e-Kafkas Journal of Educational Research

e-KJER

Research Article

Instructional Strategies in Science Education: A Dual Approach Combining Systematic Review and Secondary Qualitative Data Analysis

Şeyma Irmak[1] Duygu Yılmaz Ergül[2]

To cite this article:
Irmak, Ş., & Yılmaz Ergül, D. (2024). Instructional strategies in science education: A dual approach combining systematic review and secondary qualitative data analysis. *e-Kafkas Journal of Educational Research, 11*, 597-616. doi:10.30900/kafkasegt.1503657

Research article **Received:**23.06.2024 **Accepted:**08.11.2024

Abstract

This study employed a dual research approach, incorporating both systematic review and secondary qualitative data analysis, to investigate instructional strategies and their rationales utilized by pre-service and in-service science teachers (PaIST) in physics topics. We chose widely recognized and readily accessible sources with extensive study coverage, including Web of Science, SCOPUS, Taylor & Francis Online, and ProQuest. Only four studies that conformed to our inclusion and exclusion criteria were identified for examination. The analysis unfolded in two phases: first, the identification of instructional strategies employed by PaIST, and second, the exploration of the underlying rationales guiding their choices. Our findings revealed a diverse array of instructional strategies, encompassing direct instruction, thought experiments, demonstrations, hands-on activities, think-pair-share, peer teaching, laboratory exercises, discussion/questioning techniques, drama, and real-life narratives. The rationales underpinning these strategies were multifaceted, aiming to enhance student motivation, stimulate cognitive development, facilitate collaborative group work, and foster meaningful learning experiences. Despite evidence supporting the effectiveness of various external strategies such as STEM education, out-of-school learning, and project-based teaching on students, pre-service and in-service science teachers appear hesitant to adopt these methods. Further research is needed to explore the barriers and factors influencing their instructional choices.

Keywords:Instructional strategy; pedagogical content knowledge; pre- and in-service science teachers; secondary qualitative data analysis; systematic review

[1] Corresponding Author, seyma.bardak@gmail.com, Amasya University Faculty of Education, Department of Science Education

[2] Gazi University Faculty of Education, Department of Science Education

Introduction

The contemporary global landscape demands individuals who can proactively identify and capitalize on opportunities for personal and future well-being. This necessitates a multifaceted skill set, including inquiry, problem identification, creative and critical thinking, and the ability to establish causal relationships. Education plays a pivotal role in developing these skills, prompting researchers to investigate effective teaching approaches and instructional strategies for their acquisition (e.g., Tytler, 2003). As a result, novel teaching methodologies like STEM education, flipped classrooms, gamification, design thinking, and project-based learning have emerged, all contributing to the cultivation of highly skilled individuals.

Selecting Instructional Strategies for Effective Content Knowledge Teaching

Instructional strategies encompass choices and actions that educators undertake to attain particular learning objectives, involving the formulation of plans, methodologies, and activities (Jonassen et al., 1991). It is often discussed in the context of pedagogical content knowledge (PCK), a comprehensive model introduced by Lee Shulman, which reflects teacher competence in various domains (Kind, 2009; Loughran et al., 2006; Shulman, 1986; Van Driel et al., 1998). Within Shulman's PCK model, instructional strategies are a critical component. To delve deeper into this concept, it is apt to present the statement of Lee Shulman, who introduced the concept. According to Shulman (1986):

> ... for the most regularly taught topics in one's subject area, the most useful forms of representation of those ideas, the most powerful analogies, illustrations, examples, explanations, and demonstrations in a word, the ways of representing and formulating the subject that make it comprehensible to others.

