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A Teaching Practicum Model for Constructing Cogenerative Dialogue Amongst Preservice Teachers to Improve Science Teaching

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Abstract

The specific focus of this study is how a team of four preservice teachers experienced a collaborative practicum model to support the development of cogenerative dialogue and foster professional growth. Data sources included individual video club annotations and the associated group discussions facilitated by comparison of groups members selected annotations. The analysis found that participation in peer collaboration provided multiple viewpoints of shared teaching experiences that enabled preservice teachers' different ways to notice student thinking. Providing a structured framework for reflection, namely the individual video club annotations, served as the genesis for cogenerative dialogues centered on instructional change for the preservice teachers. This work's implications showcase the importance of allowing for the iterative enactment and reflection on pedagogical choices by preservice teachers early in their professional development.

Keywords:

Early Field Experience, Teacher Preparation, Collaborative Learning, Cogenerative Dialogue

Introduction

Teaching has increasingly become structured as a collaborative community endeavor (NCTAF, 2016). Collaboration among teachers cultivates improved instruction opportunities and is critical to effective teacher professional development (Darling-Hammond et al., 2017). These opportunities foster inquiry and reflection into teachers' practices and afford space for attending to dilemmas in practice (Ball & Cohen, 1999). Involving teachers in professional learning communities is one example of a collaborative learning space that can engage teachers in learning from each other's perspectives and expertise, modeling effective core classroom practices, and providing mutual support (Darling-Hammond et al., 2024). Communities of practice, another collaborative context for professional learning, have shown benefits with teacher motivation to extend the work form the community into their practice when collaborating in a community of a similar grade or grade band, or related subjects (e.g., math and science) (Gore & Rosser, 2022).

Beginning teachers should experience the kinds of teaching strategies they are expected to in their future classrooms to understand how various strategies may play out in different contexts (i.e., different grades and schools) (Hargreaves & O'Conner, 2018; Darling-Hammond et al., 2019). Drawing on what we know about the benefits of professional learning communities or communities of practice, similar experiences should be provided to preservice teachers (Hammerness et al., 2005). Additionally, including such experiences, which very likely could be required of these novice teachers to participate in at their future schools, will help preservice teachers learn early on how to manage challenges that arise in collaborative work and to practice giving and receiving feedback from colleagues (Darling-Hammond et al., 2024; Ingersoll et al., 2014). Considering this goal, this study seeks to explore how a collaborative teaching model, designed to encourage the development of a shared or cogenerative dialogue about the practice of teaching science, supports preservice teachers in offering and receiving feedback to improve lessons, as well as how this feedback is taken up by the team and put into practice. Also, what do the preservice teachers value about the iterative collaborative practicum model concerning their future teaching.

Theoretical Framing and Related Literature

For this study, we adopt a sociocultural perspective to teacher learning (Wenger, 1998) because learning to teach is understood to be derived from sociocultural phenomena (Tobin & Roth, 2006). The preservice teachers in this study work collaboratively as a teaching unit to plan, teach, and reflect on their science teaching to elementary-aged children. This work is contextualized in an informal community-based science program for children, mirroring the professional practices of classroom teachers in a shared learning environment (Lave & Wenger, 1991) of an informal community-based science program for children.

Preservice teachers should be engaged in a collaborative and social learning environment, like a professional learning community or community of practice, like classroom teachers. They must understand that sharing ideas and engaging with others in instructional practice can enhance all practices. Through co-planning, co-teaching, and co-teaching, which is the foundation of the practicum model for this study, preservice teachers can learn to position themselves as instructors in their classrooms and take on the identity of professionals working in a genuine classroom context with diverse learners. Cochran-Smith and Villegas (2015a) suggest that preservice teachers can learn from one another by exchanging ideas, articulating the reasoning behind instructional choices, exploring specific problems of practice, and reflecting on their teaching to improve student learning. The practicum model introduced in this study is designed to provide preservice teachers with space, time, and support to achieve each goal.

Cogenerative Dialogue

Cogenerative dialogue is a structured discussion among participants based on shared experiences and focused on improving teaching and learning (Martin, 2007). These dialogues are centered on implementing an activity, lesson, or assessment and allow teachers to reflect on practice. Scantlebury et al. (2008) "found that cogenerative dialogues occurred during weekly co-planning sessions amongst co-teachers and interns. For co-teaching to be successful, all co-teachers must participate in co-planning. The co-planning sessions led to the professional development of the teachers through shared ideas, reflection on past experiences, and development of collective, mutual understandings of practice" (pg. 972). Siry and Martin (2014) further demonstrated that video analysis and cogenerative dialogues offered structural support for preservice teachers in their field-based science methods course for critical reflection on their teaching to improve practice. Cogenerative dialogues between co-teachers that focus on pedagogical ideas and curricular instruction are referred to as brainstorming. In these dialogues, every voice is given equal importance, and no single voice is privileged over another (Scantlebury et al, 2008).

Co-teaching and Co-planning

Co-teaching cultivates a community of practice (Gallo-Fox, 2010) between preservice experienced teachers. In student teaching, preservice teachers get assigned to work with experienced teachers to share student learning responsibility (Gallo-Fox & Scantlebury, 2016; Soslau et al., 2019). The co-teaching arrangement has learning opportunities for both the preservice teacher (Bacharach et al., 2010) and the co-teacher (Gallo-Fox & Scantlebury, 2016). In co-teaching, the co-teaching, the co-teacher and preservice teachers commit to planning, teaching, and reflecting together, thus sharing knowledge and expertise to facilitate students' learning and strengthen their practice (Murphy & Martin, 2015). Teachers are knowledgeable and reflective professionals who work in the context of professional communities and make reasoned decisions in the service of their students (Cochran-Smith & Villegas, 2015a, p.10).

However, co-teaching is rarely translated to early field or practicum experiences because successful co-teaching. Requires an opportunity for co-planning (Carlisle, 2010). This phase of the collaborative process requires co-teachers to collectively develop a lesson that facilitates student learning and coordination of teaching duties amongst teachers (Gallo-Fox &

Scantlebury, 2015). It is in this phase that cogenerative dialogues are often born concerning all aspects of high-quality and equitable teaching centered on student learning and assessing student understanding. Co-planning amongst teachers increases the variety of pedagogical choices and assessment choices used. This phase, combined with co-teaching, is enhanced further when teachers engage in the act of reflective practice together (Thousand et al., 2007). This collective process of co-planning, co-teaching, and co-reflection gives preservice teachers agency in making evidence-based decisions regarding student learning (Scantlebury et al., 2008).

Co-reflection and the Role of Video Clubs

Video clubs allow teachers to reflect on teaching with authentic representations of practice (Sherin et al., 2009). In the preservice context, video clubs afford preservice teachers access to student thinking that they can then leverage to deepen their pedagogical content knowledge, including their understanding of science content and ideas for science learning (Hawkins & Park Rogers, 2016; Johnson & Cotterman, 2015). Each member analyzes the same video lesson, providing evidence to support claims and judgements. Others can then evaluate this evidence regarding the claims in the group for usefulness in achieving the learning goals (Barnhart, 2020; Nielson, 2015; Zhang et al, 2011). Socially, the ideas that emerge from collaborative reflections become new resources for club members (Gwyn-Paquette, 2001).

Further research is required to understand how teacher learning evolves through teacher's collective video analysis (Barnhart, 2020). Inservice teachers were thought to draw from both video analysis and professional knowledge to support collaborative discussions, however, when the focus shifted to their teaching, collaboration declined concerning critiquing instructional choices (Barnhart, 2020). Preservice teachers have been found in high frequency to uptake annotation of their peers in written lesson reflections regarding supporting students' science thinking (Barnhart, 2022). However, with both in-service and preservice teachers, opportunities are often not provided for iterative enactment and reflective analysis, which are critical to the long-term adoption of these practices (Barnhart, 2020; 2022).

Aim of Study and Research Questions

Before field teaching experiences, preservice teachers learn educational theories and techniques in methods courses. These single-site studies of teacher educators utilizing their courses and programs as research sites have contributed overwhelmingly to the field of teacher preparation practice (Cochran-Smith & Villegas, 2015a). The focus of these studies is on ways to help preservice teachers learn to interpret classroom life in rich, accurate, and complex ways, often by learning to analyze the data of practice. However, many studies in this area of research focus on how candidates discussed appropriate practices for various situations, but this discussion was rarely focused on their specific teaching tasks and techniques. Therefore, there is a need to link these two viewpoints about practice in new ways that are constructive and complex (Cochran-Smith et al, 2015b).

This study contributes to this need by investigating the extent to which four preservice teachers participating in a collaborative, authentic co-teaching context, a professional learning community or community of practice of sorts, to learn how to work with other teaching professionals (in this case peers) to develop a consensus of how to plan for and implement two hours of high-quality science activities each week for 3-weeks. Investigating how preservice teachers' ideas are integrated into a professional learning community during the early stages of professional development can assist the field of teacher education in determining how to help prospective teachers recognize key aspects of their practice and communicate these ideas. Encouraging novice teachers to voice their thoughts on reform-based practices is critical to the cogenerative dialogue. Often novice teachers lack the confidence in contributing to these important moments of dialogue with colleagues who are more experienced classroom teachers. Therefore, allowing the opportunity to develop this important practice with peers may give them the confidence to continue this work once they enter the profession. This study, therefore, seeks to explore how providing context and opportunity for developing peer-to-peer cogenerative dialogue can support elementary preservice teachers in learning to teach science. For this study, we draw on a video club structure (Sherin et al., 2009) to structure co-reflection, and a professional learning community to support the overall structure of the co-planning, co-teaching, and co-reflection (i.e. video club). The research questions guiding this study are:

> *Research Question (RQ)1: What ideas are individuals contributing to the cogenerative dialogue of the team and how are individual's contributions being taken up in co-reflection (video club) concerning the team deciding what to modify or plan for the next lesson?*
>
> *RQ2: What value, if any, do the preservice teachers share about participating in a video club-based professional learning community designed to support cogenerative dialogue for learning to teach science?*

Situating the Study

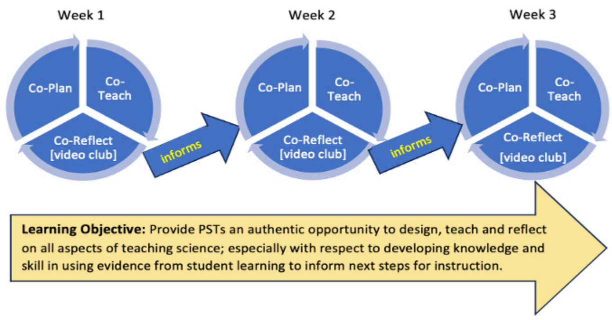
This study takes place in an advanced elementary science methods course at a Midwestern University in the U.S. The preservice teachers taking this course are juniors or seniors (3rd or 4th-year students) completing the course as a capstone to their science concentration per their education degree requirements. A significant component of this course is a 6-week teaching practicum on Saturday mornings. The teaching practicum ran for 2.5 hours and consisted of four grade level mixed classrooms representing Grades K-8. The practicum was split into two 3-week sessions during the semester of the study to accommodate local school districts and the University's fall breaks.

The preservice teachers were divided into small teaching teams of 3-4 individuals based on their prior teaching experience and the grade levels they aimed to gain experience teaching. Each teaching team functioned as a professional learning community, including a science education PhD student who served as a content expert. Author 1 served as one of these experts for one team. Author 2 was an additional expert common to all teams as they were the faculty instructor for the entire methods course and the Saturday morning teaching practicum coordinator.

The preservice teachers spent time in their weekly methods course meetings in their professional learning communities to plan for and reflect on their teaching experience. To guide this process, and support the communities' cogenerative dialogue, we adopted a three-part model (see Figure 1) that had the teams co-planning, co-teaching, and co-reflecting together weekly. The structure of each component, which Author 2 designed, is described below.

Figure 1

Instructional Model Supporting Cogenerative Dialogue



Co-Planning

Planning for the teaching experience began with each professional learning community developing a unit matrix that outlined the topic, essential questions, suggested activities, and assumptions about students thinking and experiences associated with the topic of study. The preservice teachers had to sequence the topics (weeks) in an order they believed would help to develop students learning about the topic conceptually, thus building the concepts sequentially. The preservice teachers provided justification for the topics they selected for each week. The methods instructor (Author 2) reviewed the unit matrix and gave feedback and suggestions on the organization of the lessons to support student learning. The unit matrix functioned as a 'roadmap' for weekly planning.

Like the unit matrix, a template was provided to the preservice teachers to write up their weekly lesson plans. Many of the sections on the lesson plan followed the same components as the unit matrix (e.g., essential questions and predictions of students thinking and/or experience with concepts); however, the main body of the lesson plan itself followed a 5E instructional model (Bybee, 2013) as this was a format most of the preservice teachers were familiar with from their initial science methods course. Additionally, to help the preservice teachers capture aspects of their teaching for the co-reflection component of the model, they identified up to 45 minutes of instruction from their plans to be video recorded. The preservice teachers were encouraged to break up the time into 10-15 minutes increments to capture different to lead discussion and sense-making with the students.

Co-Teaching

Regarding co-teaching, the preservice teachers were required to split the 2.5 hours of instruction so that different team members could lead segments. Sometimes this occurred by different members taking on different parts of the 5E structure. Other times, it meant leading a small group through a full activity and then working with peers to summarize what each small group explored and explained to contribute to the large elaboration or application of learning that the entire class participated in.

Co-Reflection

To begin the weekly reflection process, each preservice teacher independently reviewed and coded their team's 45 minutes video, selecting timestamps and providing annotations for how they thought the code was represented in the selected video clip. They then brought these coding sheets to the video club and shared their codes with their other professional learning community members, looking for times when they coded similar and different segments for each code (again, see Appendix A). Using what they discussed through this guided process, cogenerative dialogue, the preservice teachers identified up to three suggestions for modifying their practice going into the next week that they believed would better support student thinking and/or instruction to support student learning.

Research Design

Participant Selection

During the semester of this study, 14 students were enrolled in the course; 12 identified themselves with female pronouns, 1 identified themselves with male pronouns, and 1 identified with they/them pronouns. To accommodate the requirement of having four classrooms for the Saturday teaching practicum, the preservice teachers were divided into professional learning communities consisting of 3 to 4 individuals that were led by a PhD Science Education student serving the role of science content expert. All communities met each Tuesday evening with Author 2 for their methods course. During the practicum weeks, each Tuesday class was guided by the instructional model for cogenerative dialogue (see Figure 1).

The PhD students attended class for all co-planning aspects before the program started and when the video club portion (co-reflect phase) was complete and the communities were moving on to the lesson planning for the next week. They were not contributors of the co-teaching and co-reflection process as we wanted the preservice teachers to be independent of the content experts with identifying critical aspects of practice to modify and work on improving from week to week. Similarly, the methods instructor provided feedback broadly to the class (all teams) as Author 2 recognized essential elements in their teaching to focus on developing strategies for doing so. Author 2 only provided individual teams with specific guidance when they explicitly asked for it directly.

For this study, we selected one group to highlight and focus on their experience in the first 3-week teaching experience; as the second 3-week period, teams switched and the topic changed, but the cogenerative dialogue model did not change. We are taking a case study approach to our research design (Creswell & Poth, 2016), as we are bounded by time and number of participants within a single group (n=4). However, this one team's experience mirrors the other teams, thus we believe providing a more in-depth story of this one team's experience across the 3-weeks will provide more valuable contributions to the field about how the cogenerative dialogue model employed in this study can support novice science teacher development than a surface level analysis across multiple teams.

The team we focused on for this study taught a Grades 1-2 split class about different forms of energy. This purposefully selected team consisted of Dorothy, Nellie, Lisa, and Rene (pseudonyms). All four of these participants identified as white females and were in their early 20s. Given that this study focuses on their experience with the cogenerative model of co-plan, co-teach, and co-reflect, we do not include their content expert as a participant as they were present for only one component of this model weekly.

Data Sources

To examine how our focus group used the iterative cycle of co-plan, co-teach, and co-reflect during their practicum experience, we utilized four data sources to track their development as teachers. Table 1 describes the number of data sources collected over the 3 weeks and their usage in the practicum experience.

Table 1

Summary of Data Sources

Data Source	Research Question Alignment	Description of Data Source and Number of Data Points (N)
Individual annotations of team selected video segments from lesson taught.	RQ1	Each preservice teacher on the team independently analyzed the selected video segments of their teaching using VideoAnt College of Education and Human Development, University of Minnesota, n.d.). The five annotations the preservice teachers were to find instances of in the video and comment on how the clip illustrates the annotation code were provided by the methods instructor (see Appendix A). The annotations allowed individuals to think about incidences in the video on their own before coming together as a team to discuss similarities and differences in selected timestamps for the annotations. This individual to shared thinking is where cogenerative dialogue occurred. (*N* = 60; 5 annotations per week, 4 people, for 3-weeks)
Group –video of the video club discussion and a copy of each completed recording form. (Appendix A)	RQ1	Video club focused on preservice teachers learning about key aspects of their practice and understanding how to navigate from identified problems in practice to planning modifications for the next week. Video club discussions followed the same structure. The team's collective decisions were documented on this form and coded. (*N* = 2[a] video club discussion videos; 3 video club recording documents)
Synthesis Paper	RQ2	Used to examine preservice teachers explicitly stated value and usefulness of the cogenerative model (co-plan, co-teach, co-reflect) in terms of what they are learning about their teaching and methods for future professional growth. (*N* = 4;1 per person)
Final Video Project	RQ2	Used to examine unsolicited influence of cogenerative model (co-plan, co-teach, co-reflect) embedded in video club, and preservice teachers' thoughts about their future teaching. (*N* = 4, 1 per person)

a Due to technology issues, one video club video was not audible, but we were able to still analyze the discussion recording form for that week.

For the individual annotation data source, the preservice teachers were given five annotation codes to identify in the video segments their group had recorded. These annotation codes are identified on the first page of Appendix A. Their video was uploaded into an online program called VideoAnt (College of Education and Human Development, University of Minnesota, n.d.). As they watched their videos, they could stop and annotate how they thought that moment of the video represented the annotation they were coding for. To analyze these annotation responses, we created an Excel sheet using the annotation codes as the headers and pulled all group members' annotations into one Excel sheet. We created them for three weeks.

Along with everyone's set of comments to the five annotation codes, the first task of the video club (held in the weekly methods class) was to record the video segment, and time stamp for each of the five annotations. The purpose of this was for them to see how many different instances they, as a team, saw instances of the annotation code coming up in their teaching, or to recognize they were coding the same instances. This assisted them with identifying the similarities and differences section (page 2 of Appendix A), which lead to their discussion about modifications for their next week's lesson. Their discussion through the Video club form (Appendix A) and what they wrote on their document, were both added to the weekly excel document according to the annotation code headers. We then were able to apply our same coding scheme to all three data sources (individual codes, video club video and video club discussion form) to answer research questions one and two.

Data Analysis

Before starting the data analysis process, we reviewed the team's lesson plans for each week. Their plans helped provide context about the science ideas they were teaching and the structure of their activities. Additionally, the team listed in their lesson plan what segments of their teaching they wanted recorded for the 45 minutes of video. Together with reviewing the lesson plans and seeing what segments were recorded within the larger plan assisted us with understanding the annotation and video club comments. The lesson plans were not a data source, though, and thus were not coded. In the following sections, we describe the specific procedures used to analyze the data sources aligned with each research question (i.e., Table 1)

RQ1: Individual contributions during co-reflection phase and how they were taken up in co-planning.

Concerning the development of the coding schema applied, we employed a qualitative approach of thematic analysis (Glesne, 2015; Maguire & Delahunt, 2017). We used emergent coding to generate themes from the preservice teachers' annotations of their selected teaching video segments. Coding of the preservice teachers' annotations was done one learning community member at a time. Each coauthor coded the preservice teachers' annotations individually to identify themes that emerged surrounding the preservice teachers' ideas in relation to their teaching practice, identifying problems in their teaching practice. After both coauthors coded an individual, we met to discuss our codes to ensure we came to an agreement in coding and discuss any discrepancies. We identified four thematic codes surrounding their teaching practice based on the preservice teachers' annotations of their selected teaching video segments (see Table 2). It is important to note that the definition of the code is based on the interpretation or explanation for the issue (i.e., the code) the preservice teachers used in their annotation descriptions. To answer research question one, we tabulated the frequency of each thematic code for each week.

Table 2

Data Analysis Codes Applied to Individual Annotations and Video Club Data Sources

Codes	Definition Preservice teachers comments	Data Example From individual annotations
Facilitating Discussions	Teachers asking good questions or needing to ask better questions. Providing more discussion time. Involving students more in discussion and explaining their thinking.	When [the teacher] put the materials in front of the kids, they immediately started thinking of ways that they could build the car with the things they were given. This could be used to inform the types of questions that are asked when we later have a discussion on this activity.
Explicitness of Activity Focus or Learning Goals	Students not providing expected results/ outcomes because they are unsure of expectations/objectives	Although the activities themselves are exciting and engaging for students to do, they also need to be aware of why we are doing these activities. What's the purpose?
Science Content or Terms	Students do not have the science language to apply to their explanations or are incorrectly using	Going through the book and discussing how we use energy in our everyday lives, students are struggling with the term kinetic energy. Prior to this discussion, students participated in activities that used kinetic energy although [it] was never mentioned.
Putting Students' Ideas at the Center	A need for listening more to students first and when they do put the Ss ideas forward first there is more engagement	When [the teacher] asked what the purpose of the boat was this got at the students' ideas and she realized she didn't have to explain the fundamentals of what a boat does.

To examine how each preservice teacher's ideas carried over and contributed to the collaborative video club component of the practicum experience, we viewed both the video club recordings and discussion forms (Appendix A). To track how each instructional modification came to light, we worked backward, starting with the three proposed and agreed upon instructional modifications. For a given instructional modification, we first consulted the video recording of the group's collaborative video club discussion to determine who suggested the instructional modification. Then, we cross-referenced the ideas expressed by the preservice teachers relating to the proposed modification to their code annotations to determine if the modification solely originated from the video club discussion or a preservice teacher's individual video annotations.

RQ 2: Value shared by preservice teachers from experiencing the instructional model for supporting cogenerative dialogue.

We analyzed two data sources to determine how valuable this practicum experience was for each preservice teacher for their teaching development. The first data source was an end of session synthesis paper that posed three questions for the preservice teachers to respond to relating to their collaborative experience and teacher development. The second source was the final video reflection assignment; if the preservice teachers found the practicum experience valuable, then we expected them to mention it here. We analyzed both data sources for each preservice teacher's thoughts relating to this practicum experience and their teaching development.

Findings and Interpretations

We begin with a summary of the themes identified within the individuals' annotation comments, which are also shared in the video club. To address RQ1, we provide an audit trail of which ideas, as noted in the video club discussion as strengths or weaknesses in the prior lesson, the team selects to move forwards in planning for the next lesson. To answer RQ2, we share what each member of this collaborative team states they will take from this experience into their future teaching.

Individual's Contributions and Incorporation into Weekly Modifications

Across the grade 1-2 team, 25 instances of the four distinct themes were coded in the individual preservice teacher annotations. Of the 25 codes, explicitness of activity focus or learning goal was most prevalent (9 of 25), with putting students' ideas at the center (6 of 25) and facilitating discussions (6 of 25) second. Science content or terms was the least coded theme across the four preservice teachers' individual annotations with 4 of 25 instances. There was one combination code of putting students' ideas at the center and science content or terms and this was counted as a separate code from the others, thus establishing a 26th segment of data coded.

Examining the preservice teachers at the individual level more closely, Dorothy's responses in her annotations had five coded instances, and of these, two different codes of the four types were represented. Dorothy's coded comments initially appeared in her discussions during video club, and it was not until Week 3 that her annotation codes identified comments related to the coding scheme. Nellie responded in her annotations with seven comments representing the four distinct codes. She solely had one segment that was given the combined code of putting students' ideas at the center and science content or terms. This double-coded segment occurred because she saw a moment in the video for an opportunity in a future lesson to support content learning by leveraging students' ideas. Six instances with codes were identified for Lisa, representing three out of four codes. The most consistent codes for Lisa were science content or terms (weeks one and two) and explicitness of activity focus or learning goal (weeks two and three). She made a comment associated with the code, putting students' ideas as the center in week one, but nothing related to it after that week. Lastly, Rene received eight coded instances across the 3-weeks in her individual annotations and of these putting students' ideas at the center was consistent across the 3-weeks.

We found that Rene consistently made comments in the video club discussion that made it to the list of modifications each week. However, these comments often originated with Rene, and her teammate Dorothy often synthesized the teammates' comments based on something Rene shared. Therefore, Rene and Dorothy often agreed about modifications to put forward as Rene would initiate the idea and Dorothy would build on it and synthesize the idea for the purpose of recording. This trend in team coding and how the contributions to modifications were raised are illustrated in the audit trails described below.

Audit Trail - Week One

The group recorder for this week was Dorothy. From her synthesis of the first week's video club discussion only one of the three modifications listed related to specific changes in the preservice teachers' pedagogical practice. There were two other modifications associated with establishing classroom norms (i.e., expectations for classroom behavior) and classroom arrangement (e.g., distracting furniture and crowded), but for the purpose of this study we focus our attention on modifications only that specifically have to do with improving methods of instruction to support student learning.

The first modification, 'creating questions to guide learning that go along with our lesson', develops throughout the video club discussion. First, Lisa shares her annotation about an instance of students struggling, in which she wrote:

> *As we are going through the book and discussing how we use energy in our everyday lives, students are struggling with the term kinetic energy. Prior to this discussion, students participated in activities that used kinetic energy although 'kinetic energy' was never mentioned. Dorothy had to prompt them with the first letter, but still students were not making the connection. I think that we responded well to their attempts/guesses but eventually she had to just tell them what it is. If I had to do anything differently, I would place the focus not on identifying the correct term, but rather on the way energy was used. The point of this discussion was for students to brainstorm how they use energy in their everyday lives, so if they were making the connection that energy requires movement, I would be satisfied. I think that this age, the term is less important while the concept of, in this case, energy, is what is important. [Coded Science Content or Terms and Putting Students' Ideas at Center]*

Similarly, Rene annotated the same moment in the video as students are struggling. She writes, "I think that the students are struggling when asked if they remember what kinetic energy is. The reason that I think this is because when they were asked, they didn't say anything and were just kind of looking around or playing with the grass." From her examination of the same video clip, Rene also annotated later in the video a moment as needs improvement with the rationale,

> *It wasn't terrible but maybe it would have been more beneficial to ask the students if they think we can get energy from water. rather than saying "did you know". That way, rather than just telling the students something, we will be able to get their ideas behind that information. Maybe for next week we could have a more detailed list of questions for all portions of the lesson, so we don't forget any of them. [Coded Facilitating Discussions and Putting Students' Ideas at Center]*

Rene brings this latter idea to the video club to discuss with her group. A conversation ensued among the four group members about how each of them agreed with her comment about questioning, as they also recognized moments in the videos from that week that the questions being asked were not necessarily addressing the ideas they were hoping the students would share out. From this discussion, Dorothy, the recorder for the week, summarizes the following comment on the video club discussion form as the rationale for the team to create questions to guide students' learning better. "We all noticed that when it came to our discussion portion, it was difficult to come up with questions on the spot. This made the flow of the lesson somewhat choppy and out of order."

Audit Trail - Week Two

The group recorder for this week was Nellie. From her synthesis of the video club discussion, two of the three modifications related to the preservice teachers' pedagogical practice. This week's third modification was also not pedagogically related but focused on a piece of technology not working correctly. The two modifications associated with teaching included a) providing more constant discussion throughout activities and b) being more explicit with instruction. Concerning the first modification, Nellie, the recorder for this week, summarized that the group "noticed in the video that the students were more invested in the actual activity and now how it related to energy." For the second modification, the reason was given, "some students were not engaged because they did not fully understand what to do. For example, working together on designing the house."

