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PAPER

Professional Development for Primary School Teachers Intended to Promote Students' Spatial Ability

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ABSTRACT

Professional development (PD) plays a crucial role in equipping teachers with the necessary knowledge and skills to effectively foster spatial ability among their students. This study aimed to explore the potential of action research as a PD mode for primary school teachers to enhance students' spatial ability. The findings of this study indicate the positive impact of PD on teachers' practice, leading to significant improvements in student performance and engagement. The PD program effectively equipped teachers with new knowledge and skills, leading to noticeable progress in their instructional approaches and teaching practices. This research provides a foundation for future studies on PD programs aimed at enhancing students' spatial ability.

KEYWORDS

spatial ability, professional development, primary school, action research

1 INTRODUCTION

Like several other countries, Latvia is undergoing a curriculum reform [1, 2] that strongly focuses on developing 21st-century skills and effectively applying knowledge, skills, attitudes, and values. Due to their strong correlation with STEM (Science, Technology, Engineering, and Mathematics) disciplines, spatial abilities are particularly important among these competencies [3–5]. Proficiency in spatial skills has been linked to improved performance in mathematics [6–14] and science [15–18]. It enables students to grasp abstract concepts, visualize complex relationships, and apply logical reasoning to problem-solving [19–22]. Moreover, spatial skills serve as a means to enhance creativity and innovation [23], qualities that are highly sought after in todays' rapidly evolving technological landscape [24].

Despite its evident importance, spatial ability often receives inadequate attention in educational settings. Traditional pedagogical approaches prioritize verbal and numerical skills, inadvertently neglecting the potential for enhancing cognitive development through spatial training. In addition, studies indicate a lack of teacher

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awareness and understanding of the role of spatial abilities in learning [25, 26]. Many educators may not be familiar with the specific strategies and instructional methods that can nurture and cultivate spatial thinking among students. Consequently, opportunities to incorporate spatial tasks, exercises, and assessments into the curriculum are frequently missed. Addressing this gap in teacher awareness and knowledge is crucial to unlocking the full potential of spatial ability in education.

2 THEORETICAL FRAMEWORK

The process of teacher professional learning is complex, requiring the active engagement of teachers on cognitive and emotional levels, both as individuals and as a collective [27]. Conventional professional development (PD) approaches, such as workshops and conferences, are often associated with relatively short time commitments, which may constrain the depth of learning and skill development [28]. These methods often prove inadequate in bringing about significant changes in teachers' practices and do not lead to a positive impact on student achievement [29]. While teachers may learn new approaches, they often struggle to apply them in their classrooms due to a lack of support during implementation. To be effective, PD should be designed to inspire teachers to change their practice [30].

According to Guskey [31], effective PD interventions involve a combination of three essential phases: input, application, and reflection. Successful PD initiatives integrate seminar-style and on-the-job learning experiences into the classroom. In his seminal work, Guskey [32] established a framework comprising five distinct phases that are necessary for assessing the effectiveness and success of a PD program. The initial three stages involve evaluating teachers' responses to PD, their acquisition of knowledge and skills from the PD, and the level of support provided by their educational institutions. The fourth level of analysis focuses on the modifications that teachers implement in their professional activities. The collection of such evidence is not feasible at the conclusion of a professional development session or program. A sufficient amount of time is required to enable educators to effectively incorporate and adjust to new concepts and methodologies within their educational environments [32].

Action research is a widely recognized intervention in the field of PD. This process aims to improve social concerns, especially by identifying effective educational practices through involving stakeholders in a collaborative process that includes planning, observing, and reflecting throughout its cycles [33–35]. According to Hine [36], action research has been identified as a valuable process in education for enhancing student experiences and facilitating the professional growth of teachers. This methodology offers advantages such as fostering a participatory environment for educators and students, leading to empowerment through a systematic and reflective process.

Therefore, this study aims to identify how action research, as a form of PD, can enhance student-teacher practice by addressing the following questions:

Research Question 1: How does the mode of PD employed influence the practices of teachers and students?

Research Question 2: What are the primary school teachers' PD needs and preferences concerning spatial ability, and how can these be accommodated in upcoming training programs?

3 METHOD

This study employed an action research method involving iterative cycles of planning, acting, observing, and reflecting, allowing for continuous improvement and adaptation of instructional practices. The model's structure drew inspiration from the PD framework introduced by Greitāns et al. [1], encompassing the following key attributes:

- A consistent flow of input workshops, combined with ongoing opportunities to apply this input in classroom settings, analyze the outcomes, and participate in reflective practices.
- Active encouragement of teacher collaboration.
- Tailoring content to foster a comprehensive understanding of the teachers' specific professional development needs.