The subject of PCK, which is so important in raising individuals who will shape the future, has attracted much attention worldwide, especially after Shulman's explanations. This heightened interest has led to the proposal of numerous models associated with PCK (Abell, 2008; Gess-Newsome, 2015; Grossman, 1990; Magnusson et al., 1999; Morine-Dershimer & Kent, 1999; Park & Oliver, 2008; Rollnick et al., 2008). These models are typically developed by building upon previous ones. Within each model, teachers' PCK is unveiled through various components. It is noteworthy that upon close examination of these models, instructional strategies emerge as an essential domain. This domain is indispensable for PCK models. Instructional strategies, by revealing how and in what manner a teacher will impart knowledge to their students, encapsulate the essence of the teaching profession. Consequently, interpreting instructional strategies as the skeleton of PCK models might be an apt analogy. Teachers enter a classroom armed with the knowledge acquired during their undergraduate education, the experiences they have accumulated, and their motivation to teach. In this process, understanding why and how a teacher selects particular teaching strategies for specific subjects enables us to comprehend their perspectives and, perhaps most crucially, bridge the gap between theory and practice. In this study, the focus is on the instructional strategies employed by pre-service and in-service science teachers and the rationales guiding their choices. This sheds further light on the nature of PCK. Numerous studies in the literature investigate pre-service and in-service teachers' knowledge of instructional strategies based on any PCK model through methods such as observation (Barendsen & Henze, 2019; Nilsson & Karlsson, 2019; Scheuch et al., 2018), interviews (Van Driel et al., 1998), or a combination of both (Hanuscin et al., 2011; Nilsson & Vikström, 2015). Furthermore, there are studies in which pre-service and in-service teachers undergo training in teaching strategies (inquiry, modes, modeling, argumentation, etc.) to enhance their PCK (Faikhamta, 2013; Goodnough & Hung, 2009; Günther et al., 2019; Ladachart, 2020; Shein & Tsai, 2015; Wongsopawiro et al., 2017). These studies offer valuable insights into the levels of instructional strategy knowledge held by pre-service and in-service science teachers (PaIST), the translation of this knowledge into classroom practices, and strategies for improvement based on factors such as country, culture, discipline, and experience. Moreover, these studies illuminate how frequently a teacher employs a particular instructional strategy while teaching a subject and the underlying reasons for their choices.

Teacher's goals and purposes when selecting instructional strategies

Investigating which strategy teachers choose in their classrooms is one of the first questions of educational research. In one of the pioneering studies investigating this problem, it was found that teachers' decision-making on effective teaching strategies was mostly related to teacher attitudes

(Bender & Ukeje, 1989). However, it was also emphasized that the instructional strategies used to facilitate learning depends on the teaching conditions; thus, different instructional strategies should be chosen for different learning conditions (Jonassen, et al., 1991). In a more recent study, primary teachers chose inquiry and context-based instructional strategies because students needed to learn content knowledge about the subject matter (Walan, et al., 2017).

Teachers' science teaching goals and purposes, in other words, their beliefs significantly affect the teaching strategies they choose in their lessons (Mansour, 2009; Lee et al., 2004; Walan et al., 2017). Lee et al. (2004), in a longitudinal study with primary school teachers, listed the reasons for choosing inquiry strategies in three broad categories of goals: cognitive, affective, and pragmatic. They stated that cognitive goals include scientific inquiry, understanding science, and applying science to real-world situations. The affective goals are to develop a "love of science" in students and to get students "excited about science". Finally, they described the practical aims as "preparing students for assessments" and "integrating science into curriculum areas". Some researchers have expressed strategies as internal and external (Chou, 2013; Wang & Chen, 2013). Internal strategies, such as dialogical techniques, are pivotal in engaging students in the learning process, promoting active thinking, and drawing conclusions from data (Oliver et al., 2019). These strategies are crucial for establishing a positive classroom environment that supports student-centered teaching approaches and inquiry-based learning (Bielik & Yarden, 2016). External strategies in education can vary in terms of their focus of control for school restructuring. Strategies that are specific and prescriptive, relying on external authority, place the control for restructuring outside the school. On the other hand, strategies that are vague and rely on the school's authority place the control within the school. This indicates a continuum of control, ranging from external to internal, based on the clarity and authority of the strategies (Porter & Osthoff, 1994).