Again, for the first modification about providing more focused discussion throughout the lesson, this idea originated when Lisa shared her video annotation for needing improvement. She wrote,

> *My hope is that students should not think that these stations are simply arts and crafts time where they are creating these exciting things, but there is no purpose behind them. I think this is where teachers should be explicit with their students about the 'why' behind the activities/lesson. [Coded Explicitness of Activity focus or Learning Goal]*

From this idea presented by Lisa, Dorothy bridges the idea to something she annotated from watching the videos with respect to eliciting students' ideas. She referred to something her science methods instructor had shared with them in class about needing to consider asking questions directly (1:1) with students and not always just big class discussion. It was from this notation that Dorothy raised the idea about needing to have smaller discussions throughout an activity to gauge the students thinking more and not just wait to the end. Nellie summarized these ideas together and wrote the modification of more constant discussion throughout activities.

The second modification from the group in week two was the need for more explicit instructions with the activity's goal. This idea originated from Rene's annotation for the students are getting it, which she stated,

> *I feel like the students are starting to get the idea of how exactly to build their house. Before, there were many different ways they could make a house but after Dorothy explained to them that the solar panel goes on top, they knew that they had to make a roof for it. [Coded Explicitness of Activity Focus or Learning Goal]*

In this example, Rene thought her teammate's explanation to the students helped to give the students some direction for how to design things, but she also notes in her discussion with the group during video club that she thought there were still other times throughout the lesson that week that there was some confusion by the students and suggested this with her needs improvement annotation, "Maybe next week we can be more explicit with the directions in order to get them to work in a team/ group." This idea shared by Rene launched a discussion suggesting they agreed with Rene's assessment. In fact, Dorothy notes that she thought it should be added to the modifications list. As the recorder for week two, Nellie summarized the group's discussion by recording, "students were not engaged because they did not fully understand what to do. For example, working together on house."

Audit Trail - Week Three

For the final week, the group recorder was Lisa. From her synthesis of the video club discussion three modifications related to the preservice teachers' pedagogical practice; however, two were very closely related. For reporting purposes, they were combined as one modification associated with pedagogical practice. The two modifications identified for week 3 focused on providing support through modeling and examples of the task for the students (i.e., explicitness of activity focus or learning goal) and improving class discussion by navigating between students' ideas and connecting ideas from students to construct an explanation of the science concept (i.e., facilitating discussions).

It is important to reiterate that these modifications from the third week would not be implemented by this group in a subsequent lesson the following week, as the preservice groups were rearranged, and new teaching groups formed for the second session of the Saturday teaching practicum. These four preservice teachers would not remain together for the second session, they shifted to other grade levels and different topics were the focus of session two. However, this third video club allowed the group to reflect on how the final week of teaching in session one went, and what they may take with them into their next teaching experience.

For the first modification, the group labeled the modification as "preparing a model" and described the reason for this as, "Students seemed to be struggling trying to build their cars to get them to move, so by having a model they would have an example of what to do." From this reasoning it is evident the team believes by the end of the three weeks that explicit instructions about the activity or goal of the lesson is needed to guide students and perhaps this is best solved by the teachers providing the students with a model they can follow.

This modification was initiated with an individual comment made by Nellie, where she stated in her video annotation as a needs improvement, the following,

> *During the majority of this video, the one student is constantly complaining that he is unable to build a car that would work. He is whining and feeling defeated. Although I tried to say things to help and I tried to ask questions to make them think different ways, it was not working. I am not sure what could have been done differently, but it was hard to watch him be so frustrated and not know what more I could have done to help him. [Coded Explicitness of Activity Focus or Learning Goal]*

She then offers the following solution to this problem she is viewing in the video, "Maybe if we have a model of one and showed how it worked to everyone in the beginning, they would have been able to understand more what was expected and some ideas to make the car." When Nellie shared this example in the video club, Dorothy said she supported the idea, too. However, this was not something she noted or wrote about in her own individual video annotations.

The second modification, around improving facilitating discussions, was derived from two different group members individual video annotations. First, associated with the eliciting students' ideas' annotation, Rene noted,

> *I think that the students' ideas were elicited when Dorothy put the materials down in front of the kids, they immediately started thinking of ways that they could build the car with the things they were given. This could be used to inform us of the types of questions that are asked when we later have a discussion on this activity. [Coded Facilitating Discussions]*

On a similar note, Dorothy provided the following needs improvement video annotation based on her viewing of a 4-minute clip where the preservice teachers and students were sitting in a circle discussing what they learned from the car building activity. She said,

> *We still need to manage our time better. Towards the end we ran out of time for the discussion, we also had to rush making and testing the cars. Next time we need to give ourselves more time for each section, so we do not have this issue again. [Coded Facilitating Discussions]*

Lisa summarized the group's discussion around these two comments as needing to manage time better to allow for more in-depth discussions.

Summary of Contributions to Cogenerative Dialogue

Regarding contributions by team members in week three, there was an emphasis on making the activities and goals more explicit for the students. This theme was carried from week two to week three and raised by all group members. Additionally, there was an emphasis in week 3 on facilitating discussions, which was initially raised by Rene but taken up in the video club discussion by Dorothy and Nellie.

Looking across the three weeks, the team focused their comments for modifications mainly on the ideas of facilitating discussions, and through better questioning, but also modeling or providing directions that were more explicit towards the activity focus or learning goal. It is important to note however, that although students' ideas at the center and science content codes did not come through as part of the modifications, they did appear to serve as anchors or reasons for why the preservice teachers should consider modifications to facilitating discussions and explicitness about activity focus and learning goals. For example, in week one, these codes (students' ideas at the center and science content) came through in individual annotations by Nellie, Rene and Lisa. They came through again in week two for Rene and Lisa and in week 3 for Rene and Nellie. Despite these codes not being evident in the descriptions of the modifications for instruction from week to week, it is apparent the preservice teachers noticing of students ideas, comments, and actions in the video associated with these two codes did factor into the group's discussion and were taken up as part of the collective consensus about what modifications to make in the next lesson.

Preservice Teachers Perceived Value of the Experience

This section is focused on the findings related to the second research question. In the synthesis paper data source, three questions were presented to the preservice teachers regarding various aspects of their collaborative experience and how it has influenced their present and future teaching. The end of semester video reflection assignment intentionally did not ask the preservice teachers directly about the components of this video club/collaborative experience. The aim was to see if they valued the experience to some degree on their own that there are aspects of it that they would want to carry into their future teaching. We report on individuals' experiences, sharing what they reported about the co-reflection experience of the video club, and what, if anything they are taking away from this experience to consider for their future teaching (i.e., end of semester video reflection). We conclude with key takeaways from the team.

Dorothy

Dorothy focused on the collective consensus the group discussed from watching the videos to improve their team instruction. Concerning using video as part of the co-reflection process, she noted, "By watching over these videos, we were able to catch those moments that we had missed before and were able to come up with solutions for the next time that we taught." She also noted how peer feedback from watching the same videos provided her with constructive feedback to help her improve on aspects of her own teaching. She explained,

> *Constructive criticism is essential for bettering your teaching practices and strategies...I really appreciated the video club as well as the peer feedback. Videos can help you to see certain flaws in your teaching, but having another set of eyes and ears is very beneficial as well. This way you are expanding on the possibilities of what you could practice and how you can become better. In the future I would love to continue doing these videos and allowing colleagues to watch them and give me any feedback that they may have."*

Dorothy held a positive view towards the video club saying in her final video reflection, "Video clubs are the best thing to ever happen, and I will continue to use something similar in my future teaching." She also reiterated in the video reflection, unprompted, about how she valued receiving feedback from her peers to help develop her teaching.

Nellie

Like Dorothy, Nellie discussed the benefits of video club discussions from the perspective of what it offered them collectively as a team when co-planning and co-teaching. She shared,

> *By watching the videos each week, making the annotations, and then talking about our findings, we were able to find ways to cater more to the students' needs. We were able to recognize where some students struggled as a way to reinforce ideas the next week, and then build off of them.*

Additionally, Nellie found the video club to be a confidence booster. As she explained,

> *when the lessons were hard to teach, it was hard to remember the good things that happened but being able to look for positive moments [in the video] and then talk about it with the group allowed for us to recall that there were a lot of positive moments during the lesson. A lot of the time, we chose different time stamps for the positive moments which was interesting to see and allowed us to be happier with the end results.*

Regarding this last sentence precisely, Nellie noted in response to a couple of the synthesis paper questions that she found it helpful to have everyone view the videos independently and bring their timestamps to share with others. This allowed her to see different perspectives about the annotations and helped her to become a better teacher to see these instances in action in different ways.

In her final video reflection assignment, Nellie expressed a positive view of the video club experience, saying, "discussing strengths and weaknesses with peers helped me to recognize things I didn't notice before, become more confident in myself, and create even better lesson plans.

Lisa

Lisa also expressed the importance of having different perspectives on teaching and pointed to this in her synthesis paper as a positive aspect of the video club experience. For example, in her response to the question about how the weekly video club helped her to recognize, interpret, and address students' thinking she wrote,

> *Our discussions during video clubs allowed each of us the chance to explain our reasoning behind why we chose these moments as positive or whatever category it may be. Although we identified different points, we were still able to agree on what areas we wanted to grow in for the following weeks.*

Furthermore, Lisa explained the value of the cogenerative dialogue for her when she shared,

> *It is difficult for me to reflect on my own teaching because I am too close to the situation, but another teacher would be able to point out different things that I could work on. A video reflection would be helpful if my colleagues cannot observe my teaching because I could take a step back and actually watch myself and point out places that did not go how I expected.*

It is important to note, however, that although she found value in co-reflecting on her practice, she did not necessarily use this information to co-plan and co-teach from week to week. Perhaps she does not see the collaborative approach to co-planning and co-teaching as something accessible to her as a classroom teacher.

Rene

From her synthesis paper, Rene focused her comments on the benefits of peer collaboration in planning and teaching, and what the structure of the video club offered the team concerning doing this work. She stated,

> *If we didn't have the video club then I believe that my group would have somehow come to the consensus that we needed to change something for the classes to run smoother but I don't think we would have gotten to the point that we did. The brainstorming might not have been as thought out with the ways in which we can improve.*

Additionally, in response to the question of what features of the video club she might carry on with into her future teaching, she once again reiterated the importance of talking with others. Clearly, she noted she did not feel watching video of her teaching would be as useful. In her words, "Unless required, I doubt that I will likely use the video route for reflecting on my practices. I feel like the recording of videos would not help as much as talking with others."

When it came to her final video reflection, Rene talked extensively about her team's teaching experience, what they were teaching the students related to the concept of energy, and ow their team shifted from prioritizing definitions to conceptually working with the process of how things move and use energy to move. These ideas follow those she shared in her annotations and the video club discussion about modifications. However, in the video reflection assignment, she does not directly mention this learning from the co-planning, co-teaching, and co-reflection experience.

Overall, the team members valued the opportunity to get different perspectives on the lessons taught by each of them watching and talking about different instances of the same codes. The idea of peer collaboration to improve instruction provided them with different ways to notice student thinking, build their confidence, and provide feedback to each other on their teaching. While the specific features of the video club experience – co-plan, co-teach, and co-reflect – may not have come through in each member's reflections about the experience or their end of semester reflection video, it is apparent that the video club experience did help them with improving their teaching from week to week in the semester. It is uncertain whether a similar structure will be incorporated into their future teaching unless they actively seek it out.

Discussion

Cogenerative dialogues occur when co-teachers discuss teaching and learning issues and collectively generate solutions to any problems (Scantlebury et al., 2008). Evidence from this study shows that the individual annotation component of the co-reflection phase of the instructional model catalyzed to collaboratively identify and co-generate agreed upon modifications to include in the co-planning and co-teaching components for the following week. The video club structure guided the preservice teachers in interpreting the individual annotations they brought to the community for discussion. By first requiring the preservice teachers to compare their timestamps and annotations, group members were able to notice when they agreed on moments, had discrepancies in their annotations that offered different perspectives for consideration, or made similar comments but at different points in the video, giving more evidence about their practice.

Each of the five pedagogical modifications suggested by the team to improve their teaching could be traced back to someone's video annotation and through the video club discussion. The sequenced video club structure of synthesizing individual annotations naturally guided the preservice teachers to identify issues surrounding their teaching and collectively generate solutions to problems in their practice (Scantlebury et al., 2008). Additionally, with the practicum structure allowing the preservice teachers to teach multiple weeks, and oversee all aspects of planning and instruction, the team's cogenerative dialogue also had time to develop; leading to richer and more productive discussions (Siry & Martin, 2014).

Another important finding from this study is how the instructional model for supporting cogenerative dialogue provided an opportunity for equitable contributions from the preservice teachers (Gwyn-Paquette, 2001), not only with identifying issues in their practice but suggestions for modifications to improve practice. Through developing a cogenerative dialogue, the preservice teachers learned to take up the different instances identified by individuals and come to a mutually agreed upon set of 2-3 pedagogical modifications for the next co-planning discussion. Results show that all group members contributed essential ideas about improving teaching at least once across the three-week session. During the discussions, we noticed that some members' ideas were adopted more frequently than others. However, we observed that sometimes other members agreed with their peers' comments because they might have missed a relevant moment in the video, but they still shared the same perspective. Additionally, sometimes members' ideas overlapped, which gave the team more evidence that a teaching issue identified by more than one member needed addressing. These instances helped the team recognize the value of having multiple perspectives watching the videos to identify key areas of strengths and weaknesses in the planning and teaching phases (Barnhart, 2022; Johnson & Cotterman, 2015).

A crucial component of learning to develop a cogenerative dialogue in support of improving practice is that all voices are heard (Scantlebury et al., 2008) and are open to recognizing differences in perspectives about the same teaching moments. The shared sense-making of instances identified in the videos and the negotiating of ideas for modifications observed in this study indicate the equitable opportunity the instructional model provided (Nielsen, 2015). The structure of the co-reflection aspect of the model specifically guided the reflexive process necessary for cogenerative dialogue to lead to change in practice (Siry & Martin, 2014).

Conclusion and Implications

Participation of preservice teachers in cogenerative dialogue within a community of practice requires structured reflection opportunities. Adhering to situating learning theory can support this; preservice teachers can learn together through a shared practicum experience that is iterative over three weeks. For preservice teachers to engage in the professional practice of communicating with other teachers, known as cogenerative dialogue, it must focus on improving an aspect of their development as educators drawn from their own teaching experiences (Siry & Martin, 2014). Lastly, the preservice teachers must be allowed to enact improvements to practice by becoming aware of their tacit decision-making (Darling-Hammond et al., 2019; Johnson & Cotterman, 2015).

We acknowledge that this study was sampled from a single instance of the advanced science education methods course and focused on one specific learning community. This approach was necessary given the richness of data and following the modification origination trail. Future research could expand and investigate the nature and trends developed from the cogenerative dialogue across multiple communities of practice to identify early roadblocks to improvement in preserve teachers' improvement in practice.

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Appendix A

Weekly Video Club Protocol – EXAMPLE

Discussion Set-up

Begin with recording in the table the time stamps selected for each of your individual selections for each of the 5 codes (If you posted a code more than once, just select your favorite to share).

Code Used in Individual Video Watching and Annotation	Video Timestamps (all group members – put initials)
STUDENTS' IDEAS ELICITED and explain how you think this information is being used to inform the instruction in the lesson (or not).	
STUDENTS' ARE STRUGGLING with an idea presented and explain how you know this. What are the students doing to indicate this? Also, share your thoughts on whether or not you think the students' struggles were handled effectively in that moment, and if not, what would you do differently.	
STUDENTS' ARE GETTING IT with an idea presented, and explain how you know this. What are the students in this example doing to indicate this?	
POSITIVE MOMENT you noticed happening in the lesson (and is not one of the moments already listed above) and describe what was going on and explain why you think this was a positive moment.	
NEEDS IMPROVEMENT MOMENT you noticed happening in the lesson (and is not one of the moments already listed above) and describe what was going on and explain why you think this is a moment that to improve on. Provide a suggestion for improving on this for next week.	

CORE OF DISUCSSION

Looking across these collective timestamps for EACH code, are there similar time periods selected for where each code was represented, or were there many different times selected?

- If similar --- why do you think you several of you were drawn to this incidence? Go back and read through what you noted as your annotation and see if you identified similar things.
  - Repeat this discussion for EACH code with similar timestamps selected by team members.
- If there are differences --- why do you think you are selecting different incidences in the lesson for the same code? What are key aspects of EACH selected moment by group members?
  - Are there perhaps similar explanations but different moments recorded in the lesson?
  - Are you interpreting codes differently; thus giving varied explanations for the incidence?

CONCLUSION

From talking through the different coded segments in the videos, and understanding both similar and different explanations for these selections, what have you learned from watching your unit TOGETHER as a team and what are you thinking about adding/modifying to your instruction next week?

- List 2-3 modifications you'll be doing in the table below AND state your reason(s) for it, meaning what in the discussion today is motivating you to make this modification your team's planning for next week?

Modification	From your discussion, what is the reason for the modification?

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The Effect of K-12 Engineering Education Focused Professional Development Program on Science Teachers' Teaching Engineering Self-Efficacy*

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Abstract

The study aims to investigate the influence of the online professional development (PD) program focused on pre-college engineering education on science teachers' teaching engineering self-efficacy. A nested mixed research design was employed to conduct the study, in which the basic qualitative design was integrated into a weak experimental design and data collection was interrelated. The quantitative dimension of the study utilized the engineering teaching self-efficacy scale, while the qualitative dimension utilized the teachers' reflections as a data collection instrument. Fourteen science educators were selected through purposive random sampling in a province in the Black Sea region of Türkiye. The study's results suggested that the self-efficacy of science teachers in teaching engineering was significantly enhanced by the PD program, which focused on engineering education. The qualitative results were consistent with the quantitative results. Considering the study's results, practitioners and researchers were provided with suggestions for future research in the field of teacher education or PD programs.

Keywords:

Science Teachers, Professional Development, Pre-College, Teaching Engineering, Self-Efficacy.

Introduction

The industry 5.0 revolution, which we are currently in the process of transitioning, and which offers great hope for sustainable living, has given rise to Society 5.0. In the context of this social revolution, which prioritizes human well-being, it is crucial and necessity to provide individuals with the necessary knowledge and skills to develop state-of-the-art technologies that strengthen human-machine collaboration. In the present day, it is crucial to adopt a multidisciplinary approach to education, particularly in fields like multi-criteria decision-making, optimization, soft skills (such as leadership, teamwork, and communication), and human-machine interaction. These abilities are necessary for resolving intricate issues. Put simply, the modern form of engineering education acts as a connection between many fields of study, ranging from the natural sciences to the social sciences. Its primary function is to produce people who possess the necessary skills and knowledge to meet today's requirements. Therefore, we view the integration of contemporary engineering education methods across various educational domains, from early childhood education to professional development (PD), as a crucial prerequisite for national progress.

Many countries have designed their curricula to educate individuals who are well-suited to the demands of the current era. In particular, they have developed curriculum contents that embrace an interdisciplinary approach, especially in the field of science education (National Academy of Engineering and National Research Council [NAE and NRC], 2009; NRC, 2010). The K–12 science curriculum in the US has specifically included engineering and engineering design standards in the Next Generation Science Standards (NGSS) at both the national level and in various states such as Massachusetts, Maine, and Oregon. In addition, the International Technology and Engineering Educators Association (ITEEA) has proposed standards for improving students' technology and engineering literacy. These standards include engineering knowledge, practices, and abilities. Therefore, ITEEA (2020) urged K–12 engineering educators to prepare in accordance with the requirements. Engineering may act as a connection for children in the K–12 education system to comprehend the concepts of mathematics and science (Moore et al., 2014). Engineering may specifically address the shortcomings in STEM education effectiveness and provide the foundation for the enhancement of more robust analytical abilities (Purzer & Shelley, 2018). The Turkish Ministry of National Education included engineering in both its proposed scientific curriculum (MNE, 2024) and its previous science curriculum (MNE, 2018), mandating students to approach challenges from an interdisciplinary standpoint. The growing significance and need for educational research in this domain have led to the inclusion of engineering in the scientific curriculum at both national and international levels.

Teacher self-efficacy in engineering impacts the knowledge and abilities of students in engineering practices. PD refers to a kind of learning that provides teachers with the chance to enhance their understanding of subject matter and teaching methods. By modifying their teaching practices, PD aims to have a beneficial impact on student achievements (Supovitz & Turner, 2000). In the academic field, there is a significant trend toward providing specialized training for teachers who are already working to incorporate engineering principles into their teaching. One such program is Engineering is Elementary (EiE), which is now undergoing national expansion in the United States. The Boston Museum of Science offers EiE PD programs to assist teachers in enhancing their comprehension of engineering ideas, skills, and pedagogy (Diefes-Dux, 2014). Another organization dedicated to integrating engineering and engineering thinking into K–12 education is INSPIRE (the Institute for Pre-College Engineering Education). In 2006, Purdue University in the United States was founded. INSPIRE offers a comprehensive PD program that includes a week-long in-person workshop, online feedback for communities of learners, and support for individual teacher performance (Liu et al., 2009). Similarly, researchers have identified several STEM PD initiatives that incorporate engineering, targeting K–12 teachers (Gunning, 2021), secondary teachers (Custer & Daugherty, 2009; Singer et al., 2016), and classroom teachers (Ceran, 2021).

Teachers have a crucial role in facilitating change in their schools. From this standpoint, enhancing the professional growth of teachers in engineering is crucial for bolstering the implementation of engineering in K–12 environments. Furthermore, if teachers' attitudes toward practices are not sufficiently favorable, they are reluctant to embrace innovations or modifications in their teaching methodologies. Webb (2015) also recognized two significant obstacles that hinder the achievement of pre-college engineering education. One factor contributing to the problem is the teachers' insufficient acquisition of topic knowledge and pedagogical abilities. Second factor is the teachers' lack of self-efficacy in their ability to effectively teach engineering.

Engineering teachers' self-efficacy is a significant notion that influences their teaching actions. Bandura (1997) posited that self-efficacy has an impact on individuals' cognitive processes, emotional states, self-driven actions, and behavioral patterns. Teachers' self-efficacy beliefs have a direct impact on classroom practices, as stated by Boriack (2013). Several studies in the literature indicate that teachers who possess a strong sense of teaching self-efficacy are more inclined to experiment with various teaching methods while also being more prone to implementing and sustaining successful tactics (Allinder, 1994; Bruce et al., 2010; Guo et al., 2012). Furthermore, a strong sense of teacher self-efficacy facilitates teachers' active and purposeful engagement in educational endeavors, thereby improving the overall quality of education and students' academic progress (Gündüz-Özsoy, 2017).

Self-efficacy in teaching engineering is critical to teachers' education (Hynes, 2009). Yoon et al. (2014: 464) describe engineering teaching self-efficacy as "a teacher's personal belief in their capacity to have a positive impact on students' engineering learning." Although teacher self-efficacy is a notion that is resistant to alteration, it might be beneficial for teachers to enhance their teaching efficacy in teaching engineering ideas by actively engaging in engineering activities (Ivey et al., 2016).

Comprehensive research is crucial in order to guarantee that educators are proficient in this field, as it has a direct impact on the manner in which they instruct students in the field of engineering. Many studies have investigated the self-efficacy beliefs of teachers in engineering education. These studies include the works of Hammack (2016), Ivey et al. (2016), Marquis (2015), Sibuma et al. (2018), Yoon et al. (2012, 2014), and Webb (2015). For instance, Webb (2015) found that participating in PD programs for engineering education resulted in an enhancement in teachers' self-efficacy in their ability to teach engineering. Webb also found that the rise in teachers' self-efficacy was primarily due to their mastery experiences and the development of a growth mindset through the adoption of the engineering design process. According to Marquis (2015), three primary school teachers who taught 5th grade and used a LEGO Education renewable energy curriculum experienced an increase in their self-efficacy in teaching engineering. They specifically observed this improvement in the presentation aspect of the teaching module and their knowledge of engineering pedagogy. Similarly, Utley et al. (2019) found that engineering PD had a positive impact on classroom teachers' engineering knowledge and increased their self-efficacy in teaching engineering ideas. Unlike the findings in the literature, Hammack (2016) discovered that 542 K–5 elementary science teachers lacked the necessary readiness to incorporate engineering into their classrooms. They exhibited low pedagogical content knowledge and self-efficacy in teaching engineering, had limited understanding of engineering and engineering design, and faced inadequate opportunities, materials, training, and time to enhance their ability to teach engineering.

In his model of a PD program, Desimone (2009) used Bandura's (1977, 1982) socio-cognitive theory. According to Desimone, a PD program that incorporates six essential elements (content knowledge, active learning, coherence, duration, and collective participation) has the potential to enhance teachers' knowledge and skills. This, in turn, can indirectly impact teachers' teaching self-efficacy, ultimately leading to improvements in their teaching practices and student learning outcomes. There is a scarcity of research in the existing body of literature that investigates the self-efficacy and belief of teachers in their ability to teach engineering (Hammack, 2016; Ivey et al., 2016; Marquis, 2015; Sibuma et al., 2018; Utley et al., 2019; Vessel, 2011; Yoon et al., 2012, 2014; Webb, 2015). While there are several teacher PD programs available for engineering, such as The Infinity Project, EiE, and INSPIRE, as well as various studies conducted by Boots (2013), Daugherty (2010), Guzey et al. (2014), Liu et al. (2009), Reimers et al. (2015), and Webb (2015), we have not come across any online PD study specifically focused on K–12 engineering education for science teachers to examine their self-efficacy in teaching engineering. The study aims to enhance science teachers' engineering teaching self-efficacy (TES) and improve their teaching behaviors in the classroom through the implementation of an online PD program. Additionally, we anticipate that these teachers will successfully integrate engineering education practices into their classrooms, fostering meaningful and sustainable learning for their students.

Furthermore, by examining the impact of the online teacher PD program on science teachers' engineering teaching self-efficacy, we aim to provide valuable insights for researchers, practitioners, school administrators, and policymakers doing future studies in this field. Specifically, our goal is to ensure that the outcomes benefit teachers in both rural and urban settings, enabling them to access and learn from the teaching approaches shown on our website. The goal of this research was to examine the impact of an online teacher PD program that specifically focuses on engineering education on the self-perceived ability of science teachers to teach engineering. The following problem statements were addressed:

- Is there a statistically significant difference between the pre-test and post-test scores of the Teaching Engineering Self-Efficacy Scale (TESS) of science teachers who participated in the online PD program focused on K-12 engineering education?
- How is the engineering teaching self-efficacy of teachers with different developmental levels during the PD program?

Method

Research Model

The study is a "nested mixed research design," using both quantitative and qualitative methods (Creswell & Plano-Clark, 2011). We used the quantitative method to examine the impact of the engineering education-focused teacher PD program on their engineering teaching self-efficacy, and the qualitative method to elicit how this development unfolded throughout the process. The "One Group Pre-Test and Post-Test Design" (Fraenkel et al., 2012) integrated the basic qualitative design as one of its weak experimental methods.

The qualitative dimension of the study employed a basic qualitative approach, as described by Merriam (1998). In this study, the impact levels (low, high, etc.) of the K–12 engineering education focused PD program on teachers' engineering teaching self-efficacy beliefs were each depicted in depth, the process was described, and the results obtained were compared with each other.

Participants

The participants were service science teachers employed in a province located on the Black Sea coast of Türkiye during the academic year 2022-2023. We used one of the mixed sampling methods, the purposive random sampling technique (Teddlie & Tashakkori, 2009). The sampling method considered the following criteria to obtain detailed information from a small and carefully selected sample:

- Working range 5th to 8th grade as a science teacher,
- Having completed the Volunteer Participation Form,
- Having answered the Engineering Teaching Self-Efficacy Scale,
- Having available classrooms for the engineering education practices, since teachers will carry out practices with students for at least two class hours within the scope of the study and
- Being highly motivated to actively participate in the research.

