Improving the statistical competence and collaborative skills of preservice teachers through learning by teaching and project-based learning

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Abstract

The purpose of the current study was to investigate the impact of an integrated approach, combining Learning by Teaching (LbT) and Project-Based Learning (PBL), on the statistical knowledge, attitudes, and collaborative abilities of preservice teachers in the Thai educational context. The research, which was designed as a one-group experimental study, involved a sample of 27 preservice teachers from the Faculty of Education at Mahsarakham University in Thailand. We conducted participant selection using cluster random sampling. The study employed a set of instruments, including: 1) an LbT-PBL integrated learning management plan, 2) a collaborative skill evaluation form, 3) a statistical skill evaluation form, and 4) a statistical attitude evaluation form. Descriptive statistics and a one-sample t-test were employed for data analysis, utilizing a predefined criterion of 80. The findings indicate the enhancement of statistical knowledge and attitudes as well as collaborative skills among participants through the integrated LbT and PBL approaches. This empirical support confirms the success of the integrated model in advancing statistical competence and collaborative skills, especially in the context of teacher education. The positive impact on statistical knowledge and collaborative abilities highlights its potential to shape future pedagogical practices, underscoring the significance of this innovative approach in enhancing the skillset of preservice teachers.

Keywords: Attitudes, Collaborative skills, Learning by teaching, Project-based learning, Statistical competence, Teacher education.

Competing Interests: The authors declare that they have no competing interests.
Authors' Contributions: Both authors contributed equally to the conception and design of the study. Both authors have read and agreed to the published version of the manuscript.
Transparency: The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.
Institutional Review Board Statement: The Ethical Committee of the Mahasarakham University, Thailand has granted approval for this study on 25 October 2023 (Ref. No. 435-46952566).

1. Introduction

In the 21st century, educator's role extends far beyond traditional knowledge transmission. We entrust modern teachers with the vital task of preparing students to navigate an ever-evolving world, equipping them with the skills and abilities necessary for success in an increasingly dynamic and complex society [1, 2]. As a result, expectations for teachers have undergone a significant transformation, giving rise to the concept of teacher competencies. These competencies encompass a multifaceted skill set that extends beyond mere subject matter expertise, incorporating pedagogical knowledge, and a range of other supportive skills. The evolving demands placed on educators have prompted a fundamental shift in the landscape of teacher education and development, challenging pre-service teachers to reevaluate their perspectives and embrace a more holistic approach to their training [3].

One of the crucial competencies for teachers is the ability to conduct research to enhance their teaching practices [4]. This research competency offers several valuable benefits, enabling educators to continually improve their teaching methods, stay updated on educational developments, and make informed decisions based on data [5]. Within the realm of research, statistical skills are of paramount importance. Competency in statistical analysis empowers teachers to critically assess their teaching strategies, draw meaningful insights from research findings, and contribute to educational research. However, the development of statistical knowledge and skills also relies on one's attitude [6]. Some individuals find statistics complex and may shy away from learning and applying statistical concepts. Hence, it is clear that both statistical analysis skills and a positive attitude toward statistics are essential for educators, as they enable teachers to harness the power of data to enhance their effectiveness and adaptability in the ever-evolving educational landscape of the 21st century.

Collaborative skills are undeniably vital for educators in the 21st century [5, 7]. These skills enable teachers to work effectively with colleagues, students, and various stakeholders in the educational community, fostering a cooperative and supportive environment. In a teaching context, collaboration allows educators to share best practices, design innovative curriculum, and adapt teaching methods to diverse student needs [8]. For example, when teachers collaborate, they can create interdisciplinary lesson plans that integrate multiple subjects, providing students with a holistic learning experience. Beyond the classroom, collaborative skills are equally essential in educators' careers. In school leadership roles, such as those of department heads or curriculum coordinators, the ability to collaborate facilitates the development of cohesive educational strategies and the alignment of instructional goals across the institution. Moreover, collaboration extends to partnerships with parents, community organizations, and other educational institutions, enhancing the overall learning experience for students [9].