In research conducted by Williams and Clement (2015), it was determined that physics teachers used dialogical techniques, one of the micro techniques, within the scope of internal strategies. These techniques were employed because students share their scientific ideas in the classroom environment. Furthermore, recent studies have highlighted additional methods preferred by teachers in physics education. For example, research by Chiang et al. (2017) indicated a growing trend towards the use of inquiry-based learning strategies, where students explore physics concepts through hands-on experiments and guided investigations. This approach has been shown to enhance students' problem-solving skills and deepen their conceptual understanding. Additionally, recent research by Benabentos et al. (2021) highlights STEM education as a prominent instructional approach in physics teaching. The study emphasizes the effectiveness of student-centered practices that encourage active engagement and collaboration among learners. Faculty members reported utilizing various STEM-based strategies, which have gained traction as preferred methods for fostering deeper understanding and interest in physics concepts. This shift reflects the growing recognition of the importance of integrating innovative teaching methods into the physics curriculum, ultimately aiming to improve student learning outcomes and prepare them for future challenges in STEM fields. In middle school physics education, various instructional methods and techniques are utilized, with preferences often varying based on the topic being taught. For instance, collaborative learning has proven effective in teaching topics related to force and motion (Kıncal et al., 2007), while digital games are commonly employed to facilitate learning in energy-related topics (Martin et al., 2019). In the field of astronomy, instructional strategies frequently emphasize discussion-based activities (Miranda, 2010) and modeling techniques (Sağdıç, 2024).

There are assessment tools developed to investigate which strategy teachers use for what purpose in their lessons (e.g Ford, 2018). Although these tools provide the opportunity to reach large sample sizes, there may be a situation where teachers do not reflect on what is happening because they include self-evaluations. In essence, there is limited knowledge regarding the rationales teachers consider and how these rationales influence their selection of particular instructional strategies. Gathering such insights can enhance our comprehension of how teachers decide on teaching methods, ultimately paving the way for instructive recommendations on the successful integration of diverse teaching techniques.

Purpose of the Present Study

There may be disparities between the strategies that teachers are familiar with and those they implement in their classrooms. Such disparities can result in a gap between theory and practice when it comes to strategy selection. From this perspective, exploring the instructional strategies and the underlying rationales employed by PaIST in their natural classroom settings can illuminate the nuances of the gap between theory and practice. By examining the specific instructional strategies used by PaIST in their lessons, without any external interference, this research aims to uncover the reasons behind these choices. Such insights can provide valuable understanding of both the authentic classroom environment and the teachers' pedagogical content knowledge (PCK). These insights can contribute to a deeper understanding of the authentic classroom environment.

Consequently, the research was designed to determine the instructional strategies employed by PaIST in teaching physics subjects and the rationales underpinning their decisions regarding these strategies. The present study aims to address the following research questions:

1. What does the literature reveal about the instructional strategies preferred by middle school by PaIST when teaching physics topics at the middle school level?

2. What are the rationales and underlying factors guiding the selection of the instructional strategies by PaIST when teaching physics topics at the middle school level?

Method

This research employed secondary research methods, specifically utilizing systematic review to identify and synthesize relevant literature, and secondary qualitative data analysis to examine the themes emerging from the selected studies. It is important to note that terminological ambiguity surrounding secondary research methods persists in the literature. Terms such as secondary data analysis, qualitative secondary analysis, qualitative secondary research, meta-analysis, and meta-synthesis are often used interchangeably, without clear delineation regarding their respective roles within the domain of secondary research methods. Manu and Akotia (2021) highlight this lack of clarity, emphasizing that while these terms are prevalent, distinctions between them remain unclear. Secondary research methods are clarified in this study by specifying the systematic review as the primary research tool, complemented by secondary qualitative analysis.

Systematic reviews play a crucial role in evidence-based research and decision-making by facilitating a comprehensive and unbiased synthesis of existing research on a specific topic. Through systematic searching, selection, and critical appraisal of relevant studies, systematic reviews allow researchers to assess the overall quality and strength of the evidence, helping to mitigate bias and ensuring a more reliable and robust summary of available findings (Higgins & Green, 2011). Additionally, systematic reviews enhance research transparency and reproducibility. This study employed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines, which provide a framework for reporting systematic reviews, ensuring clear and consistent presentation of methodology and findings (Moher et al., 2009). This transparency empowers other researchers to evaluate review quality, verify validity, and potentially replicate the study.