The purposive sampling method included eighteen science teachers who met the above criteria in the study group (Patton, 2002). However, four teachers left the study at the start of the PD program, leaving a total of fourteen teachers for the experimental design. Using the maximum diversity sampling method, we selected the study group for the qualitative dimension of the research from the teachers who participated in the PD program. Using this method, we formed three distinct clusters from the experimental design results, then selected teachers from each cluster to compare and interpret their qualitative findings. Thus, we addressed the research problem by framing it within a more comprehensive framework, highlighting the similarities and differences among the teachers chosen from various groups.

Instruments

Teaching Engineering Self-Efficacy Scale (TESS): The Teaching Engineering Self-Efficacy Scale (TESS), developed by Yoon et al. (2012, 2014), is known in the literature as the first valid and reliable scale to measure US K–12 teachers' self-efficacy in teaching engineering (Hammack, 2016; Ivey et al., 2016). The TESS has a six-point Likert scale ranging from strongly disagree (1 point) to strongly agree (6 points), for a total of twenty-three items. Additionally, the scale includes a total of four sub-dimensions: a) Engineering Pedagogical Content Knowledge; b) Engineering Engagement Self-Efficacy; c) Engineering Disciplinary Self-Efficacy; and d) Engineering Outcome Expectancy (Table 1).

In 2019, Demirci (2022) conducted the adaptation of TESS into Turkish with the data obtained from a total of four hundred forty-six teachers, two hundred eighty-one (63%) science teachers, and one hundred sixty-five (37%) technology and design teachers working in forty-eight different provinces across Türkiye.

Table 1
Teaching Engineering Self-Efficacy Scale

Scale and Subscale	Definition of Subscale	Cronbach α
Engineering Pedagogical Content Knowledge	Teachers' personal belief in their ability to teach engineering to facilitate student learning, based on knowledge of engineering that will be useful in a teaching context.	0.96
Engineering Engagement Self-efficacy	Teachers' personal belief in their ability to engage students while teaching engineering.	0.93
Engineering Disciplinary Self-efficacy	Teachers' personal belief in their ability to cope with a wide range of student behaviors during engineering activities.	0.92
Engineering Outcome Expectancy	Teachers' personal belief in the effect of teaching on student learning of engineering.	0.89
Teaching Engineering Self-efficacy	Teachers' personal belief in their ability to positively affect students' learning of engineering that reflects the multifaceted nature of self-efficacy of teaching engineering.	0.98

Written Reflection: The reflections were texts collected during the PD program to obtain in-depth information on teachers' efficacy beliefs in teaching engineering. We asked teachers to complete reflection on the PD website three times: at the start of the program, during its duration, and at its conclusion. We asked the teachers to assess their "belief in competence for teaching engineering" based on the following five competency dimensions: 1) implementing the activities effectively in the classroom; 2) dealing with possible difficulties that your students may encounter; 3) preparing course materials related to the subject, 4) achieving the targeted student products; and 5) assessing and evaluating them.

Data Collection Process and Implementation

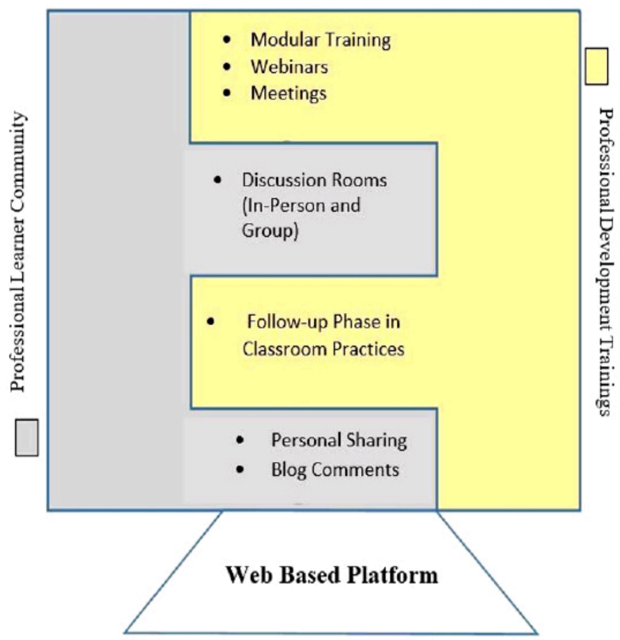
Pilot Study

The pilot study, which tested the applicability of the PD program, data collection tools, and research protocol, involved seven randomly selected science teachers. The pilot study concluded that the teachers could respond to the developed training modules and data collection tools, such as the scale and reflection. We also incorporated a feature in all the PD program's content documents, enabling teachers to acquire tangible copies of the materials. We created video recordings to accommodate teachers who couldn't attend the meetings. Furthermore, we re-planned the content presentation for the actual implementation to span five weeks, taking into account that a shorter and more concise PD program positively impacted teachers' motivation. The technical failure in the PD program's second stage, which involved the professional learner community, necessitated the creation of a backup platform to mitigate potential technical issues during the actual implementation phase. Therefore, we backed up all content of the PD program and implemented the necessary measures.

Main Study

Figure 1

The Visualization of Online K–12 Engineering Education-Focused PD Program



The online PD program's website consisted of two parts: a) PD training; and b) professional learner community (Figure 1). The overall goal of the first phase of the PD program, PD training, was to provide science teachers with a variety of resources on the web platform to improve their engineering teaching self-efficacy and enable them to communicate with experts. Under the guidance of experts, we presented some best practices in engineering teaching and encouraged teachers to share their classroom experiences with their colleagues. Additionally, they presented a progressive training module that explains how teachers can use engineering as a context for science subjects, prepare lesson plans, assess, and evaluate students' learning outcomes, and conduct virtual meetings to provide information on integrating and teaching engineering in science subjects.

The second phase of the PD program, the professional learner community, was a platform for teachers to come together to reflect on what they had learned in the training sessions, how to implement the training in the classrooms, their classroom experiences, and the materials they used. During this phase, the program encouraged teachers to share their experiences of implementing engineering-integrated lesson plans that benefit students. Figure 2 presents an example of this practice. The platform also provided discussion rooms where teachers could consult with experts and colleagues about issues and challenges, they had faced in their classroom practice. Table 2 presented the contents of the PD program, and the following section presented the contents of the modular training.

Table 2

The program focuses on K–12 engineering education and includes an online PD process and content.

Week	Content Title
1	Ethics Committee Approval and MNE Application Permission
2	Pre-Test (TESS)
3	Module 1, 2 and 3
4	Classroom Implementation Development of Individual Lesson Plans Collaboration with Colleagues
5	Classroom Implementation Development of Individual Lesson Plans Collaboration with Colleagues Reflection
6	Development of Lesson Plans Collaboration with Colleagues Reflection
7	Post-Test (TESS) Reflection Giving Incentives and Closing (Attendance Certificate and Virtual Gift Card)

Module 1:

- Details about the program's content
- Why teach engineering in K–12?
- The importance and necessity of K–12 engineering education
- Engineering discipline, nature, concepts, and skills
- Engineering professions
- Framework for quality K–12 engineering education
- The engineering design process
- Example lesson plans for engineering integration

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Module 2:

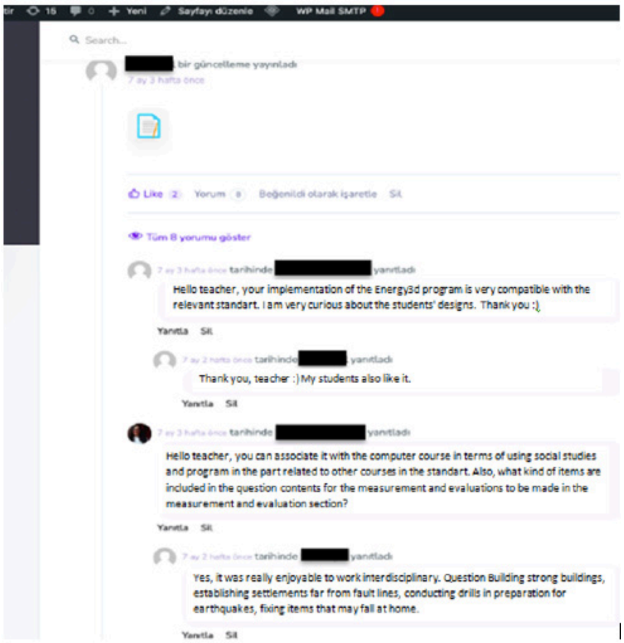
- The relationship between science and engineering
- Engineering integration in science education
- The US's national and various states' engineering standards
- Türkiye's curriculums containing the engineering standards
- Context-based engineering education
- Teaching strategies in engineering
- Measurement and evaluation in engineering
- Digital tools for engineering integration

Module 3:

- Computer-Aided Design (Energy3d) program

Figure 2

An Example of Teachers' Collaboration with the Professional Learning Community



In the PD program, Bandura's (1997) four sources of self-efficacy were considered to enhance teachers' self-efficacy in engineering teaching. Therefore, we aimed to improve:

- Mastery experiences by implementing an engineering-integrated activities in teachers' classrooms.

- Vicarious experience by sharing teachers' successful experiences with colleagues in the professional learner community where they had implemented similar engineering instruction, as well as by experts sharing their own successful experiences.

- Verbal persuasion by sharing example lesson plans with teachers during PD training and by providing encouragement, and support through information sharing during meetings.

- Psychological and affective states by setting up the supportive environment to support teachers' physiological and emotional well-being by reducing stress and anxiety.

Data Analysis

For quantitative data, we used the paired sample t-test because the pre-test and post-test data from TESS met the parametric test assumptions (Can, 2014). Additionally, when the quantitative analysis revealed a statistically significant difference between the groups, we calculated the effect size (d) to understand the magnitude of this effect. We interpreted the effect level as very high if the effect size (d) value exceeded 1.0 (Morgan, 2004). The study adopted a significance level (p) of 0.05.

Additionally, we calculated normalized gains (g) using Hake's (1998) formula, as well as the pre-test and post-test mean scores from the TESS, as follows:

g = (post-test - pre-test) / (100 - pre-test)

We evaluated teachers' teaching engineering self-efficacy (TES) levels by taking the average score from the entire twenty-three-item scale into account. The TESS allows for a minimum score of 1 point and a maximum score of 6 points. Additionally, we classified the gain values from TESS as "low" for scores between 1.00 and 2.66, "medium" for scores between 2.67 and 4.33, and "high" for scores between 4.34-6.00.

This study employed the K-means clustering analysis method, a non-hierarchical method. We analyzed the qualitative data of three teachers selected through the clustering analysis process. We used descriptive analysis to analyze the qualitative data obtained from teacher reflections. Descriptive analysis consists of four stages: a) creating a framework for descriptive analysis; b) processing the data according to the thematic framework; c) describing the findings; and d) interpreting the findings (Yıldırım & Şimşek, 2013). When necessary, we enriched these findings by providing direct quotations from the reflection statements. We presented the teachers' reflections using their pseudonyms (Alice, Brenda, and Casey) and abbreviated source titles (for example, A-R1: [A]lice Teacher-[R]eflection[1]st Reflection).

Findings

Quantitative Findings

We used the paired samples t-test to address the first problem statement, "Is there a statistically significant difference between the pre-test and post-test scores of the Teaching Engineering Self-Efficacy Scale (TESS) of science teachers who participated in the online PD program focused on K-12 engineering education?" The results are presented in Table 4. Table 3 presents the descriptive analysis statistics of the study group.

Table 3
Descriptive Analysis Results

TESS	*M*	Minimum	Maximum	*SD*
Pre-Test	4.48	2.95	5.74	2.83
Post-Test	5.82	4.91	5.95	1.05

*: n=14

Table 4
Paired Samples T-Test for TESS

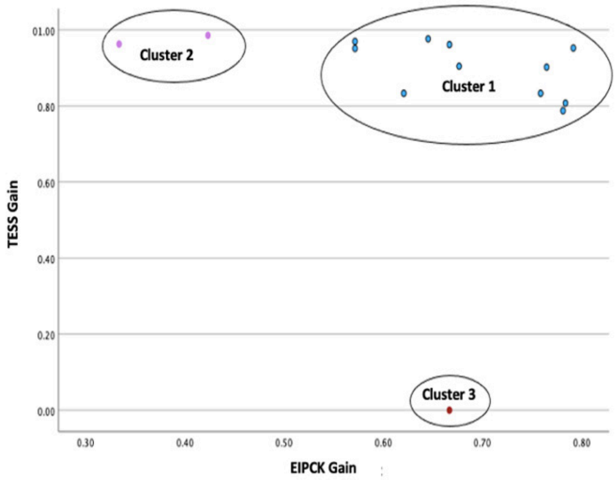
Test	*M*	*Sd*	*df*	*t*	*p***	*d****
TESS	1.33	0.83	13	6.05	0.00	1.62

*: n=14, **: p<0.05, ***: d = t/n

As shown in Tables 3 and Table 4, the t-test result shows that there was a statistically significant difference between the pre-test (M = 4.48, SD = 2.83) and post-test mean scores (M = 5.82, SD = 1.05) obtained from the TESS in favor of the post-test ($t_{(13)}$ =6.05, p = 0.00). In addition, the effect size illustrated that this difference was at a very high level (d = 1.62) (Morgan, 2004).

Furthermore, K-means cluster analysis was used to determine the membership of each teacher in the clusters. K-means cluster analysis (Anderberg's center of gravity ranking method) allows the selection of several clusters by making meaningful groupings (Aldenderfer & Blashfield, 1984). Three groups were identified as a result of the cluster analysis. To verify these independent groupings, an analysis of variance (ANOVA) was used to examine the differences between the clusters. Additionally, the clusters were independent for both dependent variables[1] (F = 12.03, p < 0.05). The findings of the clustering analysis were presented in Figure 3.

Figure 3
Scatter Plot of Teachers' Development Gains



Qualitative Findings

In order to address the second problem statement, "How are the engineering teaching self-efficacy of teachers with different developmental levels during the professional development program implemented?" descriptive analysis was used for qualitative data. The findings are presented in three subtitles below.

Qualitative Findings of Teacher Alice

At the end of each week of the PD program, Alice evaluated her competence in teaching engineering and presented her reflections in the categories of coping with challenges, preparing course materials, learning outcomes, and assessment and evaluation.

While evaluating her competence regarding the process of implementing the activities in the classroom, the teacher made statements showing that her level of self-efficacy gradually increased. For example, in her first reflection on implementing the activities in the classroom, the teacher wrote "I can sometimes, but not always" in the next reflection she wrote "quite adequate" and in the last reflection she wrote "extremely effective".

> *A-R1: "I can apply the activities in my class sometimes, but not always. Most of the time I can cope with the possible difficulties my students may face."*

> *A-R2: "As a result of the knowledge I have gained so far, I find myself very competent for teaching engineering."*

> *A-R3: "I can implement the activities in my classroom in a very effective and efficient way."*

In addition, towards the end of the professional development program, Alice found herself more and more competent in preparing lesson materials appropriate to the teaching outcomes and in assessing and evaluating them. For example, in the teacher's first reflection on the preparation of course materials, she wrote: "By using these activities, I can achieve most of the student products I aim for. I can measure and evaluate them." This statement can be interpreted as a statement indicating that she preferred to use ready-made course materials rather than developing them herself. In the teacher's next reflection, with the statement "I can prepare course materials and measure and evaluate them." it is understood that she can prepare the course materials herself and evaluate the student products. In the teacher's last reflection on this subject, she wrote: "I can prepare and produce course materials in the most perfect way. I can measure and evaluate them properly." This shows that the teacher's opinion about her own competence was quite high. In particular, we observed that she provided detailed explanations related to the curriculum in the last statement, with a focus on ensuring student outcomes.

In general, when Alice's reflections written on a modular basis were examined, it was seen that she found herself more competent in engineering teaching towards the end of the professional development program. All these qualitative findings were consistent with the findings that were classified the levels of teacher's teaching engineering self-efficacy which were medium for pre-test (*M:* 4.17) and high for post-test (*M:* 5.91), with a gain rate high (95%).

Qualitative Findings of Teacher Brenda

Brenda's reflections, in which she evaluated her competence in teaching engineering at the end of each week of the professional development program, were presented in the categories of learning outcomes, coping with challenges, and assessment and evaluation.

When the teacher's reflections were examined, it was seen that she found herself competent to play an effective role on the problem-solving skills of her students through engineering teaching practices. Her opinion on her competence was expressed at a similar level in general.

> *B-R1: "With my students, we can design models to solve a problem we have defined about the environment."*

> *B-R2: "By defining a problem with my students, we can develop models to solve the problem. If the model we develop does not solve the problem, we can make a new design."*

> *B-R3: "Engineering activities make students aware of life problems that they may encounter in daily life."*

Furthermore, in Brenda's third reflection paper, she also addressed the challenges of implementing engineering integrated activities:

> *B-R3: "In line with my lesson plans, I can also deal with possible difficulties while applying engineering activities in my lessons. For example, when designing a high-speed train related to magnets, I first let my students who have never been interested in high-speed trains watch videos on the internet. I can do these activities with my students using all kinds of materials."*

Unlike her previous reflections, findings from Brenda's final reflection showed that she would be able to apply engineering activities effectively in the classroom for meaningful learning for her students. In addition, in her final reflection, she explained in detail that she could deal with various difficulties in terms of cognitive learning difficulties (low interest in the subject and lack of prior knowledge) and supplying teaching materials.

Finally, it was also seen that the teacher provided detailed explanations about how to measure the student outcomes she aimed to provide to the students.

> *B-R3: "I can evaluate the engineering activities I implement in my class by using appropriate assessment and evaluation tools. For example, I can measure the transportation vehicle we designed with magnets using the project rubric."*

Brenda's modular reflections indicated that she became more competent in teaching engineering as she progressed through the professional development program. It can be said that in the qualitative findings, the teacher found herself competent with detailed explanations especially in her last reflection. All these qualitative findings were consistent with the findings that were classified the levels of teacher's teaching engineering self-efficacy which were medium for pre-test (*M:* 2.95) and high for post-test (*M:* 5.95), with a high gain rate (99%).

Qualitative Findings of Teacher Casey

Casey's reflections, in which she evaluated her competence in engineering teaching at the end of each week of the professional development program, were presented in the categories of learning outcomes, preparation of course materials and assessment and evaluation.

Finding of the teacher's reflections showed that she found herself competent in terms of playing an effective role in her students' problem solving and creative thinking skills through engineering teaching practices, and she evaluated this competence at a similar level in each reflection.

> *C-R1: "I can teach my students the steps to follow in finding solutions to the problems they face in daily life."*

> *C-R2: "I can encourage students to think creatively in order to achieve the targeted student outcomes."*

> *C-R3: "I can help students deal with real-world problems from a scientific and mathematical perspective."*

Additionally, Casey stated that she found herself generally competent in preparing the course materials. In the teacher's second reflection, she mentioned possible difficulties in supplying the materials, while in her last reflection, she stated that she found herself competent in how to overcome this difficulty.

When Casey's weekly reflections were analyzed, it was seen that she generally argued that she would take into account the existing deliverables related to measurement and evaluation. Especially in her last reflection, the statement "I would use preferred assessment tools" was another finding indicating that her knowledge of the assessment tools used in engineering education had increased during professional development.

In general, Casey's reflections written on a modular basis demonstrated that she found herself similarly competent in engineering teaching throughout the professional development program. All these qualitative findings showed to be consistent with the findings that were classified the levels of teacher's teaching engineering self-efficacy which were high for both pre-test (*M:* 4.91) and post-test (*M:* 4.91), with no gain (0%).

Discussion and Conclusion

A teacher's actual teaching methods can be influenced by personal beliefs about their capacity to teach engineering effectively (Parker et al., 2020; Yeşilyurt et al., 2021). Since teacher self-efficacy is a critical belief component that influences teacher behavior and student outcomes, it is imperative to enhance the effectiveness of pre-college engineering education by increasing the self-efficacy of teachers in teaching engineering (Epstein & Willhite, 2017; Kelley et al., 2020; Menon et al., 2024). According to the quantitative results of the study, teachers' engineering teaching self-efficacy (TES) was enhanced by the online professional development program that concentrated on K-12 engineering education. This result is in accordance with the results of prior professional development studies on engineering integration (Crawford et al., 2021; Ficklin et al., 2020; Kouo et al., 2023; Marquis, 2015; Parker et al., 2020; Rich et al., 2017; Utley et al., 2019; Webb, 2015). For instance, Kouo and colleagues discovered that teachers demonstrated a higher level of assurance in their capacity to instruct engineering activities during a professional development program that was specifically tailored to K-12 engineering education. Crawford et al. (2021) also determined that teachers demonstrated substantial increases in self-efficacy after the completion of the professional development course, as evaluated by the Engineering Teaching Self-Efficacy Scale. Ficklin et al. (2020) discovered that the self-efficacy of K-5 teachers teaching engineering was influence positively by professional development for elementary school teachers in a rural school in southeastern North Carolina. Nevertheless, the study conducted by Sibuma et al. (2018)'s pilot study determined that pre-college teachers' self-efficacy was not enhanced by in-service training on STEM education. This different finding in the literature may be attributable to the fact that all teachers take short (2-2.5 hours) professional development sessions. Moreover, professional development activities, including follow-up sessions, coaching, and mentoring, have the potential to enhance the self-efficacy of teachers (Boriack, 2013). The online teacher professional development program was developed in accordance with four variables that Bandura (1997) posits influence self-efficacy: a) mastery experiences, b) vicarious experiences, c) verbal persuasion, and d) psychological and affective state. Teachers' contribution to classroom practice may have facilitated the acquisition of mastery experience. The acquisition of vicarious experience may have been influenced by participation in professional learner communities and observation of colleagues' practice. Focused support and feedback for the development of verbal persuasion may have provided through the sharing of expert leadership content, counseling and encouragement by colleagues. Furthermore, the supportive environment in the professional development process may have helped to improve teachers' physiological and emotional well-being by reducing stress and anxiety.

The professional development program has the dual purpose of improving the self-efficacy of teachers and improving their engineering integration pedagogical content knowledge (EIPCK). The development of teachers in engineering education can be directly correlated with their positive development in EIPCK. Teachers' active participation in the online professional development program and their improved understanding of how to integrate engineering concepts into their instruction may have contributed to an increased sense of preparedness and, as a result, self-efficacy in their capabilities. Additionally, researchers have suggested that the designing in science courses improved personal teaching self-efficacy (Cantrell et al., 2023). The lesson plans that teachers developed during the professional development process may have contributed to their increased self-efficacy.

The purpose of this study was to assess the self-efficacy of engineering educators in engineering education by analyzing their reflections at the initial, midpoint, and final stages of the professional development program. The quantitative research results indicate that educators who attained high scores on the engineering teaching self-efficacy scale were able to improve their capabilities through professional development through self-reflection. We interpret that the study's written reflection may have helped them build their self-efficacy by getting them to think about how they teach and how they think about their own thoughts. To be more precise, educators who reported high levels of engineering teaching self-efficacy development (moderate before implementation, high after) were more likely to report feeling competent when faced with challenges, assisting students in their cognitive development, and evaluating the quality of student work. The engineering self-efficacy of teachers can be improved through positive reinforcement and exposure to shared techniques in professional learner communities (Crawford et al., 2021; Gunning et al., 2024). The professional development program may have facilitated the sharing of the experiences and instructional materials of teachers among colleagues, thereby enhancing their capacity to address the challenges of engineering education more effectively.

The purpose of the written reflections was to determine the extent to which science educators were capable of teaching engineering self-efficacy during the professional development program. We determined that the teachers' reflections supported the quantitative results. Teachers' proficiency in the preparation of lesson materials and the execution of engineering activities in the classroom had improved by the end of the professional development program. This dimension of self-efficacy is theoretically significant, as teachers who have achieved high levels of TES reported feeling highly competent in overcoming the challenges they would face in the classroom. In addition, we conducted an analysis of the explanations provided by teachers in their reflections regarding their perceived efficacy in overcoming the learning challenges of their students. This is another substantial piece of evidence that illustrates the high level of self-efficacy that educators in the field of engineering education possess. These results are consistent with those of previous research. Numerous studies have shown that educators who have high levels of teaching self-efficacy are more likely to maintain and enhance effective strategies and are less inclined to experiment with novel teaching methods (Allinder, 1994; Bruce et al., 2010; Guo et al., 2012). In addition, educators who exhibit high levels of teaching self-efficacy are more likely to establish objectives that are more straightforward, avoid difficult assignments (Gökdağ-Baltaoğlu & Güven, 2019), and exhibit inadequate effort and forbearance when faced with obstacles and threats (Bruce et al., 2010).

Furthermore, educators who demonstrate a strong sense of self-efficacy are more likely to be self-efficacious in their capacity to effectively engage students in the comprehension of engineering principles and the problem-solving process (Menon et al., 2024). The responses of all teachers indicated that they were confident in their ability to develop the inventive thinking and problem-solving abilities of their students. This discovery is in accordance with Bandura's (1997) assertion that the cognitive abilities of students are substantially influenced by the belief of teachers in their capacity to teach effectively. It also supports the idea that the self-efficacy of teachers in engineering education can be improved through professional development.

A sub-dimension of engineering teaching self-efficacy is the teacher's capacity to implement a variety of assessment strategies (Demirci, 2022; Yoon et al., 2012, 2014). Within the context of engineering education, this research revealed that teachers' perspectives on assessing student work vary. Teachers who have invested more time and energy in their TES careers have more concrete ideas about what and how to assess, whereas those who have invested less time and energy in the field have said that they are open to trying new approaches. Additionally, Allinder (1994) asserted that educators are considerably more inclined to experiment with alternative instructional methodologies. This finding demonstrates that teachers' self-efficacy in their abilities to acquire student goods and evaluate and analyze them grew as a consequence of reflective writing that included thorough explanations. The teachers' self-efficacy in this regard may have been enhanced by the fact that they expanded their knowledge of the materials to be used in the assessment and evaluation of student products in engineering education and shared the materials with their colleagues in the community of professional learners by collaborating with the professor in engineering education.

Limitations and Future Studies

Several recommendations for future research can be made by addressing the limitations of this study. Firstly, the research was restricted in its ability to acquire data through classroom observations due to the fact that it was conducted through an online professional development program. The observation method can be employed to acquire comprehensive information regarding the self-efficacy of engineering teachers in their teaching. A way to address this limitation in the future would be implementing qualitative methodologies to evaluate teachers' interactions with peers or experts in the online professional learner community based on the data collected from the website platform. This could offer a more precise level of specificity for the development of teachers' knowledge and beliefs.

Secondly, the study group comprised only female teachers. Future research could investigate gender differences. In addition, these researchers could evaluate the self-efficacy of teachers by considering factors such as their educational degrees. Therefore, the knowledge of potential factors that may influence the self-efficacy of K-12 teachers in engineering teaching can be used to enhance the practices of teacher self-efficacy development in this field.

Thirdly, the professional development program employed in this investigation was constructed in accordance with Bandura's four self-efficacy components. In this study, we utilized the TESS as a measurement tool. In future research, modular trainings covering the sub-dimensions of this measurement tool (TESS) can be developed and its impact on engineering teachers' self-efficacy can be investigated in more depth.

Fourthly, the study group of this research was limited to teachers who were identified as fulfilling the criteria for participation in the online professional development program and were highly motivated. Analyzing the self-efficacy development of teachers with low initial motivation may yield valuable insights for future research.

Lastly, this study was limited an online professional development program to efficiently supervise and monitor the science teachers' professional development. The online K-12 professional development program that was devised in this study is applicable to both pre-service and in-service teachers who specialize in science, classroom teaching, and technology. In the field of engineering education, it is anticipated that these longitudinal trainings, particularly those that involve teachers from numerous regions, will improve research.

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Footnotes

[1]The cluster analysis incorporates 'Engineering Integration Pedagogical Content Knowledge (EIPCK)' from the dissertation that provided the study's data.