Teacher education represents a pivotal juncture where educators can actively nurture and cultivate these crucial skills [10-12]. The process of becoming a teacher is an opportune moment for pre-service teachers to hone their research, statistical competence, and collaborative skills, ensuring that they enter the classroom well-equipped to excel in the 21st-century educational landscape. Teacher education programs play a significant role in facilitating this development by integrating these competencies into their curriculum and providing the necessary training and guidance.

However, within the specific context of Thai education, there have been notable criticisms, particularly concerning the predominant use of lecture-based instructional methods [2, 13]. The traditional lecture-based approach may not be conducive to the development of statistical skills and collaborative skills among pre-service teachers. Such a method can limit hands-on, experiential learning opportunities and active engagement with peers and mentors, potentially hindering the acquisition of these vital competencies [14]. In light of these considerations, it is imperative to reevaluate and adapt teaching methodologies within the Thai educational context to better align with the evolving needs and expectations of 21st-century educators and foster empowering pre-service teachers to excel in research, statistical analysis, and collaboration, thus preparing them to meet the challenges of modern education more effectively.

The learning by teaching approach and project-based learning represent potential methods to foster the development of pre-service teachers' statistical skills, attitudes, and collaborative abilities [15]. Learning by teaching involves students taking on the role of teachers to explain concepts to their peers, reinforcing their own understanding in the process. Project-based learning centers on students engaging in hands-on, real-world projects to apply their knowledge and problem-solving skills [16, 17]. These two methods can be effectively blended together, creating a comprehensive approach to teacher education. In this integrated approach, pre-service teachers not only gain a deep understanding of statistical concepts but also practice teaching them to others while working collaboratively on meaningful projects.

The current study aims to capitalize on the synergistic potential of integrating learning by teaching and project-based learning to enhance the statistical competence and collaborative abilities of pre-service teachers in the Thai educational context. The research question driving this investigation is: "What impact does the implementation of Learning-by-Teaching approach combined with Project-Based Learning have on the teamwork skills and statistical data analysis skills of undergraduate students?" This innovative approach aims to address the limitations of traditional lecture-based education and better equip future educators to excel in the dynamic and demanding modern education landscape.

2. Literature Review

2.1. Learning by Teaching (LbT)

Learning by Teaching is an educational approach where students take on the role of teachers to explain and teach concepts or materials to their peers or even to younger students [15, 18]. Teaching others reinforces one's own understanding of the subject matter, which forms the foundation of this pedagogical method. Scholars (e.g., [15, 18, 19]) have introduced the fundamental principles of Learning by Teaching (LbT), which encompass key qualities such as active learning, peer interaction, ownership of learning, and the incorporation of a feedback loop. In the classroom, teachers

facilitate this approach, creating an environment where students take turns teaching and learning from one another, fostering subject mastery, communication, collaboration, and critical thinking skills among students.

In detail, LbT promotes active engagement as students are actively involved in teaching and learning simultaneously. This active participation enhances comprehension and retention of knowledge. Moreover, the approach encourages peer-to-peer interaction and collaboration. Students learn from each other's explanations and perspectives, fostering a supportive learning community. In addition, students who assume the role of teachers take ownership of their learning process. This responsibility motivates them to delve deeper into the subject matter. Finally, LbT incorporates a feedback loop in which students receive feedback from their peers or the teacher, helping them refine their understanding and teaching skills.

Teachers play a facilitative role in managing a classroom using the Learning by Teaching approach, creating an environment where students can take turns teaching and learning from one another. Teachers provide guidance, structure, and opportunities for reflection, ensuring that the teaching and learning process is productive and enriching for all students involved. This approach not only enhances subject mastery but also fosters communication, collaboration, and critical thinking skills among students.

2.2 Project-Based Learning (PBL)

Project-Based Learning is an instructional approach that centers on students actively exploring real-world problems and challenges through the creation of projects [16, 17, 20]. In PBL, students work collaboratively to investigate and address complex questions or issues, often resulting in tangible, multifaceted projects such as presentations, reports, or creative artifacts.