Furthermore, secondary qualitative data analysis is a valuable method that involves re-examining pre-existing qualitative data to address new research questions or to validate findings from prior research (Heaton, 2008; Largan & Morris, 2019, p. 29). By systematically analyzing such data, secondary qualitative data analysis promotes data reuse, enhances research rigor, and contributes to cumulative knowledge in qualitative research (Szabo & Strang, 1997). The process of secondary qualitative data analysis involves several steps. First, researchers identify and access relevant qualitative data sources, such as archived interviews, field notes, or transcripts. These data sources are then reviewed and selected based on their relevance to the research questions or objectives, as well as factors such as data quality, richness, and diversity. Secondary qualitative data analysis thus maximizes the value of existing qualitative data, enhancing rigor and credibility through opportunities for data triangulation and validation. The use of systematic review and secondary qualitative data analysis contributes to the replication and validation of findings, promoting cumulative knowledge in the field of pedagogical content knowledge (PCK) studies (Heaton, 2008; Largan & Morris, 2019, p. 29).

Data Collection

Web of Science, SCOPUS, Taylor & Francis Online, and ProQuest were selected for their well-regarded accessibility, rigorous indexing, and extensive peer-reviewed coverage, ensuring a comprehensive and reliable foundation for synthesizing educational research. Firstly, a search was made in Google Scholar with the codes "(science teacher*) (primary | beginning | elementary | beginner*) (pre-service | candidate* | prospective) (instructional strategy*)" and "(science teacher*) (primary | beginning | elementary | beginner*) (instructional strategy*)". In this search, which was expressed as a pilot search, terms used in the literature related to research questions were identified, and a proper search code was developed for the main study. As a result, the following words were reached: science activity, strategy, pedagogical decision, practicum, teaching method, instructional decision, and knowledge of science activity. This pilot search aimed to reveal the behind-the-scenes decision-making processes of the instructional strategies that PaIST use in their lessons.

Inclusion and Exclusion Criteria
The inclusion and exclusion criteria are given in the Table 1.

Table 1.
Inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
The research must be last published in 2021	Research published after 2021
The research group of the study must be PaIST.	Publications other than theses and research articles
The research must be carried out with observation and interview techniques based on the qualitative research method.	Research conducted only by interview
The statements of the PaIST about the reason for the teaching method chosen must be included in the interviews.	Paid publications without full-text access
The publication language must be English.	Research published in sources other than Web of Science, SCOPUS, Taylor & Francis Online, and ProQuest
PaIST must choose the teaching method of the physics subject.	Research conducted on chemistry and biology within the scope of science education
PaIST participating in the study must present any physics subject in a real or realistically adapted classroom setting.	

Teachers' knowledge of teaching strategy is not a new concept and that many countries have tried to improve teachers' classroom practice from past to present. For these reasons the starting publication year for eligible studies was left open-ended. As the research began in 2021, studies eligible for inclusion were required to have been published no later than 2021. In addition, since the scope of science is very wide, the search to studies that only included teaching physics subjects. PaIST’s choose their own teaching methods without any external manipulation can reveal what they did in the real classroom environment, and why and how they decided on which teaching method. This would reflect the teachers' pure PCK. Finally, it was desired to reach studies investigating the rationale for the teaching strategies used by PaIST during their teaching practice.

The process of the selection of studies
Search codes were created according to the characteristics of each source, considering the inclusion and exclusion criteria, and searches were performed in the advanced search tab of each source. The search codes for the sources we have determined are in Table 2.