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Enhancing the Digital Competence of Prospective Primary School Teachers through Utilizing Kahoot!

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Abstract

Given the rapid advancement of modern information and communication technologies, as well as the increasing demand for distance and hybrid learning models, it is imperative that prospective teachers attain a high level of digital competence. This study aimed to determine how effective the technique of using Kahoot! to develop the digital competence of prospective primary school teachers. To diagnose the effectiveness of the developed methodology, testing was used which included various types of tasks and questionnaires in order to assess prospective primary school teachers' readiness to use digital tools in their professional activities. The results obtained (tcrit = 1.982) made it possible to conclude that utilizing Kahoot! interactive platform in prospective primary school teachers' professional training contributes to enhancing their digital competence. According to the findings, the gamified application Kahoot! contributes to students' study motivation, creates a favorable psychological atmosphere. A promising area for further research is to explore the prospective teachers' readiness to create multimedia products using state-of-the-art software iClone Pro, Toon Boom Harmony, Anime Studio Pro , etc.

Keywords:
Interactive Learning Technologies, Kahoot!, Digital Competence Development, Prospective Teachers, Primary School, Gamification.

Introduction

Computerization and informatization of the educational sector have led to a change in approaches in training prospective primary school teachers. Future specialists ought to master the methodology of implementing interactive methods during face-to-face, distance or blended learning. Given the above, during students' professional training in higher education institutions, it is imperative to actively utilize non-traditional methods that would enable teachers to properly organize the educational process in primary school. The teacher's digital proficiency is integral to their capacity for utilizing contemporary and innovative pedagogical approaches. This competence facilitates the visualization of educational materials, expedites assessments of students' comprehension, and enhances the process of knowledge assimilation with interest. Moreover, it diversifies education by introducing a range of forms, methods, and techniques.

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Digital competence is a relatively new pedagogical term that has been actively used since the early 21st century. Based on the observations of contemporary scientists, the development of digital proficiency is a novel concept that encompasses aptitudes associated with utilizing computer technologies. The related terms are technological skills, information literacy, digital literacy, digital skills, information culture (Ilomäki et al., 2011). Essentially, prospective teachers' digital competence draws upon basic skills, which include the search for information, its storage and exchange, and the ability to conduct Internet communication. The first publications on the need to form digital competence among student teachers appeared at the end of the XXth century. In December 2006, the need for digital competence was proclaimed in the Recommendations of the European Parliament when considering the issue of lifelong learning (Pérez-Navío et al., 2021))

The Kahoot digital platform enables creating diverse educational games and quizzes, as well as facilitating discussions on specific topics and conducting surveys with a vast pool of respondents simultaneously. Mastering Kahoot technology is extensively applied to test students' progress. This service offers the elaboration of games in three forms: Quiz, Discussion, Survey. Tasks completed with Kahoot! can be done in classrooms and during independent work. A positive aspect of using Kahoot! is that tasks can be shared via email and social media (Facebook, Twitter, Google).

However, despite considerable research on the implementing the interactive service Kahoot! in prospective primary school teachers' professional training, the issues of empirical study as regards this method's effectiveness remain open today. Given the above, the purpose of the current study is to investigate the effectiveness of using Kahoot! to develop prospective primary school teachers' digital competence.

The main tasks that arise from the relevance of the topic raised are as follows:

- to determine the criteria, indicators and levels of prospective primary school teachers' digital competence in accordance with their professional activity specifics;
- to explore the future primary school teachers' digital competence after the introduction of Kahoot! in the educational process and compare it with the traditional methodology;
- to assess the readiness of prospective primary school teachers to use digital tools in their future career.

Literature Review

Digital literacy is a prominent feature in contemporary political discourse and represents a major educational trend of our time. According to Sillat et al. (2021), it is necessary to stimulate the teachers' and educators' digital competence.

In a recent study, Zhao et al. (2021) noted the increased interest in students' digital competence. Research in the above area mainly focuses on the "real state" of teachers' and students' competence.

Caena and Redecker (2019) identified two levels in the context of which teachers' digital competence is enhanced, namely micro- and mesolevel. The generally accepted European Digital Competence Framework for Educators (Ministry of Digital Transformation of Ukraine, 2021) was developed taking into account the recommendations of higher education institutions and is an open system that can be updated and improved (Caena & Redecker, 2019). Its main structural elements are as follows: Educators' professional competence, Learners' competence.

In fact, prospective primary school teachers' digital competence includes information literacy, communication and collaboration, media literacy, creating their own digital content, cybersecurity, awareness of intellectual property, adherence to the principles of academic integrity (Santos et al., 2021).

The problem of teachers' digital competences is addressed by Portillo et al. (2020). The researchers maintain that nowadays teachers consider themselves only partially competent in the development of distance learning technologies (Portillo et al., 2020).

Falloon (2020) substantiates that future teachers should be able to use modern information resources safely, reliably and systematically. Lucas et al. (2021) concluded that personal factors prevail over contextual ones. Accordingly, digital competence includes a set of skills, knowledge, attitudes and strategies that enable citizens to comprehensively use digital technologies creatively, critically, meaningfully and responsibly, both individually and collectively (Lucas et al., 2021).

McGarr and McDonagh (2021) note that pedagogical HEIs are fully aware of the need to use information resources at school, are ready to implement innovations and strive to obtain the relevant knowledge. When analyzing the concept of "digital competence", McGarr and McDonagh (2021) focused on the fact that it should not be limited to certain frameworks and established measurement criteria.

Teachers ought to continuously improve their level of professional excellence and follow the distance education innovations (Garzón Artacho et al., 2020). Therefore, in order to facilitate teacher's work at a primary school, to diversify the educational process, many programs have been created that enable entering educational material quickly and effectively. These include the Kahoot!

Jankovic and Lambic (2022) described a technique for using Kahoot! while studying natural sciences with third-grade students. The results of this study showed that the experimental group that used Kahoot! to study the content of natural sciences achieved significantly higher results in post-testing than the control group.

Other researchers, Purba et al. (2019), examined the use of Kahoot! in the process of studying chemistry with high school students. The results were positive: the application of Kahoot! -generated online games effectively increased students' motivation to delve into chemistry. The successful experience of using Kahoot and Quizizz for educational material consolidation by HEI students is explored in a study by Göksün and Gürsoy (2019). The above researchers described in detail the gamification of the educational environment. In their opinion, it contributes to enhancing the educational process and significantly increases students' motivation and engagement with learning. The above scholars' standpoints on the need for learning gamification in higher education are highlighted by Lestari (2019). It was shown that the use of Kahoot! and Quizizz yielded a good result in increasing learners' motivation to study. However, according to the author, students prefer to work with Kahoot than Quizizz.

The article by Hodovaniuk et al. (2024) investigates the effectiveness of training sessions for developing digital competence among secondary school teachers. During the technology-focused training sessions, teachers from different disciplines were shown tools such as Kahoot, LearningApps, Mentimeter, and others. Pre- and post-training surveys measured self-reported digital competence, with the majority of teachers moving from "sufficient" to "high" competence after participating. The training sessions allowed teachers to practice new skills and experience the tools from the perspective of students.

The work of Aibar-Almazán et al. (2024) examines the impact of gamification on attention, concentration, creativity, and general abilities of students studying for a bachelor's degree in physiotherapy. The study participants had an average age of 19.51 ± 0.9 years. The results show that using Kahoot! for more than 60 minutes a day can improve important student skills such as attention, creativity, critical thinking, independent learning, adaptability, problem solving, and computer literacy. Research has shown that integrating Kahoot! into the learning environment, especially with longer sessions, stimulates different cognitive aspects and improves complex skills.

The article by Sáez-López et al. (2024) explores the use of gamification as an educational methodology and tool that brings motivational benefits and improves pedagogical approach. The study involved 308 teachers from Spanish educational institutions, of which 69.8% were female and 30.2% were male, which is in line with the demographic situation among teachers. The study is based on three aspects: the most frequently used apps, the devices used, and the didactic functionality. The results show that teachers have a positive attitude towards teaching digital competence in the context of gamification, although only 30% regularly use gamified tools in practice.

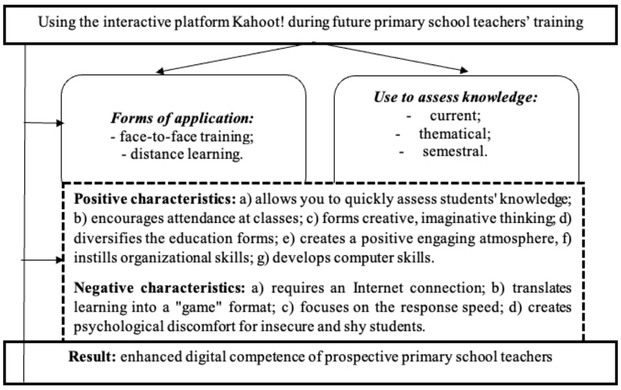
Researchers Rayan and Watted (2024) examined the impact of technology, in particular Kahoot!, on learning outcomes and student motivation to learn science. Using a quantitative methodology, data were collected through pre- and post-experiment surveys among the experimental (N = 53) and control groups (N = 56). The study found that Kahoot! significantly improves students' understanding of science concepts, self-esteem, interest, and enjoyment of learning. It was also found that grade level influences motivation to learn science. The findings highlight the potential of Kahoot! to enhance students' learning experiences, emphasising the importance of creating a dynamic and engaging learning environment.

A positive evaluation of educational gamification is also expressed by Forssell et al. (2023). The authors draw attention to the need to prepare the classroom for the game, in particular, the lighting and size of the board, also taking into account participants' age. According to Nasution et al. (2022), Kahoot! and Quizizz make teachers' job easier because they help assess students' progress more effectively.

Despite a number of positive characteristics, gamified applications still have a number of disadvantages. As noted by Wang and Tahir (2020), working with Kahoot! can cause psychological discomfort: students are afraid of the prospect of losing, anxious about the lack of points and often rush to provide an answer without sufficient consideration. A generalized analysis of modern researchers' works made it possible to develop a model "The use of interactive technologies Kahoot! to enhance prospective primary school teachers' digital competence" (Figure 1).

Figure 1

Using the Interactive Platform Kahoot! during Prospective Primary School Teachers' Training



One of the little-researched issues is the impact of digital literacy on students' psycho-emotional state. Although it is known that working with digital technologies can cause psychological discomfort, such as fear of losing or missing grades, the detailed mechanisms of this impact remain poorly understood. Further research is needed to better understand how different aspects of digital learning affect students' emotional well-being. There is also a need to update the data on how different social and cultural contexts affect the perception and implementation of digital literacy.

Methods and Materials

Research Procedure

The study design was carried out in three stages from January 2023 to December 2023.

The first stage (preparatory) included: preparing the package of methods for studying prospective primary school teachers' digital competence.

The second (main) stage included: the implementation of the Kahoot! into prospective primary school teachers (1st semester of the third year of study). We developed an implementation plan for Kahoot! in the educational environment, which involves the following stages: a) preparatory: instructors who teach professionally oriented disciplines are introduced to the features of utilizing the Kahoot! interactive technology, its possibilities for testing students' knowledge; b) practical: instructors directly develop their own information products using Kahoot!; c) organization and approbation: instructors use the product they created in the educational process, test it with higher education learners; d) final: after using Kahoot! during the study of a particular academic discipline for a certain time, based on students' feedback and recommendations, analysis of their answers to quiz questions, the marks received, teachers make certain edits to the product they have developed, improve the pool of questions, select illustrations if necessary, complicate or, conversely, simplify questions.

The third (final) stage included: interpretation of the obtained indicators, development of recommendations for the introducing digital technologies for prospective teachers.

The Kahoot! curriculum is aimed at improving the educational process through the integration of gamified tools. The main goal of the programme is to increase the motivation, engagement and understanding of educational material by students in middle and high schools, as well as universities. The programme begins with an introductory module that aims to familiarise participants with the basics of Kahoot! At this stage, students will learn what Kahoot! is, how to use it, what basic functions and settings it provides, and will look at examples of successful use of Kahoot! in the educational process. By getting to know the tool, participants will understand how gamification can enhance learning by creating a dynamic and interactive environment. The main stage of the programme involves the practical use of Kahoot! to study specific educational topics. Interactive quizzes and tasks are created based on the educational material, which allows students to better absorb information through active participation in the process. Users have the opportunity to answer questions in real time, which helps to develop their attention, creativity and critical thinking.

Sample

Vinnytsia State Pedagogical University named after Mykhailo Kotsyubynskyi was chosen as the experimental base of the study.

As of the beginning of the 2022/2023 academic year, 18,104 people studied in Ukraine at the first (bachelor's) level of specialty 013 Primary Education on a full-time basis, which made up the general population of the sample (Higher and professional pre-higher education in Ukraine in 2021: statistical information, 2022). After calculating the size of the required (representative) sample using an online calculator (with the following parameters: confidence interval – 85%, error – 7%), the size of the valid sample was 115 people. This number was the baseline for the formation of the experimental group (EG) (n = 58) and the control group (CG) (n = 57). Students of the third year of study took part in the experiment, since in the first and second years they had already developed certain professional skills, having done active pedagogical practice at school, where they experienced the needs of children and teachers in information communication.

Data Collection and Analysis

In order to diagnose prospective primary school teachers' digital competence, testing tasks was developed in accordance with the selected criteria and indicators. The tests were practice-oriented. It was based on the Professional Standard for Primary

School Teachers (Verkhovna Rada of Ukraine, 2020), Description of Educator's Digital Competence (2019), UNESCO's ICT Competency Framework for Teachers (Hine, 2023) (Table 1), DigComp UA for Citizens (2021).

Table 1

Diagnostic Tools for Prospective Teachers' Professional Competence

Criterion	Indicators
Cognitive-procedural	Understanding the principles of human interaction with the digital environment. Awareness of modern ICTs. Ability to search, select, analyze, store, transform, transfer information. Mastery of communication technologies within the digital sphere. Awareness of the digitalization directions in human life.
Value-motivational	Embracing the principles of scientific and technical expertise within the realm of digitalization. Contemplation of the digital landscape as a constituent of forthcoming vocational endeavors. Awareness of the importance to master digital culture as a competitive advantage. Engagement in the study and application of ICTs.
Reflective-actionable	Awareness of a critical attitude to information on the Internet. Independent comprehension of digital environment for future career. Compliance with social responsibility and cybersecurity rules. An adequate understanding of virtual identity and reflection on the successful application of digital tools.
Personal-developmental	Awareness of digital culture as a professional characteristic. Mastering and implementing the principles of behavior in the digital environment in accordance with moral and ethical standards. Focus on the creative use of electronic means for mastering and development. Taking initiative and maintaining an active stance in utilizing digital resources.

here were five levels in total: threshold, basic, conscious, effective, creative.

Each indicator was evaluated using 5 answer options. Each answer was evaluated with points according to the following levels: creative – 5, effective – 4, conscious – 3, basic – 2, threshold – 1. So, each criterion is evaluated by the points sum:

21-25 points – creative level;
17–20 points – effective level;
9-16 points – conscious level;
5–8 points – basic level;
1-4 points – threshold level.

Testing was conducted using the Moodle distance learning system.

In order to assess the readiness of prospective primary school teachers to use digital tools in their future career, the "Questionnaire of readiness to use ICT in future professional activities" was created. Questions 1-10 are devoted to the self-assessment of digital competence level in accordance with the descriptors given in the European Digital Competence Framework for Citizens (DigComp 2.0) (Ministry of Digital Transformation of Ukraine, 2021). Questions 11-15 reveal students' subjective attitudes and preferences for using digital media for professional needs. The survey was conducted using Google Forms.

For statistical data processing, MS Excel was used. To statistically confirm the study results and substantiate the homogeneity of students' samples, the Student's t-test was used, the value of which is calculated by the formula using the classical notation:

$$t_{емп} = |\bar{x} - \bar{y}| \cdot \frac{\sqrt{\frac{n_1 n_2}{(n1+n2)} \cdot (n_1+n_2-2)}}{\sqrt{n1 \cdot D(x) + n2 \cdot D(y)}}$$

Ethical Criteria

The study participants were engaged in the research voluntarily; during the data collection, ethical principles were strictly observed, guaranteeing the protection of their rights, security and confidentiality of information.

Results

Following are the answers to the questionnaire on the readiness to use ICT in future professional activities. The answer to the first question involved an assessment of how significantly digitalization affects society. The majority of respondents (17.88%) indicated that digital environment and ICT are used mainly for information processing and entertainment. A significant part of respondents (34.48%) is convinced that the digital environment and ICT are most actively implemented in the production and distribution of goods and services. It should be noted that 47.64% of respondents agreed that digitalization is a significant trend in social development, and digital technologies are in demand in the industrial and social spheres, considerably affecting people's lives.

In the proposed questionnaire, questions were asked about the perception of the digital environment as an attribute of professional activity. When answering the question "Is interaction with the digital environment a mandatory attribute of professional activity and person's professional characteristic?", 18.84% noted that digitalization currently concerns a limited range of high-tech professions. Yet another group of interviewees, who accounted for 26.48%, specified that the digital environment provides a small part of employees' information operations. More than half of the respondents (54.68%) showed an understanding that digitalization is a mandatory component of professional activity as part of the professional functions.

Further, the question was to determine whether digital literacy, digital competence and digital culture can be considered as a significant competitive advantage in the professional field. When answering this question, 21.38% noted that such characteristics as professional knowledge and skills are more important for a future specialist's training. Part of the respondents (38.84%) agreed that mastering digital literacy is mandatory for a good resume, but the employer exhibits a greater inclination towards the practical (applied) aspect of digital technology. Another part of respondents (33.42%) noted that the presence of digital competence is taken into account when applying for a job, but does not affect development and career growth. Only 6.36% of respondents agreed with the statement that digital literacy, digital competence and digital culture are "conversational" characteristics that distinguish a professional in any field of career.

The next question clarified the scope of digital technologies for future specialists. The response to this question facilitated the determination of perspectives regarding whether the utilization of IT constitutes a customary and mundane labor practice. The answer involved multiple choices. The results are presented in Table 2.

Table 2

Empirical Data Based on the Results of Responses to the Questions:
"For What Purposes Do You Intend to Use Icts in Your Future Career?"

Name of the activity	% of respondents
Entering and reading business and professional documentation	92.26%
Search, processing and transfer of professionally relevant information in the digital environment.	84.48%
Analysis and transformation of information in professional digital environment.	42.24%
Exchange of professionally relevant information, support and engaging in professional communication with colleagues.	22.62%
Achieving the ideal alignment and efficient exchange of ideas within expert networks manifested in the virtual environment.	14.64%
Optimization and design of production processes	6.82%
Development of new products and services within the framework of professional activity.	4.42%

The responses to the question "How important is the need for a critical attitude to professional information and data presented on the Internet" were distributed as follows. A large group of students (26.62%) answered that a critical attitude to information is not important. Another group of respondents (46.42%) believes that independent critical analysis of information does not belong to the specialist's crucial skill. A small part (20.48%) of respondents believed that general and special criteria for identifying unreliable, false or biased information should be trusted. Only 6.48% of respondents indicated that it is necessary to take a responsible and active stance to information reliability.

Students' attitude to compliance with social responsibility guidelines and cybersecurity rules in working with electronic information sources and implementing digital communication was presented as follows. Further, 32.42% of respondents agreed that data protection and information confidentiality should be ensured by the organization in which the employee works, this is the responsibility of technical specialists. The next group of respondents indicated that data protection is not a priority for the employee, but it is worth following technical specialists recommendations for the stable functioning of the organization's digital environment (39.28%). A minority of respondents (18.68%) share the opinion that data protection and responsibility for their misuse, mal-use or loss may be part of employee's professional duties. High responsibility for professional information was demonstrated by 9.62% of respondents.

Another question posed to evaluate the extent of imaginative liberty of prospective educators when employing components of the digital realm to tackle contemporary problems. Responding to this question, 36.42% of interviewees answered that the simplest digital technologies for information processing and communication are used to provide work tasks. 42.28% suggested that when addressing issues, one can choose, customize and integrate diverse digital tools for managing information. A relatively small part of the respondents (21.3%) agreed with the opinion that when solving problems, it is possible to analyze, find applications for objects' creative transformation, improve and develop their digital environment.

Another question was formulated as follows: "Is mastering digital literacy, digital competence and digital culture a means of personal and professional development?". When answering this question, 38.24% of respondents indicated that digital technologies help to solve everyday educational tasks, they should be mastered to a minimum. The opinion that digital technologies offer separate solutions for learning and mastering the professional activity means was supported by 56.68% of respondents. Only 5.08% respondents clarified that digital technologies and the digital environment are the sphere of personal self-realization, which has great potential for self-development.

An important place in the questionnaire is given to questions that revealed digital environment possibilities at HEIs for enhancing digital culture. One of the questions was aimed at identifying attitudes towards the study and use of professionally oriented digital technologies in HEIs educational environment. Thus, 12.24% respondents agreed with the statement that they did consider it, and that digital technologies could be mastered later in the production process. Further, 44.64% respondents showed limited interest, specifying that it is enough to get acquainted with general information about professionally oriented digital technologies and their capabilities during training. A total of 18.12% of respondents expressed significant interest. The data obtained during the processing of the responses to the question "What digital tools do you usually use to tackle educational tasks?" are presented in Table 3.

Table 3.
Empirical Data Based on Responses to the Questions: What Digital Tools do You Usually Use to Tackle Educational Problems?

Name of digital technology	% of respondents
Internet, search engines, databases.	68.45%
Computer means of information processing	74.46%
Means of information exchange with fellow students and teachers (e-mail, messengers).	62.68%
Networked means of communication for interacting with fellow students (social media groups).	52.68%
Tools for monitoring educational achievements (HEI website)	48.64%
Cloud technologies (shared drives, servers).	16.24%
Professional network communities for communication with representatives of the professional environment.	6.42%
Blog, forum, website.	1.22%

The last question was aimed at self-assessment of one's own experience in the use of digital technologies in the educational process. When answering this question, 12.46% of respondents answered that they are generally digitally literate, but the development of new digital tools causes some discomfort and uncertainty. Most of the respondents (36.46%) indicated that they are digitally literate and the use of digital technologies does not cause significant difficulties. Less than a quarter of respondents (22.86%) answered that the use of digital technologies greatly facilitates the educational process, the independent development of new digital tools increases interest in studying program material and mastering digital competence. Only 3.22% of respondents indicated that they are good at digital literacy and competence. The results of the pre-experimental measurement are shown in Table 4.

Table 4
Results of Pre-Experimental Measurement of Prospective Primary School Teachers' Digital Competence

Criteria for shaping digital competence							
Cognitive-procedural		Value-motivational		Reflexive-actionable		Personality-developmental	
EG	CG	EG	CG	EG	CG	EG	CG
Threshold level (person/%)							
13/22.4	15/26.3	14/24.1	12/21.0	15/25.9	14/24.6	14/24.1	12/21.1
Baseline (person/%)							
15/25.9	10/17.5	16/27.6	13/22.8	13/22.4	12/21.0	15/25.9	17/29.8
Conscious level (person/%)							
15/25.9	16/28.1	16/27.6	15/26.3	18/31.0	16/28.1	19/32.8	14/24.6
Effective level (person/%)							
13/22.4	12/21.1	10/17.3	14/24.6	10/17.3	12/21.0	8/13.8	12/21.0
Creative level (person/%)							
2/3.4	4/7.0	2/3.4	3/5.3	2/3.4	3/5.3	2/3.4	2/3.5

The substantiation of student samples homogeneity was carried out by applying the Student's criterion. Applying the general formula, we calculated the empirical values of temp for the criteria of digital culture (Table 5)

Table 5
Empirical Values of the Student's Criterion (t_{emp}) for Digital Competence Criteria Based on the Results of Pre-Experimental Measurement

Criteria	*EG* (N1 = 58)		*CG* (N2 = 57)		EG& CG
	$\overline{x}$	*D(x)*	$\overline{y}$	*D(y)*	T_{emp}
Cognitive-procedural	2.59	1.37	2.65	1.62	0.261
Value-motivational	2.48	1.31	2.70	1.46	0.994
Reflective-actionable	2.50	1.34	2.61	1.49	0.492
Personal-developmental	2.47	1.24	2.56	1.32	0.423

The critical value of Student's statistical criterion (t_{crit}) is found from special tables for the level of static significance p = 0.05 and the number of freedom degrees 113 ($n_1 + n_2 - 2 = 58 = 57 - 2$): t. Comparing t_{emp} and t_{crit}, we came to the conclusion that there are no statistically significant differences in the traits distribution we applied. This circumstance is sufficient reason to talk about the homogeneity of the experimental and control groups' homogeneity. Following the technique implementation, an experimental exchange was carried out. The results are presented in Table 6.

Summary data obtained as a result of diagnosing students' digital competence before and after the experiment is given in Table 7.

To prove the statistical discrepancy between the distributions of the studied traits in the EG and CG groups, we again used the Student's statistical criterion (Table 8)

Table 6

Results of Post-Experimental Measurement of Prospective Primary School Teachers' Digital Competence

Criteria for shaping digital competence							
Cognitive-procedural		Value-motivational		Reflexive-actionable		Personality-developmental	
EG	CG	EG	CG	EG	CG	EG	CG
Threshold level (person/%)							
6/10.3	11/19.3	4/6.9	8/14.1	4/6.9	9/15.8	4/6.9	9/15.8
Baseline (person/%)							
6/10.3	10/17.5	8/13.8	11/19.3	7/12.1	11/19.3	7/12.1	14/24.5
Conscious level (person/%)							
10/17.3	17/29.8	10/17.2	19/33.3	12/20.7	20/35.1	12/20.7	17/29.8
Effective level (person/%)							
27 / 46.6	14/24.6	28/48.3	15/26.3	25/43.1	13/22.8	26/44.8	14/24.6
Creative level (person/%)							
9/15.5	5/8.8	8/13.8	4/7.0	10/17.2	4/7.0	9/15.5	3/5.3

Table 7

Data on Diagnosing Future Primary School Teachers' Digital Competence Before and After the Experiment

Level	Ascertaining experiment (%)		Formative experiment (%)		Dynamics (%)	
	EG	*CG*	*EG*	*CG*	*EG*	*CG*
Cognitive-procedural criterion						
Threshold	22.4	26.3	10.3	19.3	-12.1	-7.0
Base	25.9	17.5	10.3	17.5	-15.6	0
Conscious	25.9	28.1	17.3	29.8	-8.6	1.7
Effective	22.4	21.1	46.6	24.6	24.2	3.5
Creative	3.4	7.0	15.5	8.8	12.1	1.8
Dynamics at an actionable and creative level					36.3	5.3
Value-motivational criterion						
Threshold	24.1	21.0	6.9	14.1	-17.2	-6.9
Baseline	27.6	22.8	13.8	19.3	-13.8	-3.5
Conscious	27.6	26.3	17.2	33.3	-10.4	7.0
Effective	17.3	24.6	48.3	26.3	31.0	1.7
Creative	3.4	5.3	13.8	7.0	10.4	1.7
Dynamics at an actionable and creative level					41.4	3.4
Reflexive-actionable criterion						
Threshold	25.9	24.6	6.9	15.8	-19.0	-8.8
Baseline	22.4	21.0	12.1	19.3	-10.3	-1.7
Conscious	31.0	28.1	20.7	35.1	-10.3	7.0
Effective	17.3	21.0	43.1	22.8	25.8	1.8
Creative	3.4	5.3	17.2	7.0	13.8	1.7
Dynamics at an actionable and creative level					39.6	3.5
Personal-developmental criterion						
Threshold	24.1	21.1	6.9	15.8	-17.2	-5.3
Baseline	25.9	29.8	12.1	24.5	-13.8	-5.3
Conscious	32.8	24.6	20.7	29.8	-12.1	5.2
Effective	13.8	21.0	44.8	24.6	31.0	3.6
Creative	3.4	3.5	15.5	5.3	12.1	1.8
Dynamics at an actionable and creative level					43.1	5.4

Table 8

Sample Means ($\overline{x}$ and $\overline{y}$), Sample Variables (D(x) and D(y)) and Empirical Values of the Student's Criterion (t_{emp}) for the Digital Competence Criteria (drawing on the results of post-experimental measurement)

Criteria	EG (N1 = 58)		CG (N2 = 57)		EG& CG
	$\overline{x}$	*D(x)*	$\overline{y}$	*D(y)*	T_{emp}
Cognitive-procedural	3.47	1.41	2.86	1.55	2.666
Value-motivational	3.48	1.24	2.93	1.32	2.584
Reflective-actionable	3.52	1.27	2.86	1.34	3.071
Personal-developmental	3.50	1.24	2.79	1.31	3.342

Comparing t_{emp} and t_{crit} (t_{crit} = 1.982), we can state the presence of statistically significant differences in the distribution of the studied traits. This circumstance confirms our conclusions that the use of the interactive service Kahoot! has a positive impact on forming future primary school teachers' digital competence.