The principles of PBL rely on the use of authentic tasks, stimulation of inquiry and exploration, encouragement of collaboration, and development of thinking skills. PBL tasks specifically stem from real-world problems, rendering the learning experience both relevant and engaging for students. In addition, PBL encourages students to ask questions, conduct research, and explore various solutions to complex problems. Students also work collaboratively in teams, developing communication and teamwork skills as they tackle the project. The method also promotes thinking skills such as critical thinking, problem-solving, and decision-making as students analyze information and make informed choices.

In a PBL classroom, the teacher acts as a guide, facilitating the learning process by providing support, resources, and opportunities for reflection. Teachers encourage students to actively participate in their education, which fosters a deeper understanding of the subject matter and the development of essential life skills.

2.3. Integrating Learning by Teaching (LbT) and Project-Based Learning (PBL)

It can be noted that both the Learning by Teaching (LbT) and Project-Based Learning (PBL) approaches are developed from fundamental educational principles that can be effectively integrated, creating a comprehensive and enriched educational experience. The integration of these two methodologies involves utilizing the active learning and peer interaction principles of LbT within the context of authentic, inquiry-driven projects characteristic of PBL. In this combined approach, students not only take turns teaching and learning from each other but also apply their knowledge and teaching skills to address real-world problems and create meaningful projects.

This integration holds substantial potential for the development of statistical competence and collaborative skills in pre-service teachers. By employing LbT principles within PBL projects, students engage in both teaching and applying statistical concepts. They not only deepen their understanding of statistics but also learn to effectively communicate and teach these concepts to their peers. Furthermore, the collaborative nature of PBL projects encourages teamwork, communication, and problem-solving, enhancing students' collaborative skills in a real-world context. This holistic approach empowers pre-service teachers with a well-rounded skill set, enabling them to excel as educators in the 21st century, where statistical proficiency and collaboration are crucial competencies.

2.4. Previous Studies

Scholars Stollhans [15]; Debbané, et al. [18]; Maachi and Benallou [19]; Ruiz-Gallardo and Reavey [21] and Setiawan [22] have explored the use of Learning by Teaching (LbT) as an approach to enhance the skills of preservice teachers, and their findings have highlighted its positive effects. For instance, Stollhans [15] discovered that providing opportunities for preservice teachers to teach enhances their transferable knowledge and skills. Maachi and Benallou [19] reported that the majority of EFL master's students are familiar with the learning by teaching technique, which helps them develop various skills beneficial for their learning and future teaching roles. Debbané, et al. [18] identified challenges faced by participants, including psychological barriers and a lack of pedagogical know-how, while shedding light on design implications to address these challenges. Additionally, Ruiz-Gallardo and Reavey [21] found that a Teaching-by-Teaching (TbT) environment contributes to the long-term retention of science concepts. Scholarly studies Alrajeh [23]; Eckardt, et al. [24] and Williams and Sembiante [25] have also examined the value and impact of Project-Based Learning (PBL) in teacher preparation programs, shedding light on its significance. Alrajeh [23] explored the value and utilization of PBL in teacher preparation programs, emphasizing its positive contributions. Eckardt, et al. [24] delved into the impact of PBL on student content knowledge within undergraduate, teacher preparation courses, highlighting its positive effects on knowledge acquisition. Williams and Sembiante [25] conducted a review of experiential learning, including PBL, in U.S. undergraduate teacher preparation programs, providing insights into its role in shaping teacher education. These studies collectively underscore the benefits of PBL as an effective pedagogical approach for enhancing teacher preparation, promoting active learning, and equipping future educators with valuable skills and knowledge. According to the results of previous studies, there is an encouragement to explore the effects of innovative teaching methods such as Learning by

Teaching (LbT) and Project-Based Learning (PBL) on 21st-century educational outcomes, aligning with the evolving trends in modern education. Scholars also recommend further research to investigate the integration of LbT and PBL with other educational principles. Recognizing the potential of these two methodologies, the present study integrates LbT and PBL to enhance preservice teachers' statistical knowledge, attitudes, and collaborative skills. The primary objective of this study was to examine the impact of the integrated approach, combining Learning by Teaching and Project-Based Learning, on the statistical knowledge, attitudes, and collaborative abilities of preservice teachers. This research aims to contribute valuable insights into the effectiveness of this combined approach in equipping future educators with the competencies required to thrive in contemporary educational settings.