3.1 Participants

The study involved five primary school teachers from two public schools and one private school in Latvia. Detailed information about the participants can be found in Table 1.

Table 1. Participants characteristics

Teacher	Grade	Gender	Teaching Experience	Degree	Weekly Workload
Teacher 1	1st	Female	5 years	M.Ed.	12 hours
Teacher 2	2nd	Female	35 years	B.Ed.	21 hours
Teacher 3	2nd	Female	3 years	B.Ed.	21 hours
Teacher 4	3rd	Female	22 years	B.Ed.	27 hours
Teacher 5	4th	Female	24 years	B.Ed.	23 hours

Table 1's data shows that all participants held a Bachelor of Education, and many teachers had over 15 years of teaching experience. In contrast, their weekly teaching load ranged from 12 to 27 hours.

3.2 Design of the model

In the present study, the PD mode spanned six months. The initial workshop was held in person, while the subsequent five were delivered online. Figure 1 depicts the PD model adapted according to specified methodological principles. During the intervals between workshops, participants work on developing and implementing a lesson plan focused on spatial ability. This emphasis is in response to the challenges students face in mathematics, science, and technology. Subsequently, the plan is assessed and revised. By utilizing these iterative cycles involving planning, acting, observing, and reflecting, it is possible to consistently enhance and adjust instructional practices.

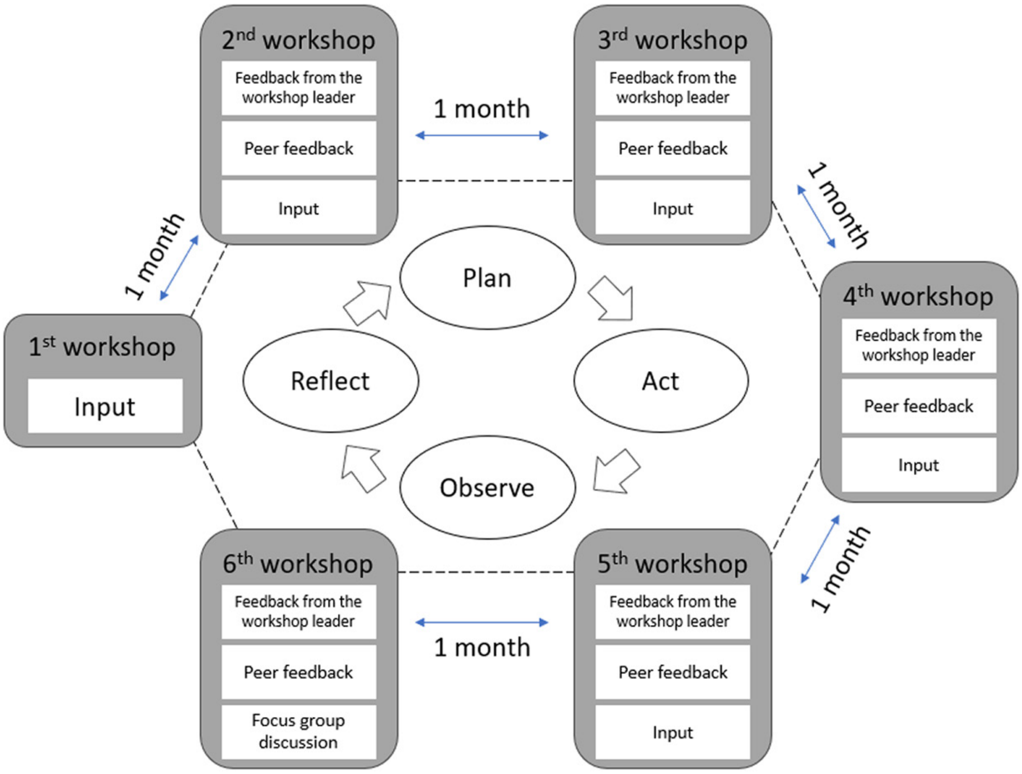

Fig. 1. The PD model design is based on the model proposed by Greitāns et al. [1]

3.3 Procedures for each workshop

During the first workshop, an input (lecture) on the four components of spatial ability (mental rotation, visualization, orientation, and mental folding) was provided. The lecture included examples and definitions of each component and explained their relevance to mathematics, science, and technology. Various illustrations and examples, drawn from everyday contexts and arithmetic situations, were presented to the participants to help them better grasp the distinctions between each component of spatial ability. Additionally, individual tasks were assigned to the participants, focusing on analyzing the students' challenges in mathematics, science, and technology.

