlational or purely qualitative accounts. Methodologically, the embedded mixed-methods design allows for a richer interpretation, using qualitative insights to illuminate complex quantitative results, particularly the unexpected self-efficacy patterns. The nuanced findings regarding self-efficacy also contribute a critical perspective, urging programs to consider the affective and cognitive load associated with deep engagement in authentic practice.

Despite the study's strengths, certain design nuances warrant consideration when interpreting the findings. The variability in the intervention duration (6–12 weeks), necessitated by the differing complexities of school-specific projects, introduces potential confounding; participants with longer placements might have experienced different impacts than those with shorter ones, although project complexity was the driver. Similarly, the inherent diversity of the school-based projects, while reflecting real-world conditions, means that participants engaged with different pedagogical challenges, potentially influencing outcomes heterogeneously across the treatment group. While randomization was employed for group assignment, the reliance on a convenience sample from a single university limits the direct transferability of findings to institutions with different demographic profiles or program structures. Furthermore, the assessment of GPK relied on a specific standardized test (König et al., 2024); while robust, its particular focus on certain knowledge facets means results might differ if alternative GPK conceptualizations or measures were employed. Finally, this study captured immediate post-intervention effects; it remains unknown whether the observed GPK advantages persist long-term or how self-efficacy trajectories evolve as graduates enter the profession.

Based on the study's outcomes and limitations, several recommendations emerge for practice and future inquiry. Teacher education programs implementing similar project-based service-learning initiatives should consider providing more targeted pre-intervention preparation tailored to specific school contexts and challenges, as suggested by participants, potentially mitigating initial hurdles. Addressing the logistical strain identified requires careful consideration of workload balance and potentially

integrating project requirements more seamlessly with other coursework. Given the unexpected self-efficacy findings, programs should proactively build in supports – such as structured peer debriefing sessions focusing on navigating challenges or mentorship explicitly addressing confidence management – to help students process the difficulties inherent in authentic practice. Clearer initial delineation of roles between student-teachers and classroom teachers, as suggested in reflections, could also smooth collaborative processes.

Future research should endeavor to track the longitudinal development of both GPK and teaching self-efficacy following participation in such interventions to understand their sustained impact and how initial efficacy fluctuations resolve over time. Replication studies in diverse institutional and national contexts are needed to assess the model's broader applicability. Investigating the differential impacts of varying project types, durations, and levels of school-university collaboration intensity could yield valuable insights for optimizing program design. Employing alternative or supplementary measures of teaching competence, such as classroom observation protocols or portfolio assessments, could provide a more holistic understanding beyond standardized tests and self-reports. Finally, further exploration, perhaps using qualitative methods like in-depth interviews immediately post-intervention, could delve deeper into the reasons behind the divergence between significant GPK gains and the more complex self-efficacy results observed in the service-learning group.

## 6 Conclusion

This quasi-experimental mixed-methods study suggests that project-based service-learning, embedded within school-university partnerships, can add to crucial dimensions of general pedagogical knowledge – namely adaptivity, structure, and assessment – among primary student-teachers compared to conventional program tracks. Participants' reflections corroborated the quantitative GPK gains, vividly illustrating how the experience bridged the often-lamented gap between educational theory and classroom reality, fostering practical competencies and a sense of professional purpose. However, the investigation also surfaced complexities regarding teaching self-efficacy, suggesting that deep engagement with authentic school challenges, while pedagogically potent, may initially temper confidence in certain areas. This exploration stands as one of the first rigorous attempts to integrate a proactive service-learning model with rigorous mixed-methods evaluation in primary teacher education, evaluating the impact of this project specifically on GPK and offering a nuanced perspective that moves beyond uniformly positive portrayals of service-learning. Ultimately, the study reinforces the imperative for teacher education programs to embed collaborative, experiential learning opportunities into teacher training, while simultaneously underscoring the need for careful program design and robust student support to navigate the inherent challenges and fully realize the transformative potential of learning through service.

## Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

## Ethics statement

The studies involving humans were approved by the review board of Zhetysu University, Kazakhstan. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

## Author contributions

AY: Writing – original draft, Methodology, Conceptualization. AT: Project administration, Writing – review & editing, Methodology. ZS: Writing – original draft, Investigation. NZ: Writing – original draft, Formal analysis, Investigation. NS: Investigation, Writing – review & editing, Data curation.

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