3. Methodology
3.1. Research Design
The study employed a one-group experimental design to systematically examine the effectiveness of the learning management system, developed through the integration of Learning by Teaching (LbT) and Project-Based Learning (PBL). We assessed the effectiveness by measuring the participants' post-treatment performance and comparing it to predetermined criteria established prior to study. This research approach allowed for a focused and controlled evaluation of how the integrated LbT and PBL methodologies influenced the participants' outcomes in terms of statistical competence and collaborative skills.

3.2. Participants
The study involved a total of 27 preservice teachers who were enrolled in a faculty of education at Mahsarakham University in Thailand. The sampling was cluster-random sampling.

The selection criteria for these participants were based on their year of study, with all participants being in the third year of their teacher preparation program. We made this selection based on the assumption that third-year students would have gained a solid understanding of teacher knowledge and pedagogical skills, which would equip them to participate in teaching activities with their peers. It's important to note that all participants were treated in accordance with ethical guidelines and standards concerning human research, ensuring their well-being and rights throughout the study.

3.3 Instruments
3.3.1. LbT-PBL Integrated Learning Management Plan
The learning management plan was meticulously crafted by integrating the principles of Learning by Teaching (LbT) and Project-Based Learning (PBL) to enhance participants' statistical and collaborative skills. As a result, each class session incorporated elements of both methodologies. Initially, this educational process tasked students with assignments related to statistical analysis within the realm of educational data. They formed groups based on their individual abilities, with each group assuming distinct roles and responsibilities. Engaging in hands-on projects, students conducted research, conceptualized ideas, applied formulas, and employed statistical data analysis procedures, involving both manual calculations and software usage to facilitate peer practice. Subsequently, projects underwent dual assessments: the first centered on the assigned statistical tasks, requiring teacher approval, while the second entailed collaborative evaluations by both the teacher and classmates during group presentations, wherein students shared their knowledge with peers as the teacher provided supplementary guidance. The learning management plan primarily covered statistical concepts such as one-sample t-test, dependent sample t-test, independent sample t-test, and F-test. Furthermore, the plan was evaluated by three educational management experts and received a commendable rating for appropriateness, with an average score of 4.63.

3.3.2. Collaborative Skill Evaluation Form
We created a Collaborative Skill Evaluation Form to assess participants' collaborative skills after the treatment. This form comprises 25 assessment items distributed across five domains, with five items allocated to each: work planning, self-awareness of one's role and responsibilities, creative communication, participation in operations, and maintaining a working atmosphere. During development, the form exhibited an Index of Content Validity (IOC) of 1.0, indicating high content validity. The items displayed discrimination values ranging from 0.34 to 0.79, signifying their ability to distinguish varying levels of collaborative skills. Furthermore, the form demonstrated high reliability with a Cronbach's alpha coefficient of 0.92, ensuring consistent and dependable evaluation of participants' collaborative abilities.

3.3.3. Statistical Skill Evaluation Form
We devised a Statistical Skill Evaluation Form to assess participants' proficiency in applying statistical analysis techniques for research purposes. This form comprises 26 items that align with the content outlined in the learning management plan mentioned earlier. The form scores each item on a scale of 1 to 4, with a maximum possible score of 104 for the entire form. The Index of Content Validity (IOC) for the form achieved a perfect score of 1.0, affirming its high content validity and suitability for evaluating participants' statistical skills in accordance with the planned curriculum.