Participants presented their analyses of the students' challenges during the second workshop and received feedback from the workshop leader. Furthermore, the workshop leader introduced a new concept regarding the component of spatial ability, specifically mental rotation. Through this input, the researchers developed activities based on curriculum learning objectives, considering the literature and the specific needs of the teachers in response to the challenges students encounter. For one month, participants utilized the action research model and the feedback they had received to create new lesson plans. These revised lesson plans strongly emphasize integrating a wider range of spatial skills. Subsequently, they actively participated in the process of implementing, observing, and reflecting on each of the newly developed lesson studies. During the next workshop, participants received feedback from the workshop leader and exchanged input with each other during the collaborative meeting.

The sequence of workshops continued, with each one delving deeper into specific spatial abilities. The third workshop focused on visualization, the fourth on orientation, and the fifth on mental folding. During the sixth workshop, a focus group discussion offered a dynamic platform for direct engagement with the participants, enabling a more profound exploration of their perspectives and experiences. Through these dialogues, we gained valuable insights into various aspects of our study. Participants shared their thoughts on the effectiveness of instructional strategies, their experiences with professional development, and the challenges they encountered in their teaching roles.

3.4 Data collection

The data collection phase employed a mixed-methods approach, combining both qualitative and quantitative methods, to comprehensively assess the impact of the PD intervention on spatial ability development. Quantitative data was collected through pre- and post-assessments using two standardized spatial ability tests: the mental folding test for children (MFTC) [37] and the children's mental transformation task (CMTT) [38], [39]. These tests measured students' mental rotation abilities before and after the implementation of the new activities in the classroom. In conjunction with the quantitative approach, qualitative data was gathered through key methods such as classroom observations, reflective journals, and focus group discussions. Classroom observations provided valuable insights into student engagement, interactions, and the application of spatial thinking strategies during in-class activities. These observations were documented using field notes and artifacts as evidence, resulting in detailed descriptions of students' spatial learning experiences. Additionally, participating teachers maintained reflective journals. During focus group discussions, they shared their qualitative insights, reflections, perceptions, and suggestions for improving the intervention. These journals serve are a valuable source of information about the impact of professional development on both students and teachers.

4 RESULTS

4.1 Findings of the first research question

To comprehensively assess the impact of the PD mode employed in this study, we applied five essential levels of PD evaluation [43].

Participants' reactions. In the first level of PD evaluation, according to Guskey [43], our focus was on assessing participants' reactions to the PD method. To evaluate their response, we addressed several questions through group discussions and collected reflective feedback.

- Did participants like it?

T.2: "Now I better understand the importance of spatial skills."

T.3: "I find inspiration in the insights shared by my colleagues, which has bolstered my confidence in incorporating spatial activities within the classroom. I now recognize the significance of these activities in fostering students' achievements, despite having previously given less attention to them due to time limitations."

T.5: "I obtained considerable satisfaction from engaging in discussions and observations of my colleagues' lesson plans, struggles, and achievements within the classroom."

- Was the input material comprehensible?

T.1: "They were interesting but not directly used."

T.2: "From the workshops we observed at the start, I incorporated the hands-on tools – pattern blocks – into one of my lesson plans, and my students enjoyed using them during the lesson. They completed many of the provided layouts, and watching them create various shapes was very entertaining."

T.3: "I have used them and other activities from the prior year."

- Will it be useful?

T.3: "It is evident that acquiring these skills is crucial during early childhood, as students often encounter difficulties with orientation in space and navigation."

T.4: "I liked the spatial activities very much and am willing to try new activities."

Participants' learning. Based on Guskey [43], our focus was on the participants' learning outcomes resulting from the PD mode in the second level of PD evaluation. This level evaluated how teachers acquired new knowledge, skills, and instructional strategies through the training.

Before implementing the PD, participants were asked about their perceptions of spatial ability, as teachers may have a limited understanding of the significance and benefits of spatial ability. Such limitations were observed when teachers were asked about spatial ability before the initial phase.

T.1: "A way of thinking that allows you to "see" things, figures, etc. in your head, the ability to imagine."

T.2: "A kind of figurative thinking."