Discussion and Conclusion

The survey results showed that prospective primary school teachers are generally familiar with the digital environment and during the experiment faced the need to use digital technologies in the learning process. At the same time, they lack substantial expertise and proficiency that may demonstrate a superior level of digital literacy, as validated by preliminary experimental assessment. Most respondents possess knowledge regarding the domains and orientations of digitalization in their professional pursuits, albeit they tend to utilize ICT for information retrieval and processing. The innovative information transformation as well as professional and personal growth are in some cases linked to digital environment constituents. Moreover, digital technologies are regarded as an integral aspect of professional activity. However, the respondents do not prioritize enhancing their proficiency and expertise in this domain. They believe that adeptness in navigating the digital milieu can confer a substantial competitive edge to a specialist It is also worth noting the insufficiently responsible attitude to digital interaction ethics. In our opinion, such answers were due to the fact that teachers use traditional teaching methods more than digital technologies during their training. Students lack proper integration into the digital educational landscape and possess limited awareness of the vast potential that these technologies offer for both academic advancement and personal growth.

The study conducted by Ramdania et al. (2021), as well as Schraube (2022), explored the importance of introducing digital technologies into the learning process. Similar conclusions were reached by Timotheou et al. (2023), as well as Licorish et al. (2018), who maintained that the integration of ICT into school education benefits not only students' academic achievements, but also other school-related aspects, the partnership of teachers and learners. That said, after conducting the experimental work, the number of students with a creative and active level in the experimental group increased: according to the cognitive-procedural criterion – by 36.3%; value-motivational criterion – by 41.4%; reflexive-actionable criterion – by 39.6%; personal-developmental criterion – by 43.1%. Elshareif and Mohamed (2021) noted that the integration of digital technologies into education enhanced the level of student motivation and involvement, which also confirms our results of diagnosing the motivational criterion of digital competence. In addition, in the experimental group, there was a marked decrease in the number of students who were able to move from the lowest (threshold) level to the highest level. Thus, the cognitive-procedural criterion of such students was 12.1%, the value-motivational criterion – 17.2%, the reflective-actionable criterion – 19.0%, the personal-developmental criterion – 17.2%. It should be noted that the corresponding positive changes are also observed among the students from the control group. First, such changes were much smaller than in the experimental group. Second, they are fully explained by natural conditions of university's information and educational environment.

The use of Kahoot! during the experimental work made it possible to identify a number of advantages. First, interactivity, the ability to diversify the educational process with online quizzes, games and tests; Kahoot! creates engaging learning and has an excellent balance between positive and negative motivation (Ramdania et al., (2021). The platform's user-friendly interface accommodates a diverse range of subjects and educational levels. As a conclusion, using a certain level of game-based learning has a positive effect on students' outcomes and their perception of learning, which is also confirmed by Tóth et al. (2019).

Professional training of future teachers ought to incorporate contemporary advancements in the realm of information and communication technology. Currently, there is a shift in the educational landscape, as universities and schools move towards prioritizing learners' interests and individual abilities over merely fulfilling program requirements. The use of digital educational technologies broadens students' worldview, unveils novel prospects for acquiring knowledge in a structured and comprehensible format. Future primary school teachers should possess a set of skills geared towards enhancing primary school learners' information literacy and digital competence while carefully considering their developmental dispositions and natural inclinations.

The acquisition of these competencies is stipulated in contemporary educational papers, not only within Ukraine but also abroad. The teacher's task is to make the learning process interesting, accessible and understandable. Younger learners spend a lot of time playing computer games, sharing information on social networks, or watching cartoons and videos on a variety of topics in social networks. Therefore, the teacher should create an environment that addresses computer dependency, while simultaneously aligning video games with educational objectives.

The significance of the selected subject matter is further underscored by the recent proliferation of distance and blended learning, necessitating a high level of digital proficiency among educators who must adeptly navigate contemporary computer technologies to develop educational software.

Active use of the Kahoot! interactive platform in teacher training contributes to the understanding of the need to use gamified content when working with children. Quizzes, Discussions, Surveys and other tasks done with the help of Kahoot! will create a proper psychological atmosphere during training sessions, contribute to educational material consolidation and motivation to attend classes, independent research.

Evaluating outcomes from the pedagogical experiment validated the efficacy of utilizing the interactive platform Kahoot! as a means to enhance digital proficiency among prospective primary school teachers.

Utilizing the interactive educational platform Kahoot! in the educational process promotes individualization and personality-oriented orientation. The use of this platform minimizes paperwork, simplifies teaching activities and activates student learning. In addition, Kahoot! fosters students' practical skills and brings learning to a qualitatively new level through digital technologies. Its interactive format allows to effectively engage students and promotes an active learning process, meeting modern educational requirements.

Promising areas for further research are the study of prospective teachers' readiness to create multimedia products using modern programs iClone Pro, Toon Boom Harmony, Anime Studio Pro, etc. Thus, enriching contemporary teaching methodologies with interactive didactic materials engenders curiosity among students and prompts them towards active cognitive engagement.

Limitations of the Study

The principal limiting factors of the study are that the study was conducted on the basis of one university, and the experiment was conducted during one semester.

Recommendations

To further elaborate the development of future teachers' digital competence, we recommend conducting a study that would include the respondents of other pedagogical specialties.

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Evaluating Pedagogical Practices in Science Classrooms: A Randomized Controlled Trial Study on Teacher Virtual Professional Development with Virtual Mentoring and Coaching

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Abstract

In this randomized control study, we evaluated science teachers' pedagogical practices via classroom observations following ongoing, intensive, and structured instructional support sessions. These sessions included virtual professional development (VPD) and virtual mentoring and coaching (VMC) that accompanied a literacy-infused science curriculum. Using a low-inference observational instrument, we explored the direct impact of VPD and VMC on fifth-grade science teachers' observed time allocation in a randomized controlled trial (RCT) validation study. The observations were collected three times during science instruction from 121 teachers in 68 schools from 35 public school districts in the U.S. state of Texas, during the 2017-2018 school year. Preliminary findings revealed pedagogical differences in time allocation among teachers between treatment and control classrooms. We identified improved instructional practices within treatment classrooms, which suggests the intervention had a positive effect by enhancing the quality of pedagogy as well as the content-area instruction in science.

Keywords:

Classroom Observation, Evaluation, Randomized Control Trial, Science, Pedagogical Practices, Virtual Professional Development, Virtual Mentoring And Coaching, Emergent Bilingual, Economically Challenged Students, United States

Introduction

Professional development (PD) has long been utilized to support teacher learning and instructional capacity to implement curriculum and instructional strategies (Darling-Hammond et al., 2017; Desimone et al., 2002; Fischer et al., 2018; Fishman et al., 2003; McChesney & Aldridge, 2021; Sancar et al., 2021; Valiandes et al., 2018). Virtual PD (VPD) coupled with the use of virtual tools can provide effective, high-quality teacher learning experiences (Irby et al., 2022; Fishman et al., 2013; Lara-Alecio et al., 2021; Lynch et al., 2021; S. Tang et al., 2022), especially for science teachers in remote or rural areas (Cady et al., 2011; Irby et al., 2021; Quinn et al., 2022).

Although PD can help teachers increase content knowledge and learn instructional strategies, PD alone does not provide teachers the opportunity to implement strategies in the classroom and receive timely feedback on their performance. Providing real-time, remote instructional feedback can improve teacher performance (Sinclair et al., 2020), and utilizing technology to provide such feedback has been found to be both cost-effective and practical in school settings (Rodgers et al., 2019; Schaefer & Ottley, 2018). Researchers have been clear that PD and real-time coaching support teacher instructional capacity. However, little has been reported about how ongoing instructional support sessions, including both VPD paired with virtual mentoring and coaching (VMC), influence elementary science teachers' pedagogical practices.

One measure of teachers' pedagogical effectiveness is classroom observation. When a classroom observation is recorded with a detailed observation protocol, such a record gives the observer a complete and nuanced picture of a teacher's instructional practices minute by minute. This detailed information can be used to understand what the teacher is accomplishing instructionally, as well as what aspects of the instruction that may need improvement. Providing observation-based performance feedback can help reinforce targeted instructional behaviors (Sweigart et al., 2016) and is an important element of effective teacher development (Darling-Hammond et al., 2017; Kettler & Reddy, 2019). Such performance feedback can be shared individually or with small groups of teachers who might have similar instructional needs.

The purpose of this study was to evaluate the pedagogical practices of fifth-grade treatment science teachers who were provided the support of VPD and VMC and control teachers who only received in the typical district PD opportunities and no VMC. These teachers participated in a randomized controlled trial (RCT) validation study implemented in 35 public school districts in the United States in Texas. The VPD and VMC intervention took place in school districts with large numbers of economically challenged (EC) students, inclusive of emergent bilingual (EB) students, and was based on implementation of a literacy-infused science (LIS) curriculum (Lara-Alecio et al., 2016).

Theoretical Framework

Classroom observation data for evaluating teachers' pedagogical practices is important to have in order to improve those practices (Tong, Irby et al., 2019). To better observe classrooms with large numbers of EBs, Lara-Alecio and Parker (1994) and Lara-Alecio et al. (2013) developed a four-dimensional pedagogical classroom observation model that integrates bilingual education theoretical principles to include interrelated dimensions of language content, language of instruction, communication mode, and activity structures. The domain of language content is grounded in Cummins' (1986) language acquisition theory that distinguishes between Basic Interpersonal Communication Skills (BICS) and Cognitive Academic Language Proficiency (CALP). The pedagogical model further separates BICS and CALP in four language content levels: (a) social routines, (b) classroom routines, (c) light cognitive language, and (d) dense cognitive language. The language of instruction domain draws from the bilingual threshold hypothesis and the use of the first heritage language (L1) and second language (L2) during content-area instruction (Cummins, 1986; Krashen, 1981). The pedagogical model includes both language(s) used by the teacher and students in the following categories: (a) content is presented in L1, (b) L1 is used to introduce L2, (c) L2 is supported and clarified by L1, and (d) content is presented in L2. The domain of communication is informed by the reciprocal interaction model (Cummins, 1986) and the context-specific model (Diaz et al., 1986) to classify students' mode of communication: receptive (listening and reading), expressive (speaking and writing), or some combination of these. The activity structure domain is grounded in Vygotsky's Zone of Proximal Development (ZPD; 1978) and in the work of Brophy and Good (1974) as related to the context of instruction and how teachers structure interactions to enhance student learning. The activity structure domain signifies the teacher's pedagogical activities (e.g., lecturing, observing, evaluating, and asking) and the students' response (e.g., listening, answering, cooperating, and asking).

The four-dimensional pedagogical model (see Figure 1) serves as the theoretical basis of the validated observation tool used in this study, the Pedagogical Observation Protocol (POP). The POP integrates observable behaviors and interactions of teachers and students in the classroom and is used in this study to capture science teachers' pedagogical practices.

Literature Review

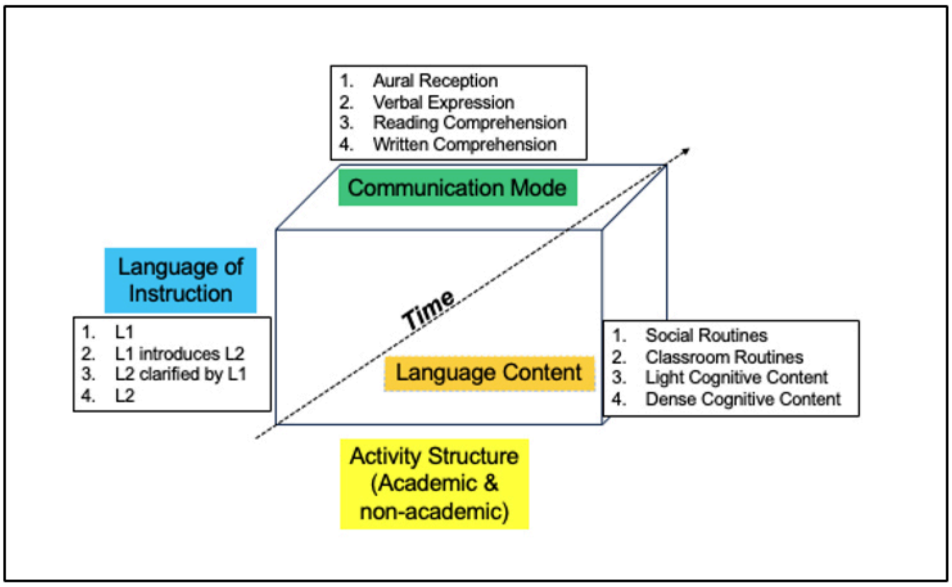
In this section, we present a narrative literature review in four sections. Those are connections between classroom observation and professional development, professional development, virtual professional development, and virtual mentoring and coaching.

Connecting Classroom Observation and Professional Development

The powerful link between classroom observation and PD might not be immediately obvious. Novice and experienced teachers sometimes find classroom observation a stressful or anxiety-producing experience because they associate it with performance evaluation, although observation

Figure 1

Four-dimensional Pedagogical Model (Lara-Alecio & Parker, 1994; Lara-Alecio et al., 2013)



also is an important indicator of educators' PD needs (Aubusson et al., 2007; Borich, 2015; Lasagabaster & Sierra, 2011). O'Leary et al. (2023) noted that one hurdle for Vietnamese schools is moving teachers and educational leaders away from thinking of classroom observation as merely an evaluative tool to utilizing it for teacher PD and learning. They summarized that this shift in thinking requires more of a collaborative approach and building of trust.

The evidence of successful PD may be observed via classroom observations, which can best demonstrate the effectiveness of such PD, and even more importantly, teachers' instructional patterns that influence student involvement in science classrooms and on students' science achievement, especially for EB and EC students (Garza, Huerta, Lara-Alecio et al., 2018; Garza, Huerta, Spies et al., 2018; Jackson et al., 2019). In early observational studies, researchers found that lower-achieving schools often devote less time and emphasis to higher-order thinking skills and cognitively demanding academic language development than do schools serving more advantaged students (Coley & Hoffman, 1990; Padrón & Waxman, 1993). Likewise, Davidson and Koppenhaver (2017) found that low-income and minoritized students were more likely to be placed in remedial coursework, thus receiving less demanding classroom instruction. Similarly, the scarcity of reported practice was found regarding teachers' support in science instruction to engage students in cognitively challenging tasks among students with low-literacy skills (Tong, Irby et al., 2019). Thus, quality PD opportunities should be provided to equip science teachers with tools and resources to serve diverse learners and EC students with science content (Irby et al., 2018; Gamez & Parker, 2018; Jackson et al., 2019; Lee et al., 2023; Meskill & Oliveira, 2019; Vera et al., 2022). The impact of these PD opportunities on teachers' pedagogical practices can be evaluated with a comprehensive observation instrument (Garza, Huerta, Lara-Alecio et al., 2018; Garza, Huerta, Spies et al., 2018).

Without direct classroom observation, it cannot be determined if teachers are implementing the strategies and information learned in PD sessions and improving their effectiveness for promoting students' achievement (Joyce & Calhoun, 2010; Tong, Tang et al., 2019). Specifically, reliable, valid, and practical observation protocols can offer a vehicle for observing and exploring how knowledge and skills acquired during the PD can be transferred into hands-on practice in the science classroom to create an environment that is conducive to student learning (Calderón et al., 2011; National Research Council, 2010).

Professional Development

Due to challenges in the recruitment and retention of highly qualified teachers, particularly in the science, technology, engineering, and mathematics (STEM) areas (Fairman et al., 2019; Sutcher et al., 2016; Whitfield et al., 2021), students often have limited access to teachers with content-area expertise (Cardichon et al., 2020; Sexton, 2018). Scholars have concurred that quality PD leads to changes in teachers' knowledge and instructional techniques in mainstream education (Bragg et al., 2021; Darling-Hammond et al., 2017; Germuth, 2018; Kim et al., 2019). Quality PD can also make a difference for content-area teachers (Maeng et al., 2020; Miller et al., 2019). For instance, Maeng et al. (2020) provided a four-week summer institute on reform-based science instruction for elementary science teachers. Utilizing an RCT design, Maeng and colleagues found that treatment teachers who attended the PD demonstrated significantly greater acumen and confidence integrating inquiry, project-based learning, and nature of science into their instruction compared to control teachers. These improvements also were evident in treatment teachers' recorded classroom observations.

Researchers have also linked effective teacher PD with student outcomes (Gupta & Lee, 2020; Llosa et al., 2016). For example, A. Tang et al. (2022) conducted a multilevel mediation analysis of fourth-grade and eighth-grade students and their teachers in Hong Kong. They found that teachers' PD in science pedagogy was significantly and positively related to student outcomes. Tang et al. also showed that teachers' focus on science investigation was a strong mediator at grade 4, but not grade 8. Llosa et al. (2016) found significant, positive science outcomes for mainstream and EB students, following a one-year science curricular intervention with teacher PD. In another study on the effects of a year-long PD for elementary science teachers, Nichol et al. (2018) found no difference in science performance between treatment and comparison students, despite the treatment teachers being absent 20% of the school year for the PD. Moreover, the investigators also examined the long-term impact of the PD by comparing the scores of students who were taught by the treatment teachers the year they received the PD and their students the following year. The latter group significantly exceeded the other group, with a medium effect size of .088. Characteristics of effective teacher PD include: (a) long-term duration; (b) collaboration; (c) voluntary; (d) subject knowledge training; (e) inclusion of outside expertise; (f) coaching support; (g) incorporation of active learning; and (h) reflection opportunities (Darling-Hammond et al., 2017; Sims & Fletcher-Wood, 2021).

Based on a systematic review of 11 empirical studies on teacher professional development for STEM integration in elementary/primary classrooms, Boz (2023) recommended that PD should: (a) be targeted to increase teachers' content knowledge and boost collaborative planning with subject-area specialists; (b) incorporate active learning strategies and provide a range of samples of integrated STEM curriculum; (c) emphasize successful practices of educators implementing integrated STEM activities; (d) be in line with school or district policies and standards, and offer teachers continual support from administrators and parents; (e) focus on assessment of student learning across the subjects integrated into the STEM lessons; and (f) bolster teachers planning and conducting STEM lessons.

Virtual Professional Development

Virtual professional development has gained traction with teachers and school administrators looking to sharpen their skills (Irby et al., 2015.; Irby, Sutton-Jones et al., 2017; Irby, Pashmforoosh, Duery et al., 2022; Tong et al., 2015). VPD for teachers can take a range of forms, such as formal online university courses, professional learning communities (PLCs) hosted through social media or other online platforms, live video conferences and webinars, and informal, just-in-time PD videos. The literature increasingly supports the effectiveness of VPD for teacher learning (Dede et al., 2016; Fishman et al., 2013; Jaber et al., 2018), and comparison studies of online and face-to-face PD have indicated similar learning outcomes for teachers (Fishman et al., 2013; Hathaway & Norton, 2012) and students (Fishman et al., 2013). In a comparison of online and face-to-face continuing PD for Saudi science teachers, Binmohsen and Abrahams (2022) observed that teachers receiving the online PD were as effective, and in some cases, more effective than the face-to-face teachers, based on classroom observations; the online teachers also reported more satisfaction with the PD. Rigorous empirical research as well as theory-building studies on online PD remains scarce, and scholars have called for more investigation (Dede et al., 2009; Moon et al., 2014). The Community for Advancing Discovery Research in Education (CADRE, 2017) noted the need for more research that:

- "targets specific program features or combinations of features and their connections to teacher learning;
- examines impacts on teacher practice and student learning; and
- invokes a range of formative and summative methodologies…." (p. 15)

With an increased government, industry, and business focus on STEM, it is crucial for science teachers to have strong PD opportunities to strengthen their knowledge and skills. VPD can fill this need, especially for science teachers serving in rural or remote schools (Cady et al., 2011). Moreover, VPD provides teachers in geographically remote areas with the same opportunities and access to quality PD (Irby, 2015; Irby, Tong et al., 2021; Quinn et al., 2022). Binmohsen and Abrahams (2022) observed that online PD has benefits in countries where social and religious customs prohibit direct interaction between men and women. Through VPD, teacher educators can build and enhance teachers' science content knowledge and pedagogical beliefs and skills. For example, Gosselin et al. (2010) reported on the creation of Laboratory Earth, three sponsored, online graduate courses, considered online PD, for K-8 educators designed to improve teacher content knowledge and teacher attitudes about science. The scholars found significant increases in both science content knowledge and sense of self-efficacy and enjoyment in teaching science among teachers who participated. In 2011, the National Science Teachers Association (NSTA) launched the PD Indexer, a valid and reliable tool that helps teachers self-assess their content knowledge and then, based their results, points them to relevant PD resources within the NSTA's online portal (Buyers et al., 2011).

The body of literature on VPD continues to increase, especially in terms of best practices for PD instruction and facilitation, and general design principles. In their case study of a year-long science VPD for in-service elementary and middle school teachers in a rural Massachusetts district, Watkins et al. (2020) emphasized the need to understand how online instructors can better support teachers' science engagement. They suggested that within an asynchronous online environment, instructors should practice responsive facilitation in three essential ways: (a) tailor prompts and assignments to teachers' needs and context, (b) encourage teachers to engage in discipline-specific critical-thinking, and (c) focus on the individual's scientific thinking. Yoon et al. (2020) stressed the need for online learning environments that support teachers in creating social connections, cultivating participant trust through sharing, engaging in collaborative "sense making" (p. 10), and connecting with other teachers and specialists.

Cavanaugh and Dawson (2010) suggested that following best practice design principles contributed to the success of their online Exploring Florida Science project, which was implemented to increase content knowledge for secondary science teachers and provide science digital media for student project-based learning. They highlighted the following principles: (a) VPD environments included engaging media to increase teacher participation; (b) teacher materials were content standards aligned in order to make them more relevant; (c) materials included personal stories to make it easier for teachers to relate to science practitioners; and (d) resources for teachers to incorporate student project-based learning were included. Based on feedback from researchers from across 11 National Science Foundation education projects, CADRE (2017) identified three significant design principles for online and blended teacher PD in K-12 STEM: (a) encouraging and supportive engagement that increases knowledge and furthers professional goals; (b) building opportunities for collaborative learning for teachers, and (c) promoting teacher reflection on content and practice. Interestingly, Luz et al. (2018) found that it was external factors (i.e., heavy workloads and technology issues) that most commonly drove Brazilian science teachers to drop out of online PD courses.

Virtual Mentoring and Coaching

Over the past 10 years, research has been expanded in the arena of online or virtual mentoring and coaching (Irby, Lynch et al., 2017; Irby, Pashmforoosh, Lara-Alecio et al., 2023; Irby, Pashmforoosh, Tong et al., 2022) — sometimes also called e-mentoring — especially for science teachers (Bang, 2013; Bang & Luft, 2014; Lee et al., 2018; Melton et al., 2019; Nugent et al., 2016). Several different models of online mentoring are present in the literature. For example, there are asynchronous, dialogue-based mentoring models that utilize discussion boards and/or private chat rooms, such as that described in Bang and Luft's (2014) case study. They reported on the mentoring dialogues of two first-year secondary science teachers located in the American Southwest who participated in a nationwide online mentoring program, and they analyzed the threaded messages of the teachers (mentees) and teacher educators (mentors). These messages, focused on science teaching, were posted privately and asynchronously in a virtual chat room three to four times a week. Bang and Luft suggested that their analysis provided evidence that online mentoring is an effective method for sharing knowledge between experienced and novice teachers and speeding the induction and professional development of new science teachers. A similar online mentoring model was used in Simonsen et al.'s (2009) study, which was derived from a multiyear, multistate National Science Foundation project on science and math teacher induction. This project leveraged both VPD and VMC. Utilizing content analysis, researchers examined private discussion postings between mentor teachers and mentee novice teachers. Content analysis of more than 1,600 posts from 19 mentor-mentee pairs indicated that conversations centered on three types of knowledge: content knowledge, pedagogical content knowledge, and pedagogical knowledge. Simonsen et al. concluded that the use of this medium created a safe space for novice teachers to construct new pedagogical knowledge and talk about sensitive topics with a trusted, experienced mentor.

Another model of online mentoring involves synchronous meetings between mentor and mentee, and the video recording of the mentee teacher delivering classroom instruction (e.g., Carson et al., 2019; Gaudin & Chaliès, 2015). In Carson et al.'s (2019) study, they detailed their model, which follows the Standards for Professional Learning (Learning Forward, 2011), for coaching rural math teachers in New York and Arizona. First, the mentor and mentee met online through a video conferencing app, such as Zoom, to discuss a lesson that the teacher had planned — all lesson materials were in a shared Google folder. Then the teacher video recorded him/herself implementing the lesson, made annotations on part of the recording for the mentor to watch, and shared the recording with the mentor. Next, the mentor also annotated a section of the video. Lastly, the mentor and mentee again met in the video conferencing app to debrief and discuss student work the teacher had uploaded to the Google folder following the lesson. Unver et al. (2023) presented a similar e-mentoring model, which involved Turkish teachers submitting videos of recorded classroom instruction and mentors providing feedback. They followed an iterative mentoring process. The authors concluded that the online mentoring model, supported by scientific inquiry as part of a professional development program, improved teachers' classroom instructional practices, regardless of their years of professional experience or the grade level they taught. Carson and Choppin (2021) used a video-based online coaching model. Their model incorporated both synchronous and asynchronous modes for planning, teaching, and reflection in math content-area teacher learning with a subject-area-focused approach, and enabled rural teachers to have access to experienced coaches with no geographical constraints.

Yet another online mentoring model is completely synchronous, including the streaming video capture of classroom instruction and live, instantaneous mentor feedback. For example, ong et al. (2015) described another online mentoring model as a VMC-RTF model implemented with teachers of EBs to improve students' English oral language, literacy, and/or science outcomes. In this VMC-RTF model, the coach/mentor observed the classroom teacher remotely over the internet at a pre-scheduled time and provided instant feedback to the mentee teacher via a bug-in-the-ear bluetooth device (with a wireless microphone and earbud) as the teacher delivered instruction uninterrupted. A web-accessible video camera placed in the classroom captured teacher and student activities during the coaching session. At a later time, the mentor and teacher reconvened virtually using a video-conferencing platform to discuss ways to improve student learning and engagement, as well as complete a pedagogical reflection using the Brown and Irby Reflection Cycle (2001) in which teachers concluded with the transform stage — transforming their next-step practice.

Research Question

The research question for this study was: When fifth-grade treatment science teachers are provided with VPD and VMC, to what extent do they differ on observed pedagogical practices from fifth-grade control teachers who were not provided VPD and VMC?