3.3.4. Statistical Attitude Evaluation Form
In this self-assessment conducted by students, a Likert-type scale with 5 levels was employed, following Likert's method, encompassing 10 items. To ensure quality, the assessment underwent a validation process involving three experts, resulting in a flawless Index of Content Validity (IOC) score of 1.00 for each item. We developed the evaluation form and

administered it to a group of 24 individuals whose qualifications matched those of the study's participants. Subsequent analysis using the item total correlation method revealed that the questions exhibited strong discriminant power, ranging from 0.42 to 0.90, indicatingthe high quality of each item. We also conducted a reliability analysis, which produced a Cronbach's alpha coefficient of 0.92.

3.4 Data Collection and Data Analysis

The data collection occurred during the first semester of the 2023 academic year and spanned a period of five weeks to complete the learning management plan. The assessment of collaboration skills was ongoing throughout the data collection period. We conducted the evaluation of participants' statistical competence, encompassing both attitudes and skills, at the conclusion of the study. Descriptive statistics and a one-sample t-test were employed for data analysis, utilizing a predefined criterion of 80.

4. Result

The effect of the integrated LbT-PBL on participants' statistical competence:

1) The participants' statistical skills reached a remarkably high level following the implementation of the integrated Learning by Teaching and Project-Based Learning management plan, with an overall mean score ($\bar{x}$) of 97.96 and a standard deviation (S.D.) of 6.77. We can interpret this achievement as an exceptionally high level of proficiency, representing 94.20% of the full mark. This substantial improvement is consistent across all evaluated skills. Consequently, it can be inferred that the integration of Learning by Teaching and Project-Based Learning effectively enhanced participants' statistical skills to an exceedingly high degree (Table 1).

Table 1.
Participants' statistical skill.

Statistical skills	Maximum point	$\bar{x}$	S.D	%	Performance level
1. Data preparation	8	7.89	0.32	98.61	Very high
1.1 Data simulation	4	4.00	0.00	100.00	Very high
1.2 Coding guidelines	4	3.89	0.32	97.22	Very high
2. Fundamental statistics	16	15.22	0.80	95.14	Very high
2.1 Establishing meaning interpretation criteria	4	4.00	0.00	100.00	Very high
2.2 Statistical selection	4	4.00	0.00	100.00	Very high
2.3 Data analysis	4	3.78	0.42	94.44	Very high
2.4 Report writing	4	3.44	0.51	86.11	Very high
3. One-sample t-test	20	18.96	1.63	94.81	Very high
3.1 Research hypothesis and statistical hypothesis writing	4	3.78	0.42	94.44	Very high
3.2 Statistical selection and significance level α setting	4	3.93	0.27	98.15	Very high
3.3 Manual data analysis calculation	4	3.81	0.40	95.37	Very high
3.4 Data analysis using software	4	3.85	0.36	96.30	Very high
3.5 Report writing	4	3.59	0.50	89.81	Very high
4. Dependent sample t-test	20	18.89	1.58	94.44	Very high
4.1 Research hypothesis and statistical hypothesis writing	4	3.81	0.40	95.37	Very high
4.2 Statistical selection and significance level α setting	4	3.93	0.27	98.15	Very high
4.3 Manual data analysis calculation	4	3.81	0.40	95.37	Very high
4.4 Data analysis using software	4	3.85	0.36	96.30	Very high
4.5 Report writing	4	3.48	0.51	87.04	Very high
5. Independent sample t-test	20	18.26	1.68	91.30	Very high
5.1 Research hypothesis and statistical hypothesis writing	4	3.48	0.51	87.04	Very high
5.2 Statistical selection and significance level α setting	4	3.93	0.27	98.15	Very high
5.3 Manual data analysis calculation	4	3.52	0.58	87.96	Very high
5.4 Data analysis using software	4	3.81	0.40	95.37	Very high
5.5 Report writing	4	3.52	0.51	87.96	Very high
6. F-test	20	18.74	1.68	93.70	Very high
6.1 Research hypothesis and statistical hypothesis writing	4	3.67	0.48	91.67	Very high
6.2 Statistical selection and significance level α setting	4	3.93	0.27	98.15	Very high
6.3 Manual data analysis calculation	4	3.78	0.42	94.44	Very high
6.4 Data analysis using software	4	3.81	0.40	95.37	Very high
6.5 Report writing	4	3.56	0.51	88.89	Very high
Overall	104	97.96	6.77	94.20	Very high

2) The participants' mean score, which was 97.96. A one-sample t-test revealed that the participants' mean score significantly exceeded the criterion of 80%, with t = 11.32, p = 0.00. When examining each aspect of the evaluation individually, it is evident that the average scores in all aspects were significantly higher than the established criteria. This suggests that the treatment effectively enhanced participants' statistical skills to a level surpassing the expected outcomes. (Table 2).