Table 2.
Search Codes for the Sources

Search Codes for Taylor & Francis Online	anywhere: "science teacher" anywhere: "physics" anywhere: "middle" OR "intermediate" OR "upper primary" OR "lower secondary" abstract: "qualitative" OR "case study" OR "mixed" OR "phenomenology" OR "grounded" OR "narrative" OR "ethnographic" OR "action research" anywhere: "practice" OR "reflection" OR "reaction" OR "science activity" OR "strategy" OR "pedagogical decision" OR "practicum" OR "teaching method" OR "technique" OR "instructional decision" OR "knowledge of science activity" OR "teaching practice"
Search Codes for Web of Science	ALL=science teacher AND ALL=physics AND ALL= (middle OR intermediate OR upper primary OR lower secondary) AND ALL=(qualitative OR case study OR mixed OR phenomenology OR grounded OR narrative OR ethnographic OR action research)
Search Codes for SCOPUS	TITLE-ABS-KEY ("science teacher") AND ALL (physics) AND (ALL(practice) OR ALL(reflection) OR ALL (reaction) OR ALL("science activity")OR ALL(strategy) OR ALL("pedagogical decision") OR ALL(practicum) OR ALL("teaching method") OR ALL(technique) OR ALL("instructional decision") OR ALL("knowledge of science activity") OR ALL("teaching practice")) AND (ALL(middle) OR ALL(intermediate) OR ALL("upper primary") OR ALL("lower secondary")) AND (ALL(qualitative) OR ALL("case study") OR ALL(mixed) OR ALL(phenomenology) OR ALL(grounded) OR ALL(narrative) OR ALL(ethnographic) OR ALL("action research"))
Search Codes for ProQuest	anywhere: "science teacher" anywhere: "physics" anywhere: "middle" OR "intermediate" OR "upper primary" OR "lower secondary" abstract: "qualitative" OR "case study" OR "mixed" OR "phenomenology" OR "grounded" OR "narrative" OR "ethnographic" OR "action research" anywhere: "practice" OR "reflection" OR "reaction" OR "science activity" OR "strategy" OR "pedagogical decision" OR "practicum" OR "teaching method" OR "technique" OR "instructional decision" OR "knowledge of science activity" OR "teaching practice"

To avoid bias in the research process, all sources were searched separately with the created codes. It should also be noted that the proxy settings of researchers' universities were used to access paid resources in these sources. In addition, studies that matched the inclusion criteria were saved. While saving the studies, the *Standards for Reporting on Empirical Social Science Research in AERA Publications* report (American Educational Research Association, 2006) was taken into consideration to ensure the validity and reliability of the selection process. According to this report, transparency and a sufficient level of evidence were sought in the studies to be included in our research, thereby enhancing content validity by ensuring that only relevant and methodologically sound studies were selected. This criterion ensured that the chosen studies had a direct connection to the research questions, aligning with the systematic review's purpose of providing reliable and applicable insights.

In addition, we developed search codes to comprehensively capture studies related to our research objectives. These codes included synonymous terms (e.g., "middle" OR "intermediate" OR "upper primary" OR "lower secondary") to ensure inclusivity and reduce the risk of overlooking relevant studies that may use varied terminology. By sharing these codes with readers, we aim to maintain transparency and enable replication of our search process, further contributing to the study's validity.

To reinforce reliability, two selection criteria both prevented bias and were decisive in evaluating the quality of the study. Separate coding was done by multiple coders to reduce the bias risk and reveal inter-rater reliability, following established guidelines (Lune & Berg, 2017). After all sources were scanned, the researchers compared the data to assess inter-coder reliability, resulting in a high agreement rate of 95 percent. This substantial agreement reflects the rigorous coding process employed, ensuring consistent interpretations of the data across coders and contributing to the study's overall reliability.

Additionally, to increase the comprehensiveness and validity of the dataset, the researchers employed both backward and forward snowballing methods. First, the references of studies that met the inclusion criteria were examined to identify additional relevant studies (backward snowballing). Then, Google Scholar was used to determine citations for these included studies to locate any further research relevant to our study objectives (forward snowballing). However, no study matching the inclusion criteria was identified through these methods. Together, these strategies minimized the likelihood of missing key studies and strengthened the validity of the final dataset.

These processes align with the PRISMA checklist (Moher et al., 2009) requirements for systematic reviews, ensuring transparency, thoroughness, and rigor in data selection, coding, and analysis, thereby safeguarding the validity and reliability of the research findings.