Methods

Research Design and Context

This study was derived from a longitudinal RCT funded by the U.S. Department of Education: Literacy-Infused Science Using Technology Opportunities (LISTO; PR/Award Number U411B160011). The purpose was to validate literacy-infused science instructional and curricular innovations in order to increase instructional capacity of teachers and to improve students' science and reading/writing literacy achievement in rural and non-rural schools for EC students, inclusive of EBs. Project personnel recruited 35 Texas public school districts that had more than 50% of students classified as EC. A goal of Project LISTO was to recruit 66% rural campuses to support schools that have limited resources. An external evaluator randomly assigned 68 participating campuses to treatment (n = 33) and control (n = 35) conditions, with 66% (45

Table 1

Chi-square Test Results on Science Teachers' Demographic Data by Condition

Variable			Condition: Control	Condition: Treatment	Chi-square	Cramer's V	*p*
Gender	Female	n	50	43	0.099	0.029	0.753
		%	75.8%	78.2%			
	Male	n	16	12			
		%	24.2%	21.8%			
Route to certification	Alternative certification	n	26	27	1.840	0.123	0.399
		%	39.4%	49.1%			
	University teaching	n	39	28			
		%	59.1%	50.9%			
Highest degree	Bachelor's degree	n	35	37	4.913	0.202	0.178
		%	53%	67.3%			
	Bachelor's degree with some graduate hours	n	8	5			
		%	12.1%	9.1%			
	Master's degree	n	19	13			
		%	28.8%	23.6%			

out of 68) of the schools from rural areas. Fifth-grade science teachers from each campus were invited to participate. For this study, 121 fifth-grade science teachers (66 in treatment, 55 in control) participated. Teachers in treatment campuses implemented LISTO curriculum and received ongoing instructional support sessions, including VPD and VMC. Control teachers implemented district-typical science instruction. The data used in this study came from the first year of Project LISTO, which was the 2017-2018 school year.

Participants

Teachers' demographic information was collected via a participant survey that included gender, route to certification, and highest education level. A chi-square test of homogeneity was conducted to determine whether treatment and control teachers differed on the demographic variables of gender, route to certification, and education level. Results indicated no statistically significant difference between treatment and control teachers regarding these variables, which meant that treatment and control teachers shared similar demographic characteristics, teaching qualifications, and education level before the intervention started (see Table 1).

Intervention at Teacher Level: Instructional Support Sessions with VPD and VMC

This study was implemented in 35 statewide school districts in Texas; therefore, it was prudent to alter the traditional face-to-face PD and traditional mentoring and coaching to virtual professional development and virtual mentoring and coaching. Teachers participated in a series of 15 ongoing instructional support sessions that included synchronous VPD and live VMC using the Applied Pedagogical eXtra Imaging System (APXIS), which consisted of (a) a laptop computer, (b) external video camera, (c) a video-conferencing platform, and (d) a scheduling platform that we built and adapted for mentoring and coaching. Ongoing group VPD sessions were conducted bi-weekly for 90 minutes per session and focused on student learning, instructional strategies, building capacity for science teaching, previewing upcoming lessons, viewing modeling videos, and reflection on student learning and teaching practices. Teachers were encouraged to engage in the VPD using voice, chat logs, polls, and webcams. Each session was recorded, and links were sent out to participants so they could have access to go back and review the VPD sessions. The VPD included embedded VMC. Trained coaches provided VMC utilizing the APXIS platform to virtually observe treatment teachers' instruction and offer support and immediate real-time feedback; thus, that process we called VMC-realtime feedback (VMC-RTF). VMC-RTF was augmented with interactions via bug-in-the-ear (earbuds). In addition to the VMC-RTF within the 15 VPD sessions, coaches provided two additional VMC-RTF sessions lasting approximately 30 minutes and conducted follow-up, one-on-one reflective sessions allowing teachers to review their recorded instruction and reflect on implementation of LIS curriculum and instructional strategies.

Instrumentation

The four-dimensional pedagogical theory (Lara-Alecio & Parker, 1994) is the basis of the Pedagogical Observation Protocol (POP) (Lara-Alecio et al., 2009), which was originally the Transitional Bilingual Observation Protocol (TBOP) (Lara-Alecio & Parker, 1994; Lara et al., 2009). TBOP has been applied in a previous literacy-infused science RCT for examining how professional development sessions support science teachers' quality of instruction with diverse learners (e.g., Garza, Huerta, Lara-Alecio et al., 2018; Garza, Huerta, Spies et al., 2018; Tong, Tang et al., 2019). Therefore, POP was adopted in the current study to investigate the impact of instructional support sessions on scaffolding teachers' pedagogical practice.

POP includes four domains: activity structure, language of instruction, language content, and communication mode. A fifth and sixth domain (physical grouping and instructional strategy) were later added when the theory was validated (Bruce et al., 1997). This instrument has been adopted and validated for evaluating teachers' instructional practices (e.g., Garza, Huerta, Lara-Alecio et al., 2018; Garza, Huerta, Spies et al., 2018; Lara-Alecio et al., 2009; Tong et al., 2020; Tong, Irby et al., 2019; Tong, Tang et al., 2019).

The POP domain of activity structure is defined as a combination of (a) teacher instructional practice (e.g., lecturing, directing, evaluating, asking) and (b) student response behavior (e.g., listening, cooperating, discussing, answering). For example, when a teacher asks a question, and students answer the question, the activity structure is thus coded as ask/answer (ask/ans). A few classroom activity structures (e.g., transitions between classes, student behavior feedback) are considered non-academic and are coded non-academic-transition (NA-tran) or non-academic-feedback (NA-feedback). In the domain of language content, four levels are included: social routines (e.g., greetings, social exchanges), (b) classroom routines (e.g., handing in assignments, handing out materials), (c) light cognitive content (e.g., reviewing previously introduced content, repetitive drills), and (d) dense cognitive content (e.g., new content-area information, critical thinking). In the domain of language of instruction, four categories are adopted for describing teachers' or students' use of (a) first language, (b) second language, (c) L2 supported and clarified by L1, or (d) L1 to introduce L2. The categories in the domain of communication mode denote students' use of one or a combination of two receptive models (aural, reading) and two expressive modes (verbal, writing). English as a second language (ESL) strategies are included in POP as one of the minor domains, so that teachers' application of effective instructional strategies, such as academic language scaffolding, cooperative/collaborative learning, or manipulative and realia use, are recorded. Physical grouping, the second minor domain, includes four categories to document whether the instructional interaction between teacher and students occur in (a) whole class instruction, (b) large group instruction, (c) teacher working with pairs of students, or (d) teacher working with an individual student.

Data Collection and Analysis

Classroom observations were collected virtually using APXIS installed in each classroom. Three rounds of virtual classroom observation were conducted at the beginning, middle, and end of the 2017-2018 school year. The recorded lessons were then rated by trained personnel via POP. During the coding process, raters recorded the presence of teacher instructional practices based on the POP rubric that contains four major domains (i.e., activity structure, communication mode, language content, and language of instruction) and two minor domains (physical grouping and instructional strategies; for details see Tong, Irby et al., 2019). In each domain of POP, raters coded over multiple 20-second intervals of recorded lessons. We established the initial inter-rater reliability (IRR) and monitored IRR at the beginning of each round. IRR at the domain and cross-domain levels was established and continuously monitored to ensure the fidelity of the rating procedure with AC1> 0.6 across three rounds of observation (Gwet, 2008). Gwet's AC1, a rigorous indicator of inter-rater reliability, is suitable for multi-domain-response rater instruments such as POP (Tong, Tang et al., 2019). The magnitude of such IRR corresponds to a substantial level of IRR per Landis and Koch (1977). Given that the POP yields non-parametric frequency data, a chi-square test was employed to identify if the proportion of each category under every domain was homogenous between treatment and control conditions.

Results

Preliminary analyses were performed based on the ratings of the three rounds of observations collected at the beginning, middle, and end of the school year after 15 VPD sessions. The average length of classroom observation was 70 minutes for treatment teachers and 55 minutes for control teachers, respectively. Observations in both conditions were coded over four 5-minute intervals evenly distributed during their observation time, with 20-second coded video clips. In this study, a total of 13,620 twenty-second video clips were recorded and observed. Statistically significant differences were identified regarding teachers' time allocation in the following domains between treatment and control teachers: instructional strategies ($\chi^2(9) = 205.016$, $p < 0.001$, Cramer's V = .123), physical grouping ($\chi^2(4) = 258.628$, $p < 0.001$, Cramer's V = .138), activities structure ($\chi^2(20) = 273.611$, $p < 0.001$, Cramer's V = .142), communication mode ($\chi^2(17) = 241.546$, $p < 0.001$, Cramer's V = .133), language of instruction for teacher ($\chi^2(3) = 35.64$, $p < 0.001$, Cramer's V = .051), and language of instruction for students ($\chi^2(3) = 25.496$, $p < 0.001$, Cramer's V = .043). No significant difference was identified in the domain of language content between the treatment and control teachers.

Pedagogical Practices

In the POP domain of instructional strategies, the visual scaffolding strategy was observed to be the most frequently used technique (21.9% in control, 27.1% in treatment, $p < 0.05$). It was observed that control teachers employed manipulatives and realia strategies more often than treatment teachers (13.2% in control, 8.4% in treatment, $p < 0.05$), while treatment teachers employed cooperative/collaborative strategies (14.1% in treatment, 11.3% in control, $p < 0.05$) and asked students leveled questions (5.8% in treatment, 3.5% in control, $p < 0.05$) more often than the control teachers.

In the POP domain of physical grouping, teachers tended to deliver instruction to the whole class in both conditions (69.2% in control, 68.0% in treatment). It was also observed that treatment teachers provided more opportunities for student pairs to collaborate (7.0% in treatment, 1.7% in control, $p < .05$). In the domain of activity structure, it was observed that lecture/listen (17.1% in control, 16.8% in treatment) was the most frequently observed instructional practice in both treatment and control conditions. It was also observed that control teachers monitored students' performance on academic tasks more often than the treatment teachers (12.6% in control, 8.9% in treatment, $p < 0.05$), while treatment teachers evaluated student understanding by providing the opportunity for students to respond to leveled questions (19.1% in treatment, 15.8% in control, $p < 0.05$) more often than the control teachers.

In the POP domain of communication mode, the following student communication behaviors were the most frequently observed in both conditions: aural (32.3% in control, 32.6% in treatment), and in combinations of verbal and aural communication (41.5% in control, 42.6% in treatment). No significant difference was identified in these communication modes. In the domain of language content, teachers in both conditions were observed to spend the majority of their instructional time delivering dense content (76.7% in control, 77.2% in treatment). In the domains of language of instruction for teacher and students, second language (i.e., English) was observed to be the most frequently used by teachers in both conditions (86.3% in control, 89.0% in treatment). Thus, as a mirror of teachers' behavior, students most commonly utilized English (47.0% in control, 50.7% in treatment).

Limitations

This study has a few limitations that researchers should bear in mind. First, the research we presented solely focused on the science teachers' instructional practices in classrooms that included EBs and ECs; therefore, we did not report student level data and outcomes in this study. This could be one avenue for possible study in the future — research that links observable pedagogical behaviors to specific student outcomes, especially in science. Second, this study centered on one aspect of teachers' observed pedagogical behaviors. Because this study was focused on classroom observation measuring pedagogical practices in the content area of science, we did not explicitly measure changes in teacher content knowledge and/or attitudes/perspectives about teaching science. This would also merit further study. Other possibilities for future research include increasing the amount of time that teachers receive VMC and VMC-RTF. While teachers received fifteen 90-minute VPD sessions with embedded VMC, they only had two 30-minute VMC-RTF sessions during the intervention due to delays resulting from Hurricane Harvey which occurred in August 2017, the first year of implementation. VPD and VMC-RTF activities were originally planned to start in September that year, but did not occur until October, as 17 of the treatment teachers (29.8%) in six school districts were adversely affected by the hurricane. It is possible that more frequent VMC-RTF would result in further pedagogical change. In a future study, researchers might utilize mixed methods to interview and survey teachers on their perspectives of the VPD and VMC.

Discussion and Conclusions

The current study was focused on a comprehensive examination of science teachers' pedagogical practices after they have received intensive virtual training and support to enhance their instruction. Specifically, the purpose of this study was to evaluate the pedagogical practices of fifth-grade treatment teachers who were provided the support of VPD and VMC, and control teachers who only received in the typical district professional development opportunities and no VMC. We have highlighted the variation in teachers' time allocation in instructional strategies, content, instructional language, communication mode, and activity structure. We identified pedagogical differences in time allocation between teachers in treatment and control conditions. We proffer that such differences are due to the effective, ongoing, and structured VPD and VMC provided. Our findings are in line with previous studies conducted by Garza, Huerta, Lara-Alecio et al. (2018) and Garza, Huerta, Spies et al. (2018), as well as Tong, Irby et al. (2019) that ongoing structured PD improves teachers' instructional capacity in a challenging content area, science, and such improvement can be accurately documented via a comprehensive observation instrument, like POP. The positive findings in observed activity structures within treatment classrooms implies that with support there can be better implementation of effective instructional practices, such as providing students with leveled questions and using cooperative/collaborative instructional strategies. We found that the POP is a flexible and comprehensive classroom observation protocol instrument that can be effectively used in the science classroom that is inclusive of EBs and ECs. It (a) provides an objective, reliable, and valid picture of science teachers' instructional patterns and their interaction with students and (b) allows researchers to evaluate how intervention factors influence teachers' quality of pedagogy.

More specifically, we found that both VPD and VMC resulted in the treatment group of science teachers engaging students in reasoning, comparing, and predicting — all of which are higher-order thinking skills. This finding was supported by the results in the domain of instructional strategies, as we found that treatment teachers applied more questioning strategies. In the domain of activity structure, we reported that treatment teachers more often asked students questions, compared to control teachers. Treatment teachers were also grouping and pairing students for collaborative work and sharing ideas with peers. Moreover, treatment teachers provided students with visual scaffolding to support their science content learning. Similar patterns of pedagogical improvement were also evident in Lara-Alecio et al. (2009).

These results indicated that the treatment teachers, through their exposure to the intervention VPD and VMC, were learning and adopting new pedagogical behaviors (or modifying existing ones) that are in line with best practice. The combination of the group VPD created a community of professional learners and the individual VMC allowed teachers to practice new skills in a safe, comfortable space, similar to Simonsen et al. (2009). The VPD+VMC blend of instructional support targeted a range of professional learning needs for the science teachers. It is important to note that the VPD and VMC were aligned with the three significant design principles for online and blended teacher PD identified by CADRE (2017). These design principles included: (a) supporting teacher engagement to increase knowledge and advance professional goals; (b) incorporating opportunities for collaborative learning; and (c) encouraging teacher reflection on content and practice. Therefore, we conclude that high-quality, ongoing VPD and VMC inclusive of VMC-RTF can support and enhance teacher implementation of classroom science intervention — thus providing EB and EC students with elevated science learning opportunities.

We observed how science teachers allocated instructional time in the critical components of language content, communication mode, language of instruction, activity structure, physical grouping, and instructional strategies. Observing how teachers use their instructional time can provide valuable insights into teaching effectiveness. Additionally, we conclude that such teaching effectiveness, which cannot be guaranteed by simply more instructional time but specifically by the quality of instruction within the available instructional time as also noted by Tong, Irby et al. (2019). The differences between treatment and control teachers in the critical components of language content, communication mode, language of instruction, activity structure, physical grouping, and instructional strategies, as observed in the current study confirmed that classroom observation is a comprehensive and reliable approach to examine teacher instructional quality.

This study is particularly impactful in rural schools, since the majority of the participating teachers taught in rural school districts. We want to emphasize that because these instructional supports were provided online, these important resources have the potential to be available to science teachers everywhere, regardless of their location. This consideration is especially important for rural or isolated school districts, where it can be challenging to recruit science teachers or to provide current in-service science educators with sufficient content-specific PD (Cady et al., 2011). Therefore, we conclude that rural districts can take advantage of VPD opportunities for their teachers.

Important to note, there had been no large-scale RCT studies as we could determine that were focused on curriculum-based training for science teachers with EBs and ECs in their classes and with a year-long intervention that incorporated ongoing instructional support sessions, including VPD, VMC, and/or VMC-RTF. To address this issue, we implemented a rigorous RCT design in which we supported science teachers via 15 bi-weekly instructional support sessions throughout the school year to implement literacy-infused science curriculum. We conclude that continuous quality instructional support via VPD and VMC, including VMC-RTF is worthwhile for improved science instruction in rural classrooms inclusive of EBs and ECs.

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RETRACTION

We would like to inform you that the article titled "Teachers' Management of Everyday-Living Skills of Intellectually Challenged Learners" published in volume 16, issue 4, pages 495-508 (https://doi.org/10.26822/iejee.2024.348) of our journal has been retracted by the author. The author, Adesegun Olayide Odutayo, has decided to retract the article. The decision to retract the article was made after a rigorous review process by the authors. In line with our responsibility to the scientific community, we aim to ensure transparency and accuracy in knowledge dissemination by sharing this retraction notice. Retractions of this nature are an important step in maintaining the quality and reliability of the scientific process. We apologize for the need to inform you about the retraction of this article and want to emphasize our sensitivity to any potential misunderstandings that may arise. Our journal remains committed to supporting the scientific community and upholding transparency and ethics in such processes.

Best regards,

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Unlocking Social Growth: The Impact of Applied Behavior Analysis on Children with Autism Spectrum Disorder

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Abstract

Autism spectrum disorder (ASD) is significantly known as social interaction impairment that can be reduced through early school-age intervention. The quasi-experimental research design was used to examine the effect of applied behavior analysis treatment on ASD children's interpersonal skills. The researchers used a purposive sampling technique to select 30 participants who have symptoms of ASD, which were divided into two groups (control and experimental) without gender discrimination. The assessment of basic language and learning skills (ABLLS-R) protocol and portage guide of early education was used to develop a questionnaire comprising four factors. The results indicate a statistically significant difference between the experimental and control groups in terms of students' interpersonal skills and the pretest and post-test scores of the experimental group. It is suggested that parents and therapists should develop a sharing ability among children with autism symptoms so they can understand social reinforcement.

Keywords:

Interpersonal Skills, Peer Interaction, Autism, Social Communication, ASD

Introduction

Autism septum disorder (ASD) is a social interaction impairment that affects three types of child development, i.e., behavioral, communicational, and interactional, which leads a child to become socially isolated from a human being(Cihon et al., 2023; Edition, 2013; Mash & Wolfe, 2015). However, some psychologists consider that ASD is a neurodevelopmental disorder that happens due to three types of deficits, i.e., social skills, communication, and stereotypies & rituals (Leung et al., 2010; Lubomirska et al., 2022). Therefore, investigators found that the core symptoms of ASD are impairments in communication, reciprocal social interaction, and restricted and repetitive behaviors that create problems in children's social development. Hence, the Centers for Disease Control reported that ASD affects one in 68 children, as cited by (Roane et al., 2016) and one in 100 adults worldwide, as cited by (Brugha et al., 2011).

Subsequently, families demand insurance coverage for research-based therapies for ASD because the proportion of children with ASD has increased to one in 59 (Zhao et al., 2018). Recently, the Centers for Disease Control (2022) reported that ASD affects children in one in 44 (Lin & Bhatia, 2022). With the dramatic increase of ASD children, the severity of the disorder highlights the importance of practical therapeutic approaches for its treatment through intervention during early school age. Thus, the most successful evidence-based interventions for children with ASD are those based on applied behavior analysis (ABA) treatments (Fein et al., 2013; Zane et al., 2023). A very significant report of autism self-advocacy community before the 1980s, the time when autism was not recognized officially, revealed by Karola, Dillenburger, and Mickey, Keenan (2023) that shares the crisis of discriminatory approach, the concept of ableism followed by medical model advocacy instead of a social model approach. This leads to misinterpretation and the least articulatory concerns regarding providing right-based equitable support services.

Lovaas first implemented the treatment ABA in the 1980s for the UCLA-Young Autism Project, which became very popular because of dramatic improvements in children with ASD (Makrygianni et al., 2018). Since the 1980s, numerous researchers, psychologists, and therapists have conducted various intervention studies to provide additional support to the effectiveness of the ABA method. They concluded that the ABA method improves children's adaptive behavior, language skills, and IQ scores and reduces autism-related symptomatology (Strauss et al., 2012). In comparison, the results of these studies vary due to environmental conditions, measuring parameters, intervention characteristics, subject characteristics, and evaluating parameters that lead to the effectiveness of ABA treatments and their efficacy.

As a result of meta-analytic studies, researchers (Peters-Scheffer et al., 2011, 2013; Virués-Ortega, 2010) defined ABA as treatment approaches that are (a) implemented systematically; (b) applied as early as possible, particularly before school age 3 to 6; (c) based on student-teacher ratio; (d) followed a typical development hierarchy; (e) used in collaboration with parent (Healy & Lydon, 2013). Early diagnosis of impairment of interpersonal skills in ASD children is essential for better language and communication skills of children (Gerhardt et al., 2023; Gillespie-Lynch et al., 2012). Even after six to eight weeks of intervention, children with ASD can develop and improve requesting skills in a spontaneous social context (Azeem, A., Faiz, Z., & Bashir, R., 2022). Julia L. Ferguson and Christine M. Milne (2023) restated the terminology used in 2016 by Leaf and colleagues, as progressive applied behavior analysis as a needed intervention strategy for ASD, followed by a response-friendly and flexibly structured approach for the learner, mainly incorporated with formative analysis of teaching social behaviors. Thus, the influential role of ABA in developing interpersonal skills in ASD children is the core need of the present world. Therefore, this pretest-posttest quasi-experimental research was designed to examine the effect of applied behavior analysis treatment on ASD children's interpersonal skills.

Theory of ABA as Treatments

The roots of ABA treatments emerged from the B. F. Skinner research work that suggested and confirmed that human behavior can be modified through a treatment process, parallel to Darwin's process of natural selection (Betz, 2011; Catania et al., 1988). Subsequently, Skinner explained that human behaviors can be modified to produce noteworthy outcomes through an intervention (a function of reinforcement) in a particular situation (Cummings & Carr, 2009). Skinner also illustrates how human behavior could develop or change over time through reinforcement called shaping (Smith & Ladarola, 2015). However, some other operant processes are also used to create new responses through modeling. The first ABA treatment for ASD children was developed by Ivar Lovaas, which is for behavioral intervention conducted 5-7 days per week (Lovaas, 1987).

Initially, ABA treatment was implemented as a one-tone format to develop learning skills and eradicate atypical behavior (S. M. Myers & Johnson, 2007). Subsequently, treatment becomes less structured for children to develop social and complex cognitive skills (Lerman et al., 2011). The ABA is generally applied around children 2 to 25 years old (for a shorter duration) as this age limit is crucial for developing social skills (LeBlanc et al., 2003). Various systematic reviews and meta-analyses support that ABA treatment is more effective for developing social skills than other interventions (Healy & Lydon, 2013; Peters-Scheffer et al., 2013).

Review of Related Literature

Numerous researchers described how applied behavior analysis (ABA) treatment plays a role in the outcome of the special needs of children having autism spectrum disorder (ASD) that are based on the interventions (Foxx, 2008; Lim & Draper, 2011). Thus, few focused on behavioral therapies of ABA treatments to enhance social skills in ASD learners (Matson et al., 2012; Petursdottir et al., 2007; Shukla-Mehta et al., 2010).

The deductive approved methods integrate interpersonal skills among autistic children comprehensively, while individual personality traits influence therapies. Therefore, reliable ABA programs are offered to overcome the special needs of autistic children. Advisors and guardians must be ready to carry out the projects in various situations, places, and situations involving different people to increase the interpersonal skills that the treatment endeavors successfully. Maladaptive behaviors, such as hatred and self-harm, are not strengthened, whereas explicit, correct elective behaviors are taught or maintained through a supportive environment (Foxx, 1982).

There is overwhelming observational evidence that early and severe conduct mediations require behavior analysis to produce observable and long-lasting practical improvements for autistic children. Parents who choose to use ABA-based intervention for their children are typically left alone with their support and have expressed discontent with the treatment condition. In addition, some experimental studies have been conducted to determine the effectiveness of the ABA program (McPhilemy & Dillenburger, 2013; Olubunmi et al., 2018).

ABA improves and changes socially significant practices within the context of the person's social condition. Adroitly efficient and intelligent, ABA accomplishes quantifiable changes in effective objective practices that last over time and conditions. It is also responsible, open, possible, enabling, and romantic. It is directed inside the logical system. It centers on utilitarian connections and replicable systems. Aversive methods keep a strategic distance from interventions that depend on accurate assessment, utilitarian research, and positive reinforcement (Zachor et al., 2007).

There are two levels of affirmation, guaranteed and directed by the Behavior Analyst Certification Board (BACB, 2007). Before completing a lengthy 4-hour test, Board Certified Conduct Analysts (BCBA) must have at least 1,500 hours of directed free hands-on work experience and a Master's degree level of preparation in conducting investigations. There are currently close to 3,500 BCBAs functional in the world to overcome autistic children's social skills. Board Confirmed Right-Hand Behavior Analysts (BCaBA), which replaced Board Certified Associate Behavior Analysts (BCABA) in January 2009, must have at least Bachelor's degree-level training in conducting the investigation and 1,000 hours of directed free hands-on work experience before taking the test. A BCBA should also manage them shortly after taking the test (Kazemi & Shapiro, 2013). To enhance various social skills, ABA is regarded as a treatment for autistic children in developed nations. To encourage parents, specialized facilities, hospitals, and clinics to adopt this approach and, through these tactics, assist children with autism in leading peaceful, ordinary lives in society, it is necessary to emphasize the value and effectiveness of ABA.

Because of this, the study's most important ABA and autism variable emerged and provided direction to conduct studies with and without treatment. In Pakistan, there are special education government institutes, psychologists, instructors, and doctors for kids with special needs. No qualified specialists appropriately evaluated autistic children or used a systematic instrument. Since ABA is new in Pakistan, many parents and even the directors of the institutions are hesitant to adopt the techniques. For many years, children with autism were enrolled in clinics or centers, and they made some small progress.

This research could be helpful to all behavior therapists, psychologists, government special education department heads, principals, and institution heads to understand how modern, scientific approaches aid in children's right skill development. Scientific methods cannot be the only means of developing robotic talents. These treatments modify people's and parents' minds to accept changes in society and centers. The goal of the current study was to demonstrate how ABA benefits autistic children and how it helps children gain interpersonal skills. With ABA therapy, researchers provide behavior therapists with various tools and procedures to help children develop social interaction skills. The present study answers multiple questions. First, does a post-test on social interaction skills in children with autism yield the same results as the pretest on interpersonal skills? Second, are there any notable differences between an ABA to foster social skills in autistic children? The scope of this study, which aimed to answer the concerns above, was limited by age restrictions, child diagnoses, the severity of autism, the IQ of the subjects, and the use of ABA therapy. All children included in this study were between 3 and 6 years old and had been diagnosed with mild autism. None of the kids were non-verbal.

Research Methodology

Research Design

A research design comprises numerous elements (i.e., research paradigm, research approach, research design, and data collection method that provide guidelines for the study (Creswell & Clark, 2017; M. D. Myers, 2019). Researchers adopted a positivist paradigm (quantitative approach). In contrast, the pretest-posttest design of quasi-experimental research was used to examine the effect of "clinic-based applied behavior analysis treatment on ASD children's interpersonal skills." Hence, a survey method was applied to collect data about participants' interpersonal skills two times (before and after intervention). The independent variable was applied behavior analysis treatment manipulated by the researchers to examine its effect on the dependent variable, interpersonal skills.

Participants

The researchers searched Google to collect information about clinics and centers in the Lahore district of Pakistan that are working to provide applied behavior analysis (ABA) treatment. It was found that forty (40) centers were providing behavior intervention services to children with autism spectrum disorder. The researchers selected one center to collect information about ABA treatment. At the same time, authorities informed them that they only used behavior and special needs services for children who are suffering from autism symptoms. The decision was made based on enrollment and the many cases in which they dealt with extensive experience and qualified staff. The researchers took permission from one center through a consent form to conduct this experimental study. Initially, researchers selected 36 children who have symptoms of ASD. The center reported that the target sample was already tested for IQ on TONI (Test for Non-verbal Intelligence), and those children had almost the same IQ range (60-75), were aged between 3 to 6 years old, and had mild symptoms of autism.