Table 2.
Praticipants' statistical skill compared to the expected outcomes.

Statistical skills	Maximum point	Criteria at 80 %	x̄	S.D	%	T	p
1. Data preparation	8	6.40	7.89	0.32	98.61	24.16	0.00*
2. Fundamental statistics	16	12.80	15.22	0.80	95.14	15.72	0.00*
3. one sample t-test	20	16.00	18.96	1.63	94.81	9.45	0.00*
4. Dependent sample t-test	20	16.00	18.89	1.58	94.44	9.52	0.00*
5. Independent sample t-test	20	16.00	18.26	1.68	91.30	7.00	0.00*
6. F-test	20	16.00	18.74	1.68	93.70	8.49	0.00*
Overall	104	78.00	97.96	6.77	94.20	11.32	0.00*

Note: *Prob < 0.05.

3) Participants in the study exhibit a positive attitude towards statistics learning (x̄ = 4.06). Their demonstrated enthusiasm for independent study and active classroom engagement corroborate the participants' positive attitude. They express confidence in their ability to handle the current semester's statistics coursework and are willing to provide guidance to peers in statistical data analysis. Despite the perceived complexity of statistics, participants exhibit proficiency in data analysis and eagerly anticipate attending statistics classes. Their contentment in teaching and learning, along with their belief in the future utility of statistical knowledge in their teaching careers, further reinforces their positive attitude towards statistics learning. Overall, these findings underscore the importance of fostering a positive attitude towards statistics as it contributes to effective learning and application of statistical knowledge (Table 3).

Table 3.
Praticipants' attitudes toward statistics learning.

Items	x̄	S.D	Degree of attitude
1. I enjoy studying statistics on my own before coming to exchange ideas in class.	3.96	0.85	Positive
2. I find the statistics I am learning this semester to be not difficult.	3.67	1.04	Positive
3. I can recommend statistical data analysis to my friends.	3.81	0.92	Positive
4. Even though statistics can be challenging, I can analyze data successfully.	4.33	0.92	Positive
5. When it's time for statistics class, I feel eager to attend.	3.74	1.06	Positive
6. I feel happy when I conduct statistical data analysis.	3.56	1.09	Positive
7. I believe that learning statistics will be beneficial for my future career as a teacher.	4.67	0.73	Highly positive
8. I can apply statistical knowledge to teach students during my teaching practice.	4.48	0.75	Positive
9. I feel content when I teach/guide others on how to use statistics for data analysis.	4.00	0.88	Positive
10. I feel content when I listen to or teach my friends and receive additional guidance from teachers in using statistics.	4.41	0.69	Positive
Overall	4.06	0.64	Positive

4) The participants demonstrated highly effective collaborative skills across various domains (x̄ = 4.61). In terms of work planning (x̄ = 4.46)., they exhibited a very high level of teamwork by conducting meetings to plan together, establishing clear work sequences, and clearly assigning responsibilities. Additionally, their active participation in team meetings and collaborative schedule creation further emphasized their high level of collaboration. Furthermore, participants displayed remarkable self-awareness of their roles and responsibilities (x̄ = 4.67), even when tasks were challenging or not within their expertise, demonstrating a strong commitment to task completion. Creative communication (x̄ = 4.61) was another strong suit, as participants used language that fostered unity, explained tasks patiently to team members, expressed gratitude, and resolved differences of opinion with reason rather than emotions. In the domain of participation in operations (x̄ = 4.62), participants excelled in problem-solving, democratic conflict resolution, and information gathering, all while actively sharing opinions during scheduling and working together without fragmentation. Lastly, the participants contributed to maintaining a positive working atmosphere (x̄ = 4.68) by providing opportunities for team members to rectify mistakes, offering equal assistance, accepting feedback gracefully, praising success, and exhibiting emotional

control when dissatisfied. Overall, the collaborative skills of the participants were consistently at a very high level, indicating their strong aptitude for effective teamwork and interpersonal interactions (Table 4).