Data Analysis

Firstly, we individually examined each article to ensure compliance with our inclusion and exclusion criteria. During this review, the primary objective was to identify instructional strategies used by PaISTs teaching physics subjects. In the process, information such as the authors of the studies, the country and year of the study, the type of study, whether the participants PaIST, and the specific physics topics taught by the participants was documented in an Excel spreadsheet. Subsequently, the assessments were then cross-checked. At last, the findings from the systematic review were presented in a concise and easily understandable fashion (Cook, et al., 1997; Moher et al., 2009).

Our secondary qualitative data analysis process consisted of several steps (Heaton, 2008; Largan & Morris, 2019, p. 29). Initially, we identified qualitative data sources within the selected studies. We scrutinized and selected these data sources based on their relevance to our research questions or objectives. We evaluated all included studies, taking into account factors such as data quality, richness and diversity, and collated the interview data provided by the original researchers. (Auerbach & Silverstein, 2003).

The first aim in the coding phase was to understand the rationales for the teaching strategies that PaIST uses during the lesson. Subsequently, it was examined whether these rationales were similar to the views expressed in the studies included in the review. In other words, the similarity and repetition frequency of the reasons for the teaching strategy used by the PaIST with the data in all studies included in this research were considered (Saldaña, 2013).

As secondary data analysts, authors are separated from the research context and have no idea about the details of the dynamics between interviewer and respondent (Smith, 2008). Therefore, direct quotations from the participants were used as the data for this study. This aimed to reach more objective results regarding the research question (Ruggiano & Perry, 2019). Before commencing the analysis, the selected qualitative data sources were compared. Subsequently, content analysis was conducted on these qualitative data sources.