T.3: "To me, spatial ability is about imagination, which should begin later in secondary school because students are so young now."

T.4: "The ability to see things as a whole, imagining the big picture."

T.5: "Spatial ability aids computational thinking."

As teachers undergo training and receive information about spatial ability and its impact on student learning, their awareness and understanding increase. The positive influences observed were documented at the end of the PD sessions, where teachers were interviewed again to gather their perspectives on spatial ability.

T.1: "Spatial ability aids a better understanding of geometry. Also, I have used them along with other activities from the prior year."

T.2: "Now I better understand the importance of spatial skills."

T.3: "It is evident that acquiring these skills is crucial during early childhood, as students often encounter difficulties with orientation in space and navigation."

T.4: "I liked the spatial activities very much and am willing to try new activities."

T.5: "The ability to visualize creatively and abstractly."

Organization support and change. In the third level of PD evaluation, based on Guskey [43], we identified difficulties or barriers encountered during the implementation process by asking the following question:

- What difficulties did you encounter when engaging in such activities?

T.1: "Time constraints, as other curricular topics must be completed, and there is no time for additional spatial activities."

T.3: "Since these activities are not part of the curriculum, it is difficult to present parents with evidence and grades about their progress."

The use of new knowledge or skills by participants. At the fourth level of Guskey's [43] PD evaluation, our focus was on assessing whether participants effectively applied the new knowledge and skills they acquired during the PD. This study aims to assess the extent to which teachers integrated the learned strategies into their classroom practices and instructional approaches. To address this challenge, we examined the following aspects:

Classroom implementation: We observed and analyzed how participants integrated the newly acquired knowledge and skills into their daily teaching practices. This involved examining lesson plans, instructional materials, classroom interactions, and artifacts to identify changes in teaching practices.

The process of classroom implementation involved the following key steps:

- Observation: The PD leader conducted systematic classroom observations. During actual teaching sessions, the observer searched for evidence of the newly acquired instructional strategies and techniques. Two teachers employed a transitional strategy from pictorial to concrete during the cube and 3D figure layout activities, as illustrated in Figures 2 and 3.

Fig. 2. Artifacts were collected from teacher 1's classroom during cube activity

Fig. 3. Artifacts collected from teacher 5's classroom during the 3D figure layout activity

- Lesson plans: We scrutinized participants' lesson plans to identify modifications or adaptations incorporating the PD mode's concepts.

As shown in Table 2, modifications were identified to the lesson plans during the workshops. These modifications included the addition of learning objectives and the formulation of new goals that correspond to the PD model's emphasis on spatial components.

Table 2. Modifications to lesson plans made by teacher four between the first two workshops and the final workshop

Teacher	Lesson Plan	Grade	Content of the Lesson Plan from the First two Workshops	Implemented Content Identified on the 6th Workshop
T4	3D Geometry	3	Introduction Learning objectives General lesson activities guidelines Required materials Homework	Curricular Connections Prior Knowledge Step-by-step lesson activities guidelines Differentiation strategies Important Terms Key Questions Spatial skills targeted Cross-Curricular Connections

- Classroom interactions: The leader of the PD program observed teacher interactions with students during instruction, including communication patterns, teacher-student dialogues, and the level of student engagement in the learning process.

"During the classroom observation of teacher 2, it was seen that the teacher actively engaged students who showed advanced learning capabilities, prompting them to support other students by employing spatial language."

"Despite the students' initial reluctance and apprehension to engage in the collaborative problem-solving task, Teacher 4 facilitated a group discussion among the students."

"Teacher 5 consistently offered support during the process of constructing 3D shapes through the utilization of scissors. However, the large class size made it challenging for the teacher to address all students' inquiries and demands."

Reflection and feedback: Feedback from the participants was essential for understanding their perspectives on integrating the new knowledge and skills. The focus group discussions provided opportunities for teachers to share their experiences and reflect on the outcomes of their implementation efforts.

T.1: "During the cube-building activity, I noticed significant student engagement among the pairs. Additionally, their counting skills showed improvement throughout the activity. However, it should be noted that they required assistance as the task became more difficult."

T2: "I guided those students who exhibited accelerated learning abilities, encouraging them to assist their peers through the use of spatial language."

T.3: "I find inspiration in the insights shared by my colleagues, which has bolstered my confidence in incorporating spatial activities within the classroom. I now recognize the significance of these activities in fostering students' achievements, despite having previously given less attention to them due to time limitations."