Table 4.
The effects of the integrated LBT-PBL on participants' collaborative learning skills.

Collaborative skills	x̄	S.D	Level of collaborative skills
1. Work planning	4.46	0.52	High
1.1 Before starting work, my team holds meetings to plan together.	4.59	0.57	Very high
1.2 My team has established a clear work sequence before starting work.	4.41	0.69	High
1.3 My team has assigned responsibilities clearly.	4.52	0.75	Very high
1.4 I participate in team meetings to plan our work together.	4.63	0.56	Very high
1.5 We create a teamwork schedule together.	4.15	0.66	High
2. Self-awareness of one's role and responsibilities	4.67	0.40	Very high
2.1 I am aware of the roles and tasks assigned by the team.	4.67	0.55	Very high
2.2 Even if I am assigned tasks that are not my strong suit, I will complete them.	4.59	0.64	Very high
2.3 Despite having a heavy workload, I can complete the tasks assigned to me.	4.70	0.47	Very high
2.4 Even if I disagree with the team's rules, I can follow them.	4.63	0.49	Very high
2.5 When I am responsible for a task, I am committed to completing it.	4.78	0.51	Very high
3. Creative communication	4.61	0.42	Very high
3.1 I use words that foster unity among team members.	4.67	0.55	Very high
3.2 When team members don't understand a task and ask for advice, I explain patiently to ensure understanding.	4.63	0.63	Very high
3.3 I know how to say thank you or apologize to my team members.	4.74	0.53	Very high
3.4 When team members have different opinions, I try to compromise and avoid taking sides.	4.48	0.58	High
3.5 When expressing conflicting opinions, I do so with reason rather than emotions.	4.56	0.58	Very high
4. Participation in operations	4.62	0.42	Very high
4.1 When problems arise, my team and I work together to solve them.	4.78	0.42	Very high
4.2 When there are differences of opinion, we resolve them democratically.	4.70	0.47	Very high
4.3 When information is insufficient, my team and I help gather additional data.	4.37	0.74	High
4.4 My team members and I take turns sharing our opinions.	4.59	0.57	Very high
4.5 When the team schedules work, I actively participate without working separately.	4.67	0.62	Very high
5. Maintaining a working atmosphere	4.68	0.31	Very high
5.1 When a team member makes a mistake, everyone in the team gives them a chance to rectify it.	4.74	0.45	Very high
5.2 I provide equal assistance to my team members.	4.78	0.51	Very high
5.3 When I make mistakes at work, I am willing to accept feedback from my team members.	4.67	0.48	Very high
5.4 When a team member successfully completes a task or does well, team members praise and commend them.	4.81	0.40	Very high
5.5 I can control my emotions when I am dissatisfied with a team member's work.	4.41	0.69	High
Overall	4.61	0.32	Very high

5) The participants' average collaborative skill level, which scored 4.61. A one-sample t-test revealed a significant deviation from the 80% criterion, with t = 9.97, p = 0.00, suggesting that participants' mean scores significantly exceeded the established criteria. Upon closer examination of individual facets within the evaluation, it is evident that average scores in all areas significantly exceeded the predetermined criteria. These findings underscore the treatment's remarkable success in elevating participants' collaborative skills beyond the expected levels (Table 5).

Table 5.
Praticipants'collaborative skills compared to the expected outcomes.