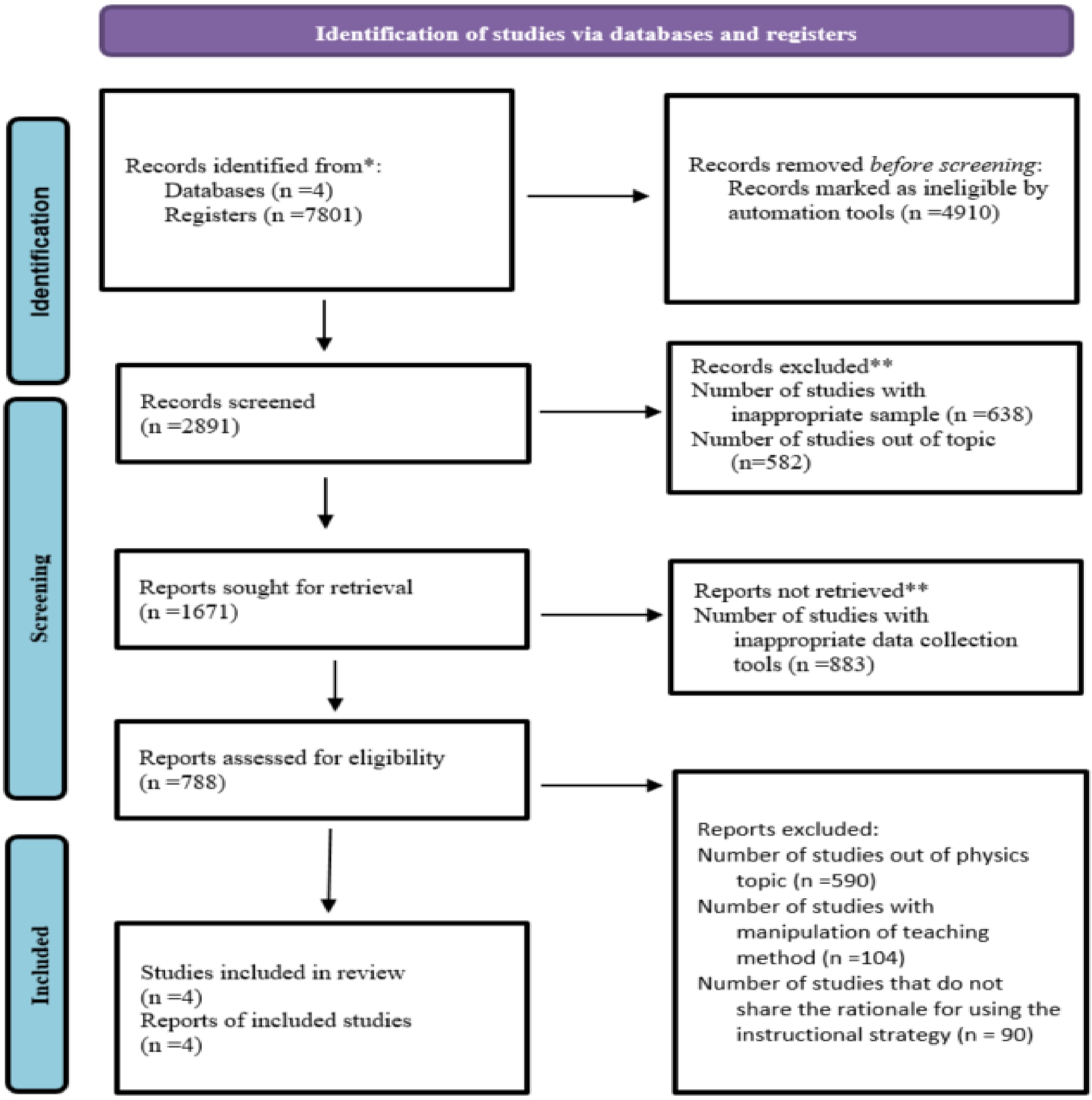

Figure 1. The Flowchart Showing the Whole Process

Results

The results related to the research questions are presented under two headings.

Preferred Instructional Strategies for Teaching Physics by PaIST

The generated search codes yielded in the four sources (n = 7801 from e-search and two from hand search; see PRISMA Figure 1.) Due to issues related to the subject matter (e.g., Walan, 2020), sample group (e.g., Engström & Carlhed, 2014; Melo, 2020), and data collection methods (e.g., Kersting, 2021) of these studies, 7,013 studies excluded after several evaluation stages. Furthermore, the remaining 788 studies excluded because the majority of them did not cover any specific physics topics. Additionally, in some of the remaining studies, there was evidence of manipulation of teachers' and teacher candidates' instructional strategy preferences (e.g., Ültay, 2017), or there were no qualitative data sources available concerning teachers' rationales for using instructional strategies (e.g., Tafrova-Grigorova, 2012). In the end, surprisingly, four studies were identified that met research criteria, involving middle school physics topics, taught by either PaIST, and explaining the rationale behind their chosen instructional strategies in these teaching practices.

Characteristics of selected original studies can be viewed in Table 3. This systematic review includes data from a total of six participants, consisting of two pre-service and four in-service science teachers.

Table 3.
Information about the Participants of the Studies, Physics Topics and Instructional Strategies

Reference	Name of Study	Country	Type of Research	Sample	Participant Name	Physics Subject/Grade	Used Instructional Strategy
Sæleset & Friedrichsen, 2021	Pre-service Science Teachers' Pedagogical Content Knowledge Integration of Students' Understanding in Science and Instructional Strategies	Norway	Article	Pre-service/ none	Lena	Energy, Technology & Design/ 6th	Direct instruction technique Thought experiment Hands-on activity
Gates, 2008	Middle School Science Teachers' Perspectives and Practices of Teaching Through Inquiry	USA	Dissertation	In service/ 10 years	Lisa	Simple machine/ 6th	Hands-on activity Think-pair-share Predict-observe-explain
				In-service/ 18 years	Lee Ann	Simple machine/6th	Hands-on activity Think-pair-share Discussion/Questioning
				In-service/ 10 years	Lena 2	Simple machine/6th	Hands-on activity Discussion/Questioning Think-pair-share
Yalaki, 2004	Science Teachers' Worldviews: A Way to Understand Beliefs and Practice	USA	Dissertation	In-service/ 3 years	Sara	Newton's laws, force and motion/ 6th, 7th, 8th	Hands-on activity Lecturing Peer teaching
Hahn, 2003	Interpretive Case Studies on the Influence of a Pre-service Contextual Science Research Course on Novice Scıence and Mathematics Teachers	USA	Dissertation	Pre-service/ none	Cathy	Force and motion, simple physics concepts, gravity/ not mentioned	Demonstration Lab activities Discussion/Questioning Drama Real-life stories Textbook instruction