T.5: "By closely examining the lesson plans of my colleagues, I have generated a set of ideas aimed at enhancing the effectiveness of my geometry activities involving the utilization of paper and scissors."

Student learning outcomes. In the final level of Guskey's [43] PD evaluation, the focus shifts to student learning outcomes, with a specific emphasis on assessing the impact of the PD model on students' spatial abilities. For this reason, a dependent t-test was employed to determine the effect of the intervention by comparing the pupils' outcomes before and after the PD implementation. Table 3 presents a concise overview of the results.

Table 3. Comparison of pre-and post-tests for each grade

	Grade	Test	Number of Students	Pre-Test Mean ± SD	Post-Test Mean ± SD	t	p
T1	1st	MFTC	12	3.33 ± 1.02	8.5 ± 1.32	9.67	< 0.001
		CMTT		2.91 ± 0.95	6.91 ± 1.49	12.28	< 0.001
T2	2nd	MFTC	25	7.04 ± 1.82	9.08 ± 0.97	5.02	< 0.001
		CMTT		9.12 ± 1.07	9.96 ± 0.19	4.08	< 0.001
T3	2nd	CMTT	22	8 ± 2.02	8.68 ± 2.0	1.65	0.113
T4	3rd	MFTC	18	7.5 ± 2.08	9.05 ± 1.17	2.74	0.013
		CMTT		9.05 ± 1.80	9.77 ± 0.41	1.83	0.084
T5	4th	MFTC	19	7.15 ± 2.23	8.10 ± 1.02	1.56	0.013
		CMTT		8.84 ± 1.69	9.10 ± 1.16	0.53	0.601

Note: $p < 0.05$. SD: Standard deviation.

In the case of teacher 1 (T1), there were notable differences between the pretest (M = 3.33, SD = 1.02) and post-test (M = 8.5, SD = 1.32) scores for the MFTC. Significant differences were observed in the pre-test (M = 2.91, SD = 0.95) and post-test (M = 6.91, SD = 1.49) CMTT scores. A statistically significant difference ($p < .05$) was observed in teacher 2 (T2) for each of the tests, indicating that the instruction had a positive impact and led to improved spatial skills among the students compared to the initial stage of implementing the PD. Teacher 3 (T3) carried out a single CMTT, and the results showed that there was no statistically significant difference ($p < .05$) between the scores achieved in the pre-test (M = 8, SD = 2.02) and post-test (M = 8.68, SD = 2) assessments. In addition, there was a significant difference between the pre- and post-test scores for MFTC for teacher 4 (T4), but there was no significant change for the last test (CMTT; $p < .05$). Moreover, there was no statistically significant difference observed between the pre- and post-test results for T5 across all assessments. One plausible explanation for this finding may be attributed to the fact that the participants were fourth-grade students and the administered tests were designed for a younger population.

4.2 Findings about the second research question

Addressing the needs and preferences of teachers through PD is a crucial element in empowering them to effectively develop and implement teaching practices that enhance students' spatial ability and improve learning outcomes. Based on the collected data, there is evidence supporting the identification of the following needs:

Understanding the concept of spatial ability: Teachers may require a comprehensive understanding of the concept of spatial ability and its significance in learning. Not all teachers ultimately know its definition; many perceive it as a distinct subject. Misconceptions were identified during the initial intervention stage, where participants were asked to define spatial ability based on their understanding.

Before engaging in PD, teacher 5 (T5) had a certain level of understanding of spatial ability within computational thinking. Following the completion of the training, T5's articulation of spatial ability exhibited notable enhancement, as it was now described as "*the capacity to creatively and abstractly visualize*." After the training, several teachers exhibited similar changes, experiencing a positive transformation in their understanding of spatial ability concepts.

The impact on student learning: To effectively incorporate more spatial activities into their teaching practice, teachers need to understand the direct impact of spatial ability on student learning outcomes. By presenting research evidence and practical examples that demonstrate how spatial activities enhance student understanding, problem-solving skills, and critical thinking across different subjects, teachers can cultivate a deeper appreciation for the value of spatial ability in the classroom.

Access to appropriate resources: Teachers may have difficulty accessing the right resources, such as manipulatives and technological tools, to support spatial learning. Although the participants had access to various resources at their respective institutions, some public-school teachers found it challenging to acquire sufficient manipulatives. This is reflected through their use of basic materials in their lesson plans.