Collaborative skills	Maximum score	Criteria at80%	$\overline{X}$	SD	t	p
1. Work preparation	5	4	4.46	0.52	4.59	0.00*
2. Self-awareness of one's role and responsibilities	5	4	4.67	0.40	8.83	0.00*
3. Creative communication	5	4	4.61	0.42	7.63	0.00*
4. Participation in operations	5	4	4.62	0.42	7.77	0.00*
5. Maintaining a working atmosphere	5	4	4.68	0.31	11.61	0.00*
Overall	5	4	4.61	0.32	9.97	0.00*

Note: *Prob < 0.05.

5. Discussion

The results of this study demonstrate that the integration of Learning by Teaching (LbT) and Project-Based Learning (PBL) in teacher education is highly effective. This finding aligns with previous research by Stollhans [15]; Debbané, et al. [18]; Maachi and Benallou [19]; Ruiz-Gallardo and Reavey [21], and Setiawan [22] which all support the effectiveness of these two pedagogical principles. Additionally, this study is consistent with the findings of Alrajeh [23]; Eckardt, et al. [24] and Williams and Sembiante [25]. They have also emphasized the beneficial effects of LbT and PBL on educational outcomes.

This project's activities have proven to be highly beneficial for enhancing statistical skills, particularly through the opportunity for students to teach their peers. Initially assigning tasks related to statistical analysis in the context of educational data compelled students to delve into the intricacies of the subject matter. The formation of groups based on individual abilities allowed for a diverse range of skills and insights. Through hands-on projects, including research, idea conceptualization, formula application, and statistical data analysis, students gained a comprehensive understanding of the material [15]. Notably, the incorporation of both manual calculations and software usage facilitated peer learning and practice. Additionally, the dual assessment process, which involved teacher approval and collaborative evaluations during group presentations, encouraged knowledge sharing among students and provided invaluable guidance from the teacher.

The activities in this study also significantly contributed to the development of collaborative skills, primarily through the implementation of Project-Based Learning (PBL). As students engaged in project work, they were required to collaborate closely within their groups. This process included planning, task allocation, and problem-solving. According to Krajcik and Shin [20] in the project-based learning, when challenges arose, students collectively worked to find solutions and make democratic decisions. Furthermore, the rotation of opinions and active participation in discussions continued to nurture collaborative abilities [16, 17]. Moreover, maintaining a positive working atmosphere involved giving team members opportunities to rectify mistakes and providing equal assistance, promoted a culture of mutual support and constructive feedback. Overall, these activities within a PBL framework fostered an environment conducive to the growth of collaborative skills among participants.

6. Conclusion

This study has shed light on the effectiveness of integrating Learning by Teaching (LbT) and Project-Based Learning (PBL) in teacher education, unveiling key findings that hold significant implications for pedagogical practices. The primary finding of this research reveals that the integrated LbT and PBL approaches enhance both statistical and collaborative skills among participants. The contribution of this study lies in its empirical support for the integrated LbT and PBL models' success in enhancing both statistical competence and collaborative skills, particularly within the context of teacher education. This research adds to the existing body of knowledge by demonstrating the practical applicability of these pedagogical approaches in teacher training programs. Furthermore, it underscores the significance of peer teaching and active collaboration in fostering skill development, which is vital for educators preparing to enter the teaching profession.

7. Implications and Limitations

The study's findings suggest several recommendations for future research and educational practice. Firstly, it is advisable for educators and teacher training programs to consider integrating LbT and PBL methodologies into their curriculum, given the positive impact observed in this study. Secondly, we should explore a more comprehensive approach to assessment, incorporating both self-ratings and objective testing, to offer a more comprehensive evaluation of participants' skills. Additionally, future research should incorporate qualitative data to gain deeper insights into the experiential aspects of skill development and the qualitative nuances of collaborative learning.

It is essential to acknowledge the limitations of this study. One significant limitation is the reliance on self-rating for skills assessment, which may introduce subjectivity and potential bias. The absence of objective testing data poses a challenge to ensuring the validity of the findings. Moreover, this study focused primarily on quantitative data, which may not capture the qualitative aspects of skill development comprehensively. These limitations should be considered when interpreting the results and designing future research endeavors in this domain.

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