In contrast, six children were dropped from the experiment because they had comorbid disabilities. Thus, a purposive sampling technique was used to select 30 children who were latterly divided into two groups (i.e., control and experimental) without gender discrimination based on their assessment scores. The inclusion criteria were established and focused on the selected children: i) visit the center from Monday through Friday. ii) can follow a therapist's instructions, iii) speak 4 to 5 phrases, words, and sentences. Before the setup, the researchers followed the approval meeting protocol with parents and the director of that setup, outlining the study's goal and every process step in detail. As a result, both parents and the center director signed the approval letters. In order to determine the children's level, communication and social skills assessment through ABLLS-R and portage guide of early education were performed with each child by the researchers before the beginning of "Clinic-based ABA therapy" and compared with already performed assessment results at the center. After a satisfactory comparison, the intervention took place.

Measures

The researchers developed a pre-assessment and post-assessment tool (questionnaire) by taking help from the assessment of basic language and learning skills (ABLLS-R) protocol and portage guide of early education (main focus was language/communication and social milestones). The ABLLS-R protocol is an evaluation instrument used to measure language, social communication, and social interaction skills among children with autism spectrum disorder. In contrast, the portage guide of early education is used to measure developmental milestones according to infant stimulation, cognition, speech/language, motor, social, and self-help skills of children from birth to 5 years of age. The researchers picked up the goals from the social and language section of the portage guide to early education. Thus, researchers developed a questionnaire that was divided into two sections. In the first section, the Child's demographic information was asked, while the subsequent section consisted of four interpersonal skills sub-constructs (i.e., social group skills, peer interaction, social communication, and interaction, and appropriate behavior). The first sub-factor dealt with social group skills had ten statements. The second sub-factor dealt with peer interaction and had six goal statements. The third sub-factor dealt with social communication and interaction and also had six statements. The fourth sub-factor dealt with a child's appropriate behavior and had eight statements. Both groups completed the questionnaire before and after an intervention. The researchers systematically gave the experimental group "Clinic-based ABA therapy," which consisted of 45 minutes with each student five days a week.

Instrumentation

The assessment of basic language and learning skills (ABBELS-R) protocol of the social interaction domain originally consisted of 34 items. To execute the current research, each item was named "a social goal" for children with autism spectrum disorder. However, in Portage Guide of Early Education, the selected goal statements comprised 83 "peer interaction goals" items. The researchers merged all the goals of both protocols by avoiding duplication and developed a questionnaire comprising 38 items. Each goal was divided into four-point Likert-type percentages (i.e., the child's Master of goal percentage falls between 80 to 100%; the child at a competent level of goal percentage falls between 60 to 80%; the child; the child at a developing level of goal percentage falls between 40 to 60%, and child score less than 40% knows as a child has no social interaction skills. The overall percentage of all goals shows in percentage as (0%-40%, 41%-60%, 61%-80%, and 81%-100%), which means the range of interpersonal skills falls among no improvement, slight improvement, developing improvement, and mastery improvement. Five assessment experts validated the instrument, keeping in view the valuable comments of the experts, eight items/goals were omitted (due the risk of response duplication), and five were modified. Thus, the final questionnaire consisted of four sub-factors and 30 items/goals. However, the instrument's reliability was calculated through Cronbach alpha statistics (0.896), which was acceptable. Before starting the treatment, the researcher made a sheet in which all goal names were mentioned, and the discriminative stimulus (SD), introduced date, and mastered date in a written form. Another sheet was made for every trial recording and percentage. In the end, this percentage helps to know which goal was mastered and which skill was developed in a child's during a marked time duration. The Control group treated with the traditional method used by the center was the experimental group treated with "Clinic based ABA therapy/treatment," while the environment, time, and therapists were the same for both groups.

Data Collection Procedure

The experimental group was treated through "Clinic based ABA therapy," while the control group was treated with the traditional method. The researchers follow the ABA protocol structure and properly address the rules of measures. Each target receives five trials every day. A score of 20% is equivalent to each trial mark, and 4 levels of prompts were given by examining the child's requirement. Table 1 below contains the Mark sheet, which helps you understand the requirements.

Treatment Duration

The treatment continued for six months (September 2022 to February 2023). A total of 30 children took part in the trial. Five days a week, the researchers offered each child 45 minutes to complete many concurrent goals listed in the instrument. Time and goals for each day's performance during therapy were maintained in a child's portfolio.

Procedure

The researchers taught behavioral therapists and practiced ABA therapy in a private clinic. They completed a registered behavior technician (RBT) program to learn ABA therapy and have complete control over managing autistic children while providing behavior therapy. For participants in the control and experimental groups, five sessions per week were planned for kids with autism. Five sessions comprised a week's five days (Monday through Friday). Each session lasted 45 hours. The same criteria were applied to both groups, but participants in the experimental group received "Clinic-based ABA therapy", while those in the control group received standard, unstructured instruction. Within the same clinic, three therapists treat youngsters. Both groups used the same clinic, measurements, atmosphere, time, and assessment techniques, but the criteria differed. Session description was divided into 4 phases, which were described below:

Phase 1: The two rooms were initially configured by therapists following the needs of the therapy. One room was correctly organized and built, following ABA guidelines. According to the pre-assessment results,

Table 1:
Running Goals Record for Every Trial Each Day

Statement #	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Prompt Level	Total Percentage
1	+	+	_	_	_	2	40
2	+	_	_	+	+	1	60
3	+	+	+	+	_	3	80
4	+	+	+	+	_	3	80
5	+	+	+	+	_	3	80
6	+	+	_	_	_	2	40
7	+	+	_	_	_	2	40
8	+	+	+	+	_	1	80
9	_	+	_	+	+	2	60
10	+	+				1	40
11	+	+	+	+	_	1	80
12	+	+	+	+	_	2	80
13	+	+	+	_	_	2	60
14	+	+	+			1	60
15	+	+	+	_	+	3	80
16	+	_	+	_	_	1	40
17	+	+	+	_	_	2	60
18	+	+	+	_	_	2	60
19	+	+	_	_	_	2	40
20	+	+	+	+	_	1	80
21	_	+	_	+	+	2	60
22	+	+				1	40
23	+	+	+	+	_	1	80
24	+	+	+	+	_	2	80
25	+	+	+	_	_	2	60
26	+	+	+			1	60
27	+	+	+	_	+	3	80
28	+	_	+	_	_	1	40
29	+	+	+	_	_	2	60
30	+	+	+	_	_	2	60

the room's tables and chairs were arranged, and each student is given a basket. Researchers used an instrument to pre-assess all the chosen children before beginning treatment, and they then established the baseline for each aim. The amount of work therapists begin depends on where the child falls—pre-assessment results in almost all the kids falling into the same level. Every child in the experimental group also had an objectives chart and a reinforcement plan created by the researchers. A reinforcement schedule was then created and pasted into each child's file by ABA behavior therapy practitioners. Another room had previously been selected to use the conventional session layout. Researchers mapped every child's body when they entered the center, and when they left, parents signed and got their children. Body mapping includes the child's behaviors and shows them to the parents so they may start cooperating during the sessions. The ABC (antecedent, behavior, consequence) model displays all behavioral data. This form, which is only available to members of the experimental group, aids in understanding why this behavior occurs.

Phase 2: In the second phase, therapists separated the group into two sub-groups of 10 youngsters, five in the control group and five in the experimental group. The therapists and researchers remained consistent and met with the child in person. The researcher begins developing pairing or repo building with the youngster in the experimental group. During this process, the researcher offers the child a free hand, lets the youngster choose whatever they want, and continues to play with the child. The primary tenet of the "Clinic-based ABA therapy" ABA is to instill in a child that they are the therapist's employees and must obey all of the therapist's instructions. The establishment of a rapport between children and therapists took two weeks. Therefore, the therapists never made the child sit or work against their will. However, the control group members showed up and engaged in lonesome play. Therapists don't give the child their whole attention and don't interact with them constantly. Therapists run goals side by side while partnering.

Phase 3: Therapists utilized prompt levels when administering "Clinic-based ABA therapy" to experimental group children. There were four steps at the prompt level (complete physical, partial physical, light touch, and independent level). These actions assist in the systematic development of a child's talents. Therapists used those stages to carry out aims during sessions. Therapists used a baseline to create sheets with all goals written out and properly run plans. Therapists never gave the child the same instructions twice. In addition, the child was physically and mentally active for 45 hours. When working with the control group, therapists never used any level of prompting before beginning in an unstructured style and giving the child control. If a youngster makes eye contact, the therapist repeats the instruction/s.

Phase 4: In the last phase, therapists drop the children's level and continue considering the starting level where the child in the experimental group demonstrates no improvement in any goal. The control group attempts all goals inappropriately. Therapists discontinue the objective and move on to the next one if the child doesn't respond. The details of week-wise activities with the treatment and control groups are in Table 2.

Table 2
Work of Control and Experimental Group

Work according to weeks	Control Group	Experimental Group
Month of September	start with pairing	start with pairing
Last week of September and the Start of November	Start run goals without developing reinforcement Schedule	pairing also takes a preferred assessment of reinforcement
The third week of the November	session, run anywhere, not sit in a table chair. also, start with the 15 goals	Compulsory to sit in a table chair that increases the compliance level of a child and start running goals. Select 2 to 3 goals from each domain
Month of December	start with the 15 goals	start with goals with a preferred item of a child Reinforcement schedule
The first week of January	all goals run side by side	after achieving seven primary goals, Add more goals
Third week of January	use reinforcement, not proper schedule design, and work on all 30 goals	runs all goals according to the data results entered in a file
The second week of February	achieved goals closed run non achieved goals run	Achieved goals added as a maintenance goal also run other goals as acquisition goals
Fourth week of the February	post-assessment	post-assessment

Data Analysis

The statistical package for social sciences (SPSS version 24) software was used to apply inferential statistics to collect data for analysis. The researchers applied independent samples t-test, paired samples t-test, and Univariate Analysis of Variance test to find out the difference between the control and experimental groups and to examine the effect of applied behavior analysis treatment on ASD children's interpersonal skills.

Ethical Considerations

All ethical norms were observed in this study, ensuring respondents' anonymity. The University of Management and Technology Lahore granted Ethical approval to conduct the study (Approval No: 236-06-09-2022).

Results

Table 3:
Pre-Assessment Scores of Children Regarding Interpersonal Skills

Factor	*M*	*SD*
Social Group Skills	2.71	1.021
Peer Interaction	2.63	1.624
Social Communication & Interaction	2.21	1.352
Appropriate Behaviors	2.81	1.873
Overall Interpersonal Skills	2.74	1.406

Note: N=30.

Table 3 shows the results of children's pre-assessment scores of their interpersonal skills and their sub-factors. It is depicted that children develop level-appropriate behaviors that were higher than social group skills, peer interaction, and communication & interactive skills as the *M= 2.81; SD=1.873*> than *M=2.71; SD=1.021; M=2.62; SD= 1.624;* and *M=2.21; SD=1.352*, respectively. However, the least contributing factor was social communication and interaction among children. Moreover, the mean score of overall interpersonal skills indicated that children have developing level interpersonal skills as *M=2.74; SD=1.406.*

Table 4:
Comparison of Control Group of Children Pretest and Post-test Scores of Interpersonal Skills

	Pretest		Posttest		*t*	*df*	*p*	*g*
	M	*SD*	*M*	*SD*				
SGS	2.43	.652	2.61	1.004	1.331	28	0.249	0.187
PI	2.92	.946	3.07	.974	1.526	28	0.846	0.284
SCI	2.99	.639	3.23	1.045	.939	28	0.987	0.235
AP	2.87	.474	3.01	1.235	1.427	28	0.496	0.139
OIS	2.68	.737	2.94	.934	-1.430	28	0.167	0.273

Note: N= 15; SGS: Social Group Skills; PI: Peer Interaction; SCI: Social Communication and Interaction; AB: Appropriate Behaviors; OIP: Overall Interpersonal Skills; g= Hedge's g; and * = p < 0.05.

To compare the difference between the pretest and post-test scores of the control group regarding their interpersonal skills, a paired sampled t-test (Table 4) was applied. The results showed no statistically significant difference between pretest and post-test scores of children's overall interpersonal skills, and all the four sub-factors as *t* (28) = -1.430, *p* (0.167); *t* (28) = 1.331, *p* (0.249); *t* (28) = 1.1526, *p* (0.846); *t* (28) = .939, *p* (0.987); *t* (28) = 1.427, *p* (0.496) respectively. In contrast, the values of Hedge's *g* indicated a small (0.1 to 0.2) effect size (Albers, 2017; Fallon, 2016) as *g* = 0.273, 0.187, 0.284, 0.235, and 0.139. Thus, the null hypothesis, "There is no significant difference between the pretest and a post-test score of a control group of children's interpersonal skills," is accepted.

Table 5:
Comparison of Experimental Group of Children Pretest and Post-test Scores of Interpersonal Skills

	Pretest		Posttest		*t*	*df*	*p*	*g*
	M	*SD*	*M*	*SD*				
SGS	2.43	1.271	3.75	2.982	3.743	23.673	0.001*	0.576
PI	2.92	1.843	3.87	2.964	-4.765	24.984	0.000*	0.563
SCI	2.99	1.759	3.83	1.834	-3.652	24.733	0.001*	0.706
AP	2.87	1.834	3.79	1.851	2.934	27.634	0.003*	0.687
OIS	2.68	1.807	3.69	2.863	-8.981	25.097	0.000*	0.609

Note: N= 15; SGS: Social Group Skills; PI: Peer Interaction; SCI: Social Communication and Interaction; AB: Appropriate Behaviors; OIP: Overall Interpersonal Skills; g= Hedge's g; and * = p < 0.05.

To compare the difference between the pretest and post-test scores of the experimental group regarding their interpersonal skills, a paired sampled t-test (Table 5) was applied. The results showed a statistically significant difference between pretest and post-test scores of children's overall interpersonal skills and all the four sub-factors as *t* (25.097) = -8.981, *p* (0.000); *t* (23.673) = 3.743, *p* (0.001); *t* (24.984) = -4.765, *p* (0.000); *t* (24.733) = -3.652, *p* (0.001); *t* (27.634) = 2.934, *p* (0.003) respectively. In comparison, the values of Hedge's *g* indicated medium to large (0.5 to 0.7) effect size (Albers, 2017; Fallon, 2016) as *g* = 0.609, 0.576, 0.563, 0.706, and 0.687. Thus, it is concluded that applied behavior analysis treatment significantly affected the experimental group of children's interpersonal skills. Therefore, the null hypothesis, "There is no significant difference between the pretest and post-test score of the experimental group of interpersonal skills," is rejected.

Table 6:

Comparison of Control and Experimental Group Children Post-test Scores of Interpersonal Skills

	Control Group (15)		Experimental (15)		*t*	*df*	*p*	*g*
	M	*SD*	*M*	*SD*				
SGS	2.93	1.221	3.86	2.083	-2.812	26.156	0.041*	0.544
PI	3.21	1.743	3.78	2.093	-2.035	25.987	0.039*	0.487
SCI	3.17	1.604	3.81	1.934	2.412	26.593	0.016*	0.512
AP	3.26	1.935	3.73	1.957	1.452	28	0.082	0.134
OIS	3.08	1.203	3.76	2.004	-3.074	25.073	0.001*	0.629

Note: N= 30; SGS: Social Group Skills; PI: Peer Interaction; SCI: Social Communication and Interaction; AB: Appropriate Behaviors; OIP: Overall Interpersonal Skills; g= Hedge's g; and * = p < 0.05.

To compare the difference between the post-test scores of the control group and experimental group regarding their interpersonal skills, an independent sampled t-test (Table 6) was applied. The results showed a statistically significant difference between the control and experiment group children's interpersonal skills as *t* (25.073) = -3.074, *p* (0.001). At the same time, the values of Hedge's *g* indicated a large (0.6) effect size as *g* = 0.629. Thus, it is concluded that applied behavior analysis treatment significantly affected autism spectrum disorder children's overall interpersonal skills. Thus, the null hypothesis "There is no significant effect of applied behavior analysis treatment on autism spectrum disorder children interpersonal skills" is rejected.

Moreover, there was a significant difference in the control group of children's social group skills, peer interaction, and social communication & interaction as compared to experimental groups as *t* (26.156) = -2.812, *p* (0.041); *t* (25.987) = -2.035, *p* (0.039); *t* (26.593) = 2.412, *p* (0.016), respectively, whereas the values of Hedge's *g* showed medium (0.4 to 0.5) effect size. However, there was no significant difference between the control and experimental groups of children's appropriate behaviors as *t* (28) = 1.452, *p* (0.082).

Table 7:

Univariate Analysis of Variance among Two Groups

	N	*M*	*SD*	*f*	*df1*	*df2*	*p*	r^2
Control Group	15	34.67	19.223	.206	1	28	.653	.156
Experimental Group	15	52.00	22.424					

Table 7 (control and experimental) displays the variance analysis between the two groups. The findings indicate that the experimental group exhibits greater progress than the control group *M* = 34.67, *SD* = 19.223; *M* = 52.00, *SD* = 22.424; *p* = .653).

Discussion

Researchers examine the effect of "Clinic-based ABA therapy" (ABA) on interpersonal skills of autism spectrum disorder (ASD). They used the pretest-posttest design of quasi-experimental research while a survey method was applied to collect data two times (before and after intervention). The researchers selected 30 participants from the 3 to 6 age group of children divided into two groups (experimental and control). The children have mild symptoms of autism that were already diagnosed by the center where they enrolled. The selected children can speak 4 to 5 phrases, words, and sentences by following the command of the therapist. The researchers gave ABA treatment to the children chosen, which lasted six weeks. The researchers developed a pre-assessment and post-assessment tool comprising four interpersonal skill sub-factors. Descriptive and inferential statistical techniques were applied to examine the effect of ABA treatment on ASD children's interpersonal skills. The pre-experimental results showed that children have no proper eye contact and no proper response when called names.

Moreover, they are less able to communicate easily with others and prefer to play individually. Children cannot share toys with peers, whereas throwing and hitting behaviors exist. It is also depicted that children must develop level-appropriate behaviors compared to social group skills, peer interaction, and communication & interactive skills. At the same time, the least contributing factors were social communication and interaction among children. Numerous researchers found similar results before the treatment of ABA; children develop interpersonal skills (Eldevik et al., 2010; Virués-Ortega, 2010).

After the pre-assessment results, researchers formed two groups and started giving treatment: the control group, using the traditional method, and the experimental group, using the ABA treatment. Afterward, researchers compared the pretest and post-test scores of the control group regarding their interpersonal skills and found no statistically significant difference between pretest and post-test scores of children's overall interpersonal skills and all four sub-factors; these findings support the findings of (Abid et al., 2022; Aslam et al., 2022; Eldevik et al., 2010) and inconsistent with the results of (Gillespie-Lynch et al., 2012; Kasari et al., 2010). Moreover, researchers also compared the difference between the pretest and post-test scores of the experimental group regarding their interpersonal skills. They found a statistically significant difference between pretest and post-test scores of children's overall interpersonal skills and all four sub-factors (i.e., social group skills, peer interaction, social communication & interaction, and appropriate behaviors). These results have supported the findings of (Dillenburger & Keenan, 2023; Matson et al., 2012; Özerk, 2016, 2018; Petursdottir et al., 2007; Shukla-Mehta et al., 2010), who found a significant difference between pretest and post-test scores of children before and after the ABA treatment regarding complex cognitive abilities and communication skills.

Furthermore, the researchers found a significant difference between the control and experiment groups of children's interpersonal skills, concluding that applied behavior analysis treatment significantly affected autism spectrum disorder children's overall interpersonal skills and sub-scales. Numerous studies concluded the significant effect of ABA on ASD children's communication skills, supporting the study findings (Gunadi, 2019; Leaf et al., 2016; Mohammadzaheri et al., 2014; Strain & Schwartz, 2001). Previous research indicates that ABA therapy benefits the development and requesting relationships of children with autism via various strategies (Strain, Schwartz, & Disabilities, 2001). There is ample empirical evidence in the literature that early and severe behavior mediations based on behavior analysis result in visible and long-lasting practical benefits for the enhancement/development of different dimensions of social skills in children with autism (Azeem.A., Faiz & Bashir, R., 2022).

Limitations and Direction for Future Researchers

The researchers faced some difficulties while conducting this study, i.e., unavailability of early assessment centers for ASD, especially at the state level (Public sector schools/centers/clinics), unavailability of many centers that provide authentic ABA treatment by licensed practitioners, less enrollment of autistic children in public and private sector institutes, no proper facilitation for children, and researchers. Future researchers may use other variables (i.e., enablers, psychologists' characteristics, cognitive and non-cognitive variables) that significantly develop interpersonal skills. They may also plan intervention studies to seek the role of other therapies in developing social skills in children with an autism spectrum disorder. The current research findings reflect that after authentic assessment, the children with autism are consistently provided with authentic applied behavior analysis therapeutic intervention, resulting in a desirable change in all aspects of social behavior: language skills, social and interpersonal skills, and a clear understanding of the contextual obligations. Likewise, the study aimed to examine the effect of applied behavior analysis (ABA) treatment on interpersonal skills in children with autism spectrum disorder (ASD), which was achieved through the experimental study conducted in the Pakistani context. At the same time, future researchers can select ASD children for intervention studies from other countries to share the possibilities to increase the generalizability of all types of ABA therapy through the findings of their research. Moreover, future researchers may design longitudinal studies to examine variations in ASD children's behaviors over time through the changes in conditions.

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This fact should be taken into serious account since in this current post-pandemic phase, teachers are the ones expected to be the frontliners of restoring a disruptive education system through their leadership to ensure the opportunities of continued teaching and learning process (Sawalhi & Chaaban, 2023). Prior studies (Eltanahy, 2018; Wenner & Campbell, 2017; Killion, et.al, 2016) showed that teacher leadership has been contemplate as one of the main aspects which elicits the quality of teaching and learning and the efforts of school improvement after pandemic because teachers are able to properly develop teaching practices both inside and outside the classroom. In South Africa education context, Klerk & Smith (2021) said that significant challenges for schools due to unparalleled catastrophe remain teachers as leaders who should take steps to transform and making that transformation process in schools becomes much easier. In a research and development study, they proposed transformative intervention strategies (TIS) to empower teachers' role as leaders in their schools amid the pandemic and beyond.

In national education of Indonesia, one of the goals of 'independent curriculum' policy is to facilitate students' freedom to learn through learning transformation and, Sihotang, et.al., (2023) said that this objective can only be achieved with the efforts of teachers to have leadership insight in order to support educational ecosystem. Their qualitative study revealed that independent learning built through teacher leadership is urgent to overcome learning loss at this current post-pandemic. In similar vein, Singh (2024) argued that educational leadership holds pivotal role in education in India to promote continues learning, safe and supportive learning zone for students as the elements of independent learning, particularly after disruptive education system during and after Covid-19. Due to its crucial role to keep quality learning process and outcomes, proposing a model of teacher leadership which promotes independent learning will obviously give positive contribution to educational system of the world since the impacts of school closures in pandemic has been affecting all countries.

According to Kende (2020), teachers are required to have a transformation to strengthen education scope and system, oriented to 'quality' by having an excellent strategical role, professional vision, and learning leadership character. Muff, et.al., (2020), added that leadership could be created through sustainable action as an ability to make a weak system becomes irrelevant. This approach covers four dimensions, i.e., 1) having systemic thought, 2) placing school and its communities as one unity, 3) facilitating every individual to analyze function, and, 4) maximizing role and inter-pendent among components. These abilities become the basis to improve teachers' capacity in managing process and transformation of leadership for learning. Further, Muff, et.al., (2020) added that transformation process or transformation of change is a collaborative effort to find positive things in individuals and organization, based on strengths; analyzing problems and the causes and fixing them for a better improvement in the future.

As the world is currently in the phase of post-pandemic in which most students have been experiencing learning loss during the school closures, guiding them to become independent learners seen to be emergency. Education becomes more dynamic, instructional process is not fully back to traditional system yet in which most of schools is still conducted hybrid learning. Thus, students' autonomy and independence are needed called 'independent learning'. In accordance to this, leadership for learning of the teachers is obviously demanded. Teachers who possess leadership for learning are professionals and optimistic to bring a change of excellent quality in education (Leithwood, et.al., 2020). Besides, Luksha & Kinsner (2020) explained that theories and empirical studies showed that leadership role in teachers transformed the learning process to be superb and it was in line with the learning of 21st century. Leadership for learning of teachers becomes a model of developing their pedagogical competence, both in soft and hard skills. This should be started from doing sustainable action and a transformational of change to achieve high quality of learning process (Schlusche, et.al., 2023; Alimo-Metcalfe & Alban-Metcalfe, 2013).

Independent learning is experienced by students when teachers are able to set goals, strategies and assess the learning based on students' competence without neglecting their individual characters, and this independent learning is formed once students are able to develop themselves (Masters, 2023). In independent learning, students have their autonomy and freedom to motivate and inspire themselves to understand and be skillful in learning (Tran & Vuong, 2022). Salendab (2023) opined that in independent learning, students have the ability to determine and possess what they want to learn, how and when to learn it, and what the objective of their learning is. Independent learning makes every student able to develop their own metacognitive skill (Anca, 2023), as the power to understand, organize and introduce his/her own thinking process (Jannah & Fadillah, 2021). This skill of thinking is very important for students in independent learning in order to grow and develop themselves to become critical and reflective individuals (Iloka, 2022). Independent learning gives a meaning that students are able to be responsible for their own learning experiences, as the pillars for long-life learning.

In accordance to this, the discussion on teachers' leadership has been arising various issues posed by scholars and researchers. In the late 40 years, empirical studies about leadership for learning mostly explored leadership in managing education and students' achievement including the implementation of learning method and educational leadership with the aspects of credibility, reflections, emotions, openness to experiences and values (Antonacopoulou & Bento, 2003); the skills of leadership for learning which is facilitated, reflective, and team-work oriented (Hirst et al., 2004); the perspectives of values, contexts, and leadership sources (Hallinger, 2011); and, individual characteristics of educator and organization in shaping skill of leadership for learning (Susanto et al., 2019). The researches on specific dimensions of learning leadership model which covers sustainable action and transformational of change were still scarce. Thus, in this study, the researchers endeavor to explore how learning leadership model constructed by sustainable action and transformational of change and quantitatively report the correlation between learning leadership to independent learning. Based on the conceptual theories above, the researchers aimed to find the answers of the following research questions: 1) What are the validity and reliability of sustainable action and transformational of change in the construction of learning leadership model? 2) How significant is learning leadership correlated to independent learning? The researchers believe that the findings of this research work will positively give insights to pedagogical practices, especially primary school teachers that enhance independent learning and help educators to refine their teaching strategies. Besides, this study also contributes to the broader discourse on educational leadership shedding light on the important role teachers hold in shaping independent learners.

Sustainable Action in Teacher Leadership

Theoretical and empirical studies are strengthening the transformation that the process of learning excellence begins with placing the role of learning leadership with actions to transform 21st century learning patterns (Schlusche et al., 2023). The task of leadership in the learning leadership model is to create alignment of strengths by making system weaknesses irrelevant and with the approach of sustainability actions and transformation of change (Alban-Metcalfe & Alimo-Metcalfe, 2018). The concept of sustainable development (sustainability) is the empowerment of students' ability to take appropriate actions, be responsible, and make decisions. Sustainability Action is an action in thinking systemically, continuously and placing schools and their communities as a whole, facilitating individuals to examine functions, roles and interdependencies between components. In a broader perspective, Müller, et.al. (2020) discussed Education for Sustainable Development (ESD) in which it encourages people to act and think in a positive way for the future. At this point, education takes a significant role in sustainable societies. Cook (2014) said that "the establishment of high-quality sustainable educational leadership is essential to the continual growth of schools beyond the leader's tenure at the school" (p. 3). Learning leadership is a concrete and strategic effort of teachers that must be pursued to guide and optimize the potential of students. Learning leadership requires teacher creativity and innovation in creating an educational organization's learning environment and culture that must continue to develop sustainably (Oppi et al., 2020).