Integration with curriculum objectives: Aligning spatial activities with existing curriculum standards and learning objectives is crucial for teachers. Supporting teachers in seamlessly integrating spatial activities into their existing lesson plans, while ensuring they meet content-specific and spatial learning goals, enables them to deliver a comprehensive education that encompasses spatial skills. During the workshops, the input supported teachers by introducing them to various spatial activities aligned with the curriculum's specified topic objectives. Furthermore, the workshops included illustrations of curricular connections within mathematics, science, and design and technology. Notable examples of this nature were observed during the teacher's adjustments to lesson plans. After the sixth workshop, their lesson plan had been enhanced with the inclusion of curricular interactions.

Differentiation strategies: Recognizing their pupils' diverse needs and abilities, teachers may require assistance in differentiating spatial activities. Providing strategies to modify spatial activities to accommodate students with different levels of spatial ability, learning styles, and special needs enables teachers to design inclusive learning experiences that support all students. During the group discussion, several approaches were observed, including teacher 5 (T5) assigning an additional task to students who finished their work early.

T.5: "In my case, pupils who finished early had to build a task for the teacher."

In the case of teacher 2 (T2), pupils who possessed advanced skills and completed the task ahead of schedule were encouraged to help their peers.

T2: "I encouraged students who exhibited accelerated learning abilities to assist their peers through the use of spatial language."

Collaboration and peer support: The implementation of collaborative learning experiences produced positive results in the context of action research, as teachers enhanced and refined their lesson plans through peer feedback and the observation and collection of examples from their colleagues. Positive feedback was shared during the group discussion:

T.3: "I find inspiration in the insights shared by my colleagues, which has bolstered my confidence in incorporating spatial activities within the classroom."

T.5: "By closely examining the lesson plans of my colleagues, I have generated a set of ideas aimed at enhancing the effectiveness of my geometry activities."

5 DISCUSSIONS

The application of Guskey's five critical levels of PD evaluation in this study revealed encouraging outcomes for the PD model employed. Participants showed positive reactions to the training, expressing satisfaction with the information provided and engaging in collaborative discussions with colleagues, which is consistent with previous research on effective PD [40–43]. As stated by [44], team training requires effective communication and a change in attitudes and behavior to empower team members to apply their knowledge to autonomous actions. The positive response indicates that the PD mode was well-received and aligned with participants' professional needs and interests. Moreover, the study findings align with existing literature [45–47] that emphasizes the significance of PD in enhancing teachers' knowledge and instructional practices. Participants' learning outcomes showed significant improvements in their comprehension and utilization of spatial abilities, consistent with previous studies on spatial cognition and professional growth [48–50]. These results suggest that the PD mode effectively enhanced teachers' pedagogical skills and knowledge, contributing to their professional growth.

While participants faced some difficulties in implementing new activities, a common challenge observed in PD initiatives [51], [47], the study could not capture data on the school organization's support and facilitation. According to [52], taking into account students' diverse learning styles and individual characteristics is a practical approach to fostering critical thinking.

Future research could explore the organizational context and leadership's role in promoting PD implementation, as administrative support is crucial for successful PD outcomes [53], [32]. The significant translation of newly acquired knowledge into classroom practice, as observed in classrooms, aligns with research emphasizing the importance of applying PD's practically [54], [55]. Effective integration of the PD mode's strategies by teachers highlights the potential for sustained impact on student learning. Indeed, the positive effects observed on student learning outcomes align with studies demonstrating the association between effective teacher PD and improved student achievement [56], [57], [29]. The study's findings indicate that when teachers improve their instructional practices through targeted PD, students' academic performance and achievement benefit accordingly.

6 CONCLUSION

This study's findings underscore the positive impact of PD on teachers' practice and highlight their need for additional support. The acquisition of new knowledge and skills through the PD resulted in significant improvements in student performance and engagement. This was demonstrated through improved spatial thinking abilities, as well as increased interest and active participation in spatial tasks. The study's positive outcomes for teachers and students demonstrate the potential of targeted interventions to foster meaningful changes in teaching practices and student learning experiences.

Furthermore, emphasizing collaboration and ongoing support for teachers is essential for the long-term sustainability of effective instructional practices. Creating a supportive learning community enables educators to continually exchange ideas, share best practices, and refine their pedagogical approaches, ensuring a collective commitment to student success.

To maximize the benefits of spatial ability instruction, it is crucial to integrate real-world contexts into the learning process. By connecting abstract concepts to practical applications, students can better grasp the relevance of spatial thinking in their daily lives and future endeavors.

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