There are seven principles of sustainable leadership developed by Hargreaves and Fink (2003) cited by Cook (2014), namely: 1) creating and preserving sustained learning; 2) securing success over time; 3) sustaining the leadership of others; 4) addressing the issues of social justice; 5) developing rather than depleting human and material resources; 6) developing environmental diversity and capacity; and 7) undertaking activist engagement with the environment.

Transformation of Change in Teacher Learning Leadership

One of the emerging factors in educational discourse is the concept of learning leadership. Learning leadership encompasses the critical role of educators in creating environments that nurture students' capacity to become independent learners (Demanuele & Calleja, 2023). By demonstrating inspiring and empowering qualities, teachers can play a transformative role in shaping the way students learn (Hayward et al., 2023). Learning leadership has the meaning of how teachers in their roles are able to motivate, direct and support students for changes in learning behaviour.

Learning leadership is a tangible manifestation of the teacher's role in the task of guiding and facilitating academic growth. This ability is clearly seen from the application of innovative and student-centred learning methods. Teachers who have learning leadership qualities are teachers who are able to create an environment that encourages active participation, critical appraisal and learning autonomy in students. The learning leadership approach is closely related to the dimension of continuous action. This continuous action is a pedagogic strategy that contributes to the long-term development of students' learning abilities.

"School improvement depends on all teachers' efforts to take responsibility for change and transformation" (Bolat, 2023, p. 100). Transformation of learning leadership into a pedagogic competency development model, as a soft and hard skills basis for preparing teacher competencies. The ability to transform change includes: (1) the ability to use existing components in the organizational environment, (2) the ability to develop the economy for optimal learning, (3) the ability to focus learning experiences that hone the optimization of the existence of the educational community (teacher and student welfare, and (4) the ability to develop values in the cultural system.

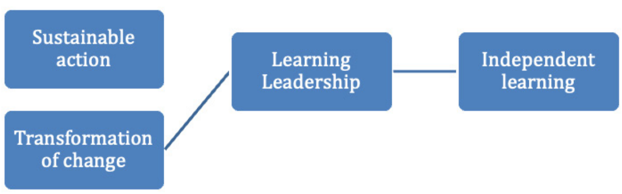
Teachers' Learning Leadership Model

"Teachers led by learning and learn by leading" (Lovett, 2023, p. 1014). This axiom was explained by Lovett that teachers' work aimed to improve student learning, thus, they need to learn to develop their knowledge since it serves as the seeding ground for teacher leadership as professional influence. Ye, Wang, & Weerasawainon (2024) opined that teacher leadership is demanded by current dynamic educational system in which their leadership style will give positive growth and change within educational system.

Wolff, et.al. (2022) said that as a social phenomenon, education needs a transformation and sustainability discourses. Transformation of change adapts critical attitude, habits, and minds to transform conventional teaching to a more sustainable life at schools. Education system needs a change to secure a sustainable future (Shephard, 2015), therefore, teachers as the agents of change of schools are required to apply leadership learning model that composes transformative and sustainable action.

Referring to the review of literature previously discussed, this study proposes a model of teachers' learning leadership as displayed in the following figure:

Figure 1.
Teachers' Leadership Learning Model



Independent Learning

Learning independence is closely related to students' ability to develop learning skills and becomes a principle of lifelong learning. In the context of education, freedom of learning emphasizes that humans basically need independent learning, that is, humans who are born free and mentally independent in learning (Niemczyk, 2023). Livingstone (2012) explained that independent learning is a process of learning in which the learners self-regulate, direct and assess their own learning. Thus, an independent learner will be able to set objectives, take decisions and make options to support his/her needs in learning and responsible for any single process and progress. Qizi & Kobiljanovna (2021) argued that students cannot become independent learners unless they have to work with their teachers, show their strategies in learning, build their own learning zone, and learn 'how to learn'. At this stage, teachers play their roles to promote this independent learning on the basis of process-oriented teaching that facilitates students to be actively engage in the learning process.

According to Naibaho (2019), as part of cognitive learning theory, in independent learning, student's achievement is affected by several facets, including motivation, behaviour, and learning environment. Thus, an independent learner shows his/her abilities to be actively involved in learning in terms of motivation, metacognitive, and focus to achieve their learning objectives (Meyer, et.al, 2008). Independent learning is reflected by learning conditions filled with happiness, free from stress and students get educational environment that is able to optimize the achievement of 4Cs competencies (critical thinking, creativity, collaboration and communication). These competencies are needed to counter the challenges of future work in 21st century (Miller, et.al, 2023). They further explained that the 4Cs are interrelated four basic elements important to help students develop their cognitive potentials.

Methods

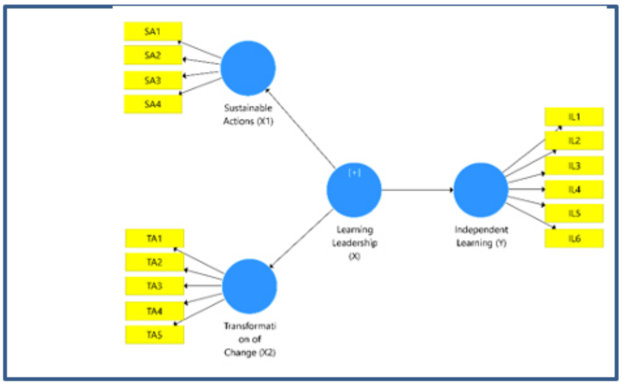
A quantitative descriptive method is applied as the research approach in this study. In order to measure how sustainable action and transformational of change and all their indicators correlate to learning leadership, and how significant this learning leadership correlates to independent learning, a questionnaire composing 4 indicators of sustainable action (Meth, et.al, 2023; Muneeb, et.al., 2023; Xing, et.al, 2023; Aaron, et.al., 2021; Al-Kubaisi, et.al., 2020), 5 indicators of transformational of change (Schiuma, et.al., 2022; Carney, 2022; Gurr & Drysdale, 2020; Fisher, et.al., 2018; Nair, 2023), and 7 indicators regarding independent learning (Erkinovna, 2022; Prameswari, 2020; Koutroubas & Galanakis, 2022; Marín & Castañeda, 2023) was constructed.

In order to get its clarity, relevancy, reasonability and unambiguity, face validity was taken. With the help of raters; two experienced teachers who are competent in teacher leadership, the researchers did five stages of having face validity, namely: 1) preparing face validity form, 2) discussing and choosing the experts, 3) distributing the form, 4) reviewing and revising the feedback from the validators, and, 5) finalizing the questionnaire items based on the % results of which items should be used. To get clear picture of teachers' readiness in applying sustainable action and transformational of change and also building independent learning, several statements covering the profile of each variable were formulated into a- 5-Likert scale questionnaire with the options of 'always' (5), 'often' (4), 'rarely' (3), 'sometimes' (2), and 'never' (1). This questionnaire was made into Google Form and distributed online to all respondents.

The population in this study was all Elementary school teachers in the three areas of West Jakarta, Indonesia. There were totally 77 teachers approached by the researchers through convenience sampling. However, only 59 of them who fulfilled the questionnaire completely. This might due to several activities that some teachers needed to join, such as workshop, seminar, training, etc., hence they were unable to contribute giving their response based on the researchers' deadline.

The analysis involved rigorous statistical techniques including Structural Equation Modelling (SEM) PLS to measure the validity and reliability of each variable and to elucidate how significant the relationship between one variable to another. Meanwhile, in order to measure the correlation between teachers' learning leadership and independent learning, a statistical analysis of regression was used.

Figure 2.
Learning Leadership Model



X = Learning Leadership

X1 = Sustainable Action

X2 = Transformational of Change

Y = Independent Learning

Research Hypotheses:

[1]: The more effective the learning leadership is, the more optimal independence of learning will be.

[2]: The higher the ability of sustainable action is, the more effective leadership for learning will be.

[3]: The higher the ability to apply transformational of change is, the more effective leadership for learning will be.

Results

Construct Validity and Reliability of Learning Leadership Model

The construct validity and reliability test showed the indicator size reflects the theoretical latent construct through Confirmatory Factor Analysis (CFA) as presented in the following Table 1.

Table 1.
Construct Validity and Reliability

	Cronbach's Alpha	rho_A	Com-posite Reliability	Average Variance Extracted (AVE)
Independent Learning (Y)	0.847	0.912	0.895	0.593
Learning Lead-ership (X)	0.936	0.937	0.946	0.663
Sustainable Action (X_1)	0.883	0.883	0.919	0.740
Transformation of Change (X_2)	0.896	0.898	0.923	0.707

Based on table 1, validity and reliability analysis data were obtained. This analysis assesses the quality of the measurement scale used in the study and its ability to accurately measure the model-forming construction as follows:

1. Independent Learning (Y), with Cronbach's Alpha (0.847), rho_A: 0.912, Composite Reliability 0.895, and Average Variance Extracted (AVE): 0.593 describes the values of the Learning Independence (Y) measurement scale indicating good internal consistency (Cronbach's Alpha and rho_A) and reliability (Composite Reliability). However, the Average Variance Extracted (AVE) is 0.593, which indicates that 59.3% of the variance in the observed variable is obtained from the latent construct of Independent Learning (Y). This indicates an acceptable degree of convergent validity.

2. Learning Leadership (X), Cronbach Alpha: 0.936, rho_A: 0.937, Composite Reliability 0.946, and Average Variance Extracted (AVE): 0.663 describe values from the Learning Leadership measurement scale (X) indicating high internal consistency, reliability, and convergent validity. Cronbach's Alpha, rho_A, and Composite Reliability scores are all above 0.9, indicating excellent reliability. An AVE of 0.663 describing values from the measurement

scale indicates that 66.3% of the variance in the observed variable is captured by the latent construct of Learning Leadership (X), indicating good convergent validity.

3. Sustainable action (X1), Cronbach Alpha: 0.88, rho_A: 0.883, Composite Reliability: 0.919 and Average Variance Extracted (AVE): 0.740 describe the values of the measurement scale for continuous action (X1) indicating strong internal consistency, reliability, and convergent validity. All metrics, including Cronbach's Alpha, rho_A, Composite Reliability, and AVE, show that the scale reliably measures the latent construction of continuous action (X1).

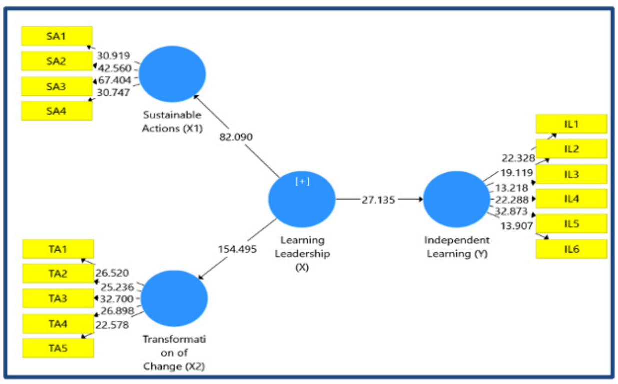
4. Transformational of Change (X2), Cronbach Alpha: 0.896, rho_A: 0.898, Composite Reliability: 0.923, and Average Variance Extracted (AVE): 0.707, describing the values of the measurement scale for Change Transformation (X2) also indicate good internal consistency, reliability, and convergent validity. Cronbach's Alpha, rho_A, Composite Reliability, and AVE values show that the scale effectively measures the latent construction of Transformational of change.

In summary, the results show that the measurement scales used for the constructs of independent learning, learning leadership, sustainable action, and transformation of change have a satisfactory level of reliability and convergent validity. These findings gave credence to the validity of the measurement instruments and became a support for further analysis of the relationships between research constructs.

The Correlation between Learning Leadership and Independent Learning

To measure the relationship between learning independent and independent learning, a statistical analysis of regression was used. The following diagram of regression analysis presents the results:

Figure 3.
Regression Results



The diagram above provides summary information on statistical regression test results in the research model which can be presented in the following table data:

Table 2.
Regression Results

	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T Statistics (|O/STDEV|)	P Values
Learning Leadership (X) -> Learning Independence (Y)	0.867	0.873	0.032	27.135	0.000
Learning Leadership (X) -> Sustainable Actions (X1)	0.947	0.949	0.012	82.090	0.000
Learning Leadership (X) -> Transformation of Change (X2)	0.968	0.970	0.006	154.495	0.000

Hypothesis Testing

Hypothesis testing was carried out with Critical Ratio (CR) criteria > 1.96 or probability value (P) < 0.05 then the basis for decision making:

If the probability value (sig value) > 0.05 or -t table < t calculation the table< t then H_0 is not rejected.

If the probability value (sig value) <0.05 or the arithmetic t <-t table or the arithmetic t> t table then H_0 is rejected.

The presented data indicate the results of testing hypotheses for path coefficients in structural equation models. This model assesses the relationship between different constructs, specifically Learning Leadership (X) and its influence on Learning Independence (Y), Sustainable Actions (X_1), and Transformation of Change (X_2). Here is an interpretation of the results:

1. Learning leadership (X) to Learning Independence (Y), with Original Path Coefficient: 0.867, Sample Mean: 0.873, Standard Deviation: 0.032, t-value (|O/STDEV|): 27.135 and p-value: 0.000 (significant), indicating that the path coefficient between Learning Leadership (X) and Learning Independence (Y) is 0.867. The sample average is very close to the original coefficient. A t-value of 27.135 shows a very significant relationship between Learning Leadership and Learning Independence supported by a very low p-value (0.000).

2. Sustainable action (X_1) on Learning Leadership (X), with Original Path Coefficient: 0.947, Sample Mean: 0.949, Standard Deviation: 0.012, T-Value (|O/STDEV|): 82.090 and P-Value: 0.000 (significant), indicating that the path coefficient between Learning Leadership (X) and Sustainable Actions (X_1) is 0.947. The average of the sample perfectly matches the original coefficient. A high t-value of 82.090 indicates a very significant relationship between Learning Leadership and Sustainable Actions, supported by a very low p-value (0.000).

3. Transformation of change (X_2) to Learning Leadership (X), with Original Path Coefficient: 0.968, Sample Mean: 0.970, Standard Deviation: 0.006, T-Value (|O/STDEV|): 154.495 and P-Value: 0.000 (significant), indicating that the path coefficient between Learning Leadership (X) and Transformation of Change (X_2) is 0.968. The average of the sample perfectly matches the original coefficient. A very high T-value of 154.495 indicates a very significant relationship between Learning Leadership and Transformation of Change, supported by a very low p-value (0.000).

The results above show that there is a significant positive relationship between learning leadership and each of the three constructs, both learning independence, sustainable action and change transformation. A low p-value indicates that this relationship is statistically significant, indicating strong support for the proposed hypothesis. Hypothesis testing yielded remarkable results, confirming the significant positive influence of Learning Leadership on Learning. Independence Path coefficient for the impact of Learning Leadership on Learning Independence (0.867), Sustainable Action (0.947), and Transformation of Change (0.968), indicated that all dimensions are very significant ($p < 0.001$).

Discussion

These findings underscore the important role of good practice of learning leadership in fostering students' capacity for learning independence. The linkage of learning leadership is a fundamental factor for learning independence. Learning leadership becomes part of the development of teacher pedagogic competence, reflecting how teachers interact with students in experiencing their learning experiences. Learning leadership is part of pedagogics, about how teachers transform continuously, qualified, with the role, values, philosophy of educators and reflection in providing learning experiences. (Sandri, 2022). The effectiveness of learning leadership is evident based on the results of hypothesis testing that produces results that confirm the significant positive influence of Learning Leadership on Learning. Independence with path coefficients for the impact of Learning Leadership on Learning Independence (0.867), Sustainable Action (0.947), and Transformation of Change (0.968), which shows all dimensions are very significant ($p < 0.001$) and with a contribution rate of 66.3%.

Learning Leadership

The effectiveness of learning leadership is a factor of the effectiveness of the quality learning process. The effectiveness of learning leadership explains that a teacher is an organizer of student learning experiences required to be able to facilitate meaningful learning so that how the learning leadership model becomes a form that needs to be designed. The learning leadership model from this research study can be constructed with dimensions of a sustainable action strategy profile of 0.947 and a change transformation profile of 0.968. shows all dimensions are very significant ($p < 0.001$).

Sustainable Action

The first dimension, namely the profile of sustainable action strategies, is part of the sustainable leadership model which is characterized by four indicators, including: namely: the ability to use existing components in the organizational environment as learning resources, the ability to develop economic systems for optimal learning, the ability to focus on learning experiences that optimize the existence of teachers and students as learning communities, and the ability to develop organizational culture learning leadership.

The first indicator in the form of the ability to empower components in the organizational environment as a learning resource is the closest empowerment in the student learning environment, which needs to be done by developing the ability to recognize the learning needs of individual students by paying attention to learning modalities in the form of strengths, weaknesses, interests and learning styles (Meth et al., 2023). Furthermore, teachers also need to map the availability of school infrastructure and facilities that can be used as optimal learning resources in their suitability to meet student learning experiences, such as repairing-shop or laboratories, libraries, technology. In addition, teachers also need to design authentic learning experiences that integrate students' exploration not only in theory but also practice and out of the classroom scope alone (Muneeb, et.al., 2023).

The second capability indicator in the sustainable action strategy profile is how teachers are able to develop economic systems for optimal learning. This means that teachers have the ability to design and determine effective and efficient ways to utilize the availability of educational resources with the principle of justice where students are given the opportunity to use the availability of existing infrastructure and facilities, and also economic principles, namely increasing student potential to become competencies optimally (Xing et. al., 2023).

Another third capability indicator in the sustainable action strategy profile is the ability to focus learning experiences that optimize the existence of teachers and students as learning communities to achieving positive outcomes. In this case, teachers need to understand the learning policies that apply within the institution and nationally related to teacher professional development. The existence of teachers in their profession is supported by the recognition of portfolio. The portfolio port-folio is a collection of teacher performance and professionalism that has a positive impact on the development of student existence. The portfolio port-folio is intended to be a collection of documents on teacher professional achievements, which can include research and publications on learning that has been done, self-reflection, search for new information, innovation works, student achievements resulting from mentoring and self-achievement and work of service in the field of learning. How capable the teacher is of doing the portfolio, the more superior the teacher's professionalism in optimizing the potential relevant to the existence of students (Aaron et. al., 2021).

The fourth ability indicator is the ability to develop an organizational culture of learning leadership. This is synonymous with the ability to create a harmonious, innovative and adaptive work environment to the development and progress of science and technology and is carried out in a sustainable manner. This achievement can be seen from the teacher's desire to become lifelong learners, involve active participatory in lecturer professional development activities, carry out a continuous reflective pedagogic paradigm to study the success of the learning experience process and overcome weaknesses or failures, create learning leadership figures who initiate ideas and potential development (Al-Kubaisi, et. al., 2022).

Transformation of Change

The transformation profile dimension of change is part of the Learning leadership model which is a form of the ability to manage change in collaboration positively with each individual and organization by focusing on strengths, paying attention to problems faced and what is wrong that needs to be corrected and managing a positive atmosphere of empowerment to achieve vision, appreciate and take concrete actions of change centred on quality improvement learning (Boonstra, 2023). Transformation of change is characterized by five indicators in the form of: The ability to formulate questions that can determine the direction of the search related to the change initiative to be carried out (the ability to define), the ability to collect – uncover – examine various positive experiences that have been achieved in school or community and what lessons can be drawn from these positive things (the ability to find and learn from positive things. The ability to construct a narrative about the picture of ideal conditions is expected to occur in the school / community environment based on the results at the stage of finding (ability to inspire dreams), ability to list all concrete action plans about important and actionable things to realize the future picture, agreed measures of success and what it takes to know it (ability to design plans), and the ability to decide and execute execution steps (who will be taken, who will be involved, when the deadline will be, what the strategy will be, and other actions to bring about the change initiative within the agreed time period (ability to take action) (Katyeudo &; de Souza, 2022).

The first indicator of the change transformation profile is the ability to ascertain the changes to be achieved and how the problems and opportunities that exist need to be fully and fundamentally understood so that they can focus on the positive results of the desired change. This places a teacher to be able to identify what changes they want to make in the scope of learning with students. This ability includes the ability to set goals and objectives for changing the process and what learning outcomes to be achieved with students, then formulating strategic questions that become questions about what action plans will be carried out, then collecting information that becomes a source of data for action, conducting studies of available problems and opportunities, then making decisions to take change actions and with Organize the resources needed and must be provided. This action also needs to be continued by evaluating and improving things that occur to stay in line with the established change initiative plan (Schiuma et al., 2022).

The second indicator of the change transformation profile is the ability to find and learn from positive experiences that can be done through efforts to recognize successes, collect and express positive experiences. This is a means of improving the performance of individuals and communities. The next step that can be done is to set success factor criteria for good practices that have been carried out. This can be a continuous learning that provides a place to continue to share good practices so that they become motivation and empowerment (Carney, 2022).

The third indicator is the ability to compile a narrative about the picture of ideal conditions expected to occur in the school / community environment based on the results at the finding stage. This ability is referred to as the ability to inspire dreams. Individuals and the school community need to set a passionate, motivating and inspiring vision that represents a realistic achievable future (Gurr & Drysdale, 2020).

The fourth indicator is the ability to list all concrete action plans about important and actionable things to realize the future picture, agreed measures of success and what it takes to know it. To realize this step, each individual needs to determine an action plan in the form of concrete steps towards achieving the vision. After that, it is necessary to determine the measure of success that needs to be formulated specifically, measurable, achievable, relevant and time-able (SMART) (Fisher et al., , 2018). To support this, the ability to identify available and optimizable resources is needed, including human, financial, and technological resources. In its implementation, change transformation also needs to anticipate risk consequences so that other alternative actions are needed to secure the implementation of a decision. This indicator is an important element of change transformation actions and an important part of learning leadership management (Susanto et al., 2020).

The fifth indicator is the ability to decide and execute execution steps, which includes determining what will be taken, who will be involved, when the deadline is, how the strategy is, and other actions to realize the change initiative within the agreed time period, so it is also referred to as the ability to take strategic actions. In this section, it is very necessary to have a specific plan or action plan, integrated team involvement, efficient time planning, strategies that need to be carried out and including how monitoring and evaluation are conducted (Nair, 2023).

Independent Learning

The results of the study prove that independent needs to be facilitated and can be achieved through effective learning leadership. Learning independence reflects learning conditions that are filled with happiness, free from stress and students get an educational environment that is able to optimize the achievement of 4Cs competencies in elementary school graduates, teachers are required to have creativity and be innovative in facilitating the availability of a conducive learning environment that is able to integrate teacher and student involvement as transformation actors through Learning Leadership. Learning independence for students is when teachers are able to facilitate students to be able to direct goals, ways, learning assessments that are filled with competence and without neglecting individual characteristics, and students are able to self-work (Erkinovna, 2022; Prameswari, 2020).

Learning independence is highly contextual with varied environments that provide a dynamic space for students to have self-management skills and manage their learning. Learning independence is a manifestation of the teacher's ability to condition learning that is pleasant and filled with happiness, free from fear and pressure / stress. The learning environment is also conditioned for students' ability to have critical thinking, creativity, collaboration and communication (4Cs). In learning freedom, teachers need to be actively involved to facilitate the active involvement of students as actors of transformation, and this can be done by directing students to understand and set learning goals (goal setting) (Koutroubas & Galanakis, 2022). Furthermore, teachers need to facilitate the optimization of students to have a way of learning with good time management, quality-oriented, targets and filled with positive values and responsibilities. Another thing is that teachers are able to provide opportunities for students to assess their learning processes and outcomes. One thing that is no less important is also communication literacy and technology that provide a vehicle for students to explore their learning abilities individually and collaborate (Marín & Castañeda, 2023). In the end, students should also be given the opportunity to exercise the ability to manage differences and conflicts as dimensions of individual and social self-existence (Adhikari, 2023).

Conclusions

The results of research on learning leadership have important implications in improving the quality of learning and professional development of learning leadership. A better understanding of the leader's role in the learning process is needed as it can help create a more effective, responsive, and relevant learning environment. The findings of this study showed that learning leadership can be constructed with two aspects of the continuous action and the transformation of change of teachers. Both of these aspects are part of the formation of an organizational culture that supports the quality of student learning. It can be stated that both dimensions of learning leadership, which include the profile of teacher continuous action need to be realized with teacher consistency to actively carry out change transformation strategies in organizing optimal learning experiences for students.

The impact of learning leadership affects the quality of student learning. This means that learning leadership best practices become a facilitating model for a quality of learning that manifests in learning independence. In conclusion, this study explains the importance of learning leadership in maintaining learning independence among elementary school students. These findings emphasize the need for educational institutions and policymakers to prioritize the development of learning leadership skills among teachers. Thus, teachers can contribute to the development of students who are not only adept at acquiring knowledge but also at navigating the course of their learning experience with autonomy, creativity, and a deep sense of responsibility.

In light of these findings, this research recommended involving more teachers as the respondents and measuring more variables such as comparing between male and female teachers as well as the period of their teaching years to get broader insights. Besides, this study directed principals of the schools, especially in Indonesian context, to fully support leadership of both experienced and novice teachers through teachers' learning leadership model in order to keep learning quality, hence students' independent learning will also be well-achieved.

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APPENDIX

QUESTIONNAIRE OF LEADERSHIP FOR LEARNING PROFILE

1. DEMOGPRAHIC INFORMATION

Name	:
Institution	:
Sex	:
Age	: Male/Female
Educational Background	: Teacher Education/Non-teacher Education

2. DIRECTION: Please put tick [ü] under the option that best represents you:

A = Always
O = Often
R = Rarely
S = Sometimes
N = Never

Dimension	Indicator	A [5]	O [4]	R [3]	S [2]	N [1]
Sustainable action profile	Ready in sustaining the environment of the organization as the ability of utilizing all components available in the environment of the organization					
	Ready in sustaining economic system as the ability of developing economic for optimum learning					
	Ready in sustaining welfare as the ability to focus on learning experience that sharpens the existences of school communities (teachers and students)					
	Ready in sustaining cultural system as the ability of developing the organization culture of leadership for learning					
Transformation of change profile	Ready in giving definitions as the ability of formulating questions that determine direction of what changes would be taken					
	Ready to discover as the ability of gathering, expressing, and scrutinizing any positive achievements reached by the school and what lessons can be learnt from those positive things					
	Ready in inspiring dreams as the ability of describing expected ideal conditions at school (referring to the result in 'discovery' stage before)					
	Ready in designing plan as the ability of listing all concrete action plans about what important things to do to embrace the future, its measurement success, and what other things to consider					
	Ready in implementing the action plans as the ability of deciding and carrying out the executions (what things to do, who will be involved, when will the deadline, and what other actions to make changes within agreed period of time)					
Independent learning strategy profile	Ready in developing learning condition as the ability of building learning atmosphere that are fun and free from the feelings of fear/depressed/stressful					
	Ready in developing learning environment that encourages the achievement of 4Cs					
	Ready in developing engagement as the ability of integrating students as transformation agents and teachers' involvement					
	Ready in developing learning objectives as the ability of facilitating students' competence in using time effectively, doing quality-oriented tasks with full of responsibility, doing any works with better target, and emphasizing on values in doing those tasks					
	Ready in developing assessment ways as the ability of doing academic evaluation on how student express reasons, their learning process and outcomes					
	Ready in developing competence as the ability of doing communication both in written and spoken, organizing information, utilizing technology, managing stress, differences and conflict					