The findings highlight several instructional strategies preferred by PaIST based on the physics topics being taught. These strategies include hands-on activities, think-pair-share, practical reasoning-explanation, and discussion. Specifically, hands-on activities were predominantly used for teaching basic mechanics topics, force and motion. Think-pair-share strategy was employed by both pre-service and in-service teachers across different physics topics. Discussion-based strategies were also frequently observed. Real-life stories and demonstration were incorporated into lessons. The studies in this review were conducted in the United States and Norway, reflecting instructional approaches within these two distinct educational systems. Hands-on activities and peer teaching approaches were observed in the U.S., while the Norwegian study highlighted the use of reflective practices and the integration of science with students' everyday experiences. The studies reviewed span key middle school physics topics such as force, motion, and energy, with grade levels ranging from 6 to 8. Hands-on activities were widely used in teaching concepts like force and motion. Think-pair-share, discussion techniques, and real-life stories were also preferred strategies.

While SQDA (Systematic Qualitative Data Analysis) was utilized to categorize and interpret these findings, the systematic review process underscored a lack of sufficient research focusing on PaIST's instructional rationales and the effectiveness of these strategies across different physics topics. The limited pool of relevant studies highlights a need for further research to comprehensively understand the decision-making processes of teachers and to explore the impact of various strategies on student learning outcomes.

Rationales and Decision-Making Factors Behind Instructional Strategy Preference by PaIST in Physics Topics

As a result of the secondary data analysis, we shared the rationales for the instructional strategies in the form of assertion. These assertions include the rationales for why and how PaIST uses instructional strategies. These assertions are themes we create by combining codes according to their similarities and differences. The relationship of instructional strategies with code and themes is as in Figure 2.

Assertion 1: Using Hands-On/Laboratory Activities to Improve Learning, Motivate Students, And Connect Subjects to Real-World Situations

PaIST preferred classroom-based (hands-on) and laboratory-based (experimental) student-centered physics learning activities to promote students' learning, motivate them toward the lesson, and associate the subject matter with their daily lives.

In this secondary qualitative analysis, three participants in Gates (2008), one participant in Hahn (2003), one participant in Yalaki (2004), and one participant in Sæleset and Friedrichsen (2021) preferred active learning approaches so that their students could better learn and understand the subject. Lena2, Lisa, and Lee Ann preferred to use hands-on activities to enable students to learn by discovery. Lena2 thinks that students should experience the discovery process in their lessons. She stated that students took control and experienced learning in this process with the following words: "I think, for me, would be the phenomena first. For me, not to explain everything first, upfront, at least for me is a big change. Having, giving and putting more control into the students and letting them figure things out, without actually telling them how to do something or the way to do it is the biggest thing for me..." (Gates, 2008, p. 114). Lena2 thought students were not mature enough to explore concepts in the discovery process. She emphasized that the teacher's direction should be limited for her students to explore, but that being able to do this may not always be suitable for every student profile, and sometimes teachers should make extra efforts to realize this. On the other hand, Lee Ann emphasized the importance of students experiencing the discovery process. She expressed her ideas in the following words: "Ask a general question and have them refer back to it as different concepts are mastered. Giving students the opportunity to discover the concept versus spoon-feeding them can be beneficial." (Gates, 208, p.108). Lee Ann also stated that experience is significant for students to understand the relationship between concepts. Another teacher, Lisa, asked her students to do pulleys. In this lesson, she expected students to discover without giving any information. Lisa expressed her happiness when she saw her students make a moving pulley as: "I didn't give them any information on pulleys at the beginning of the lesson and I had the students explore making a pulley. I was surprised that they were able to make the moveable pulley!..."(Gates, 2008, p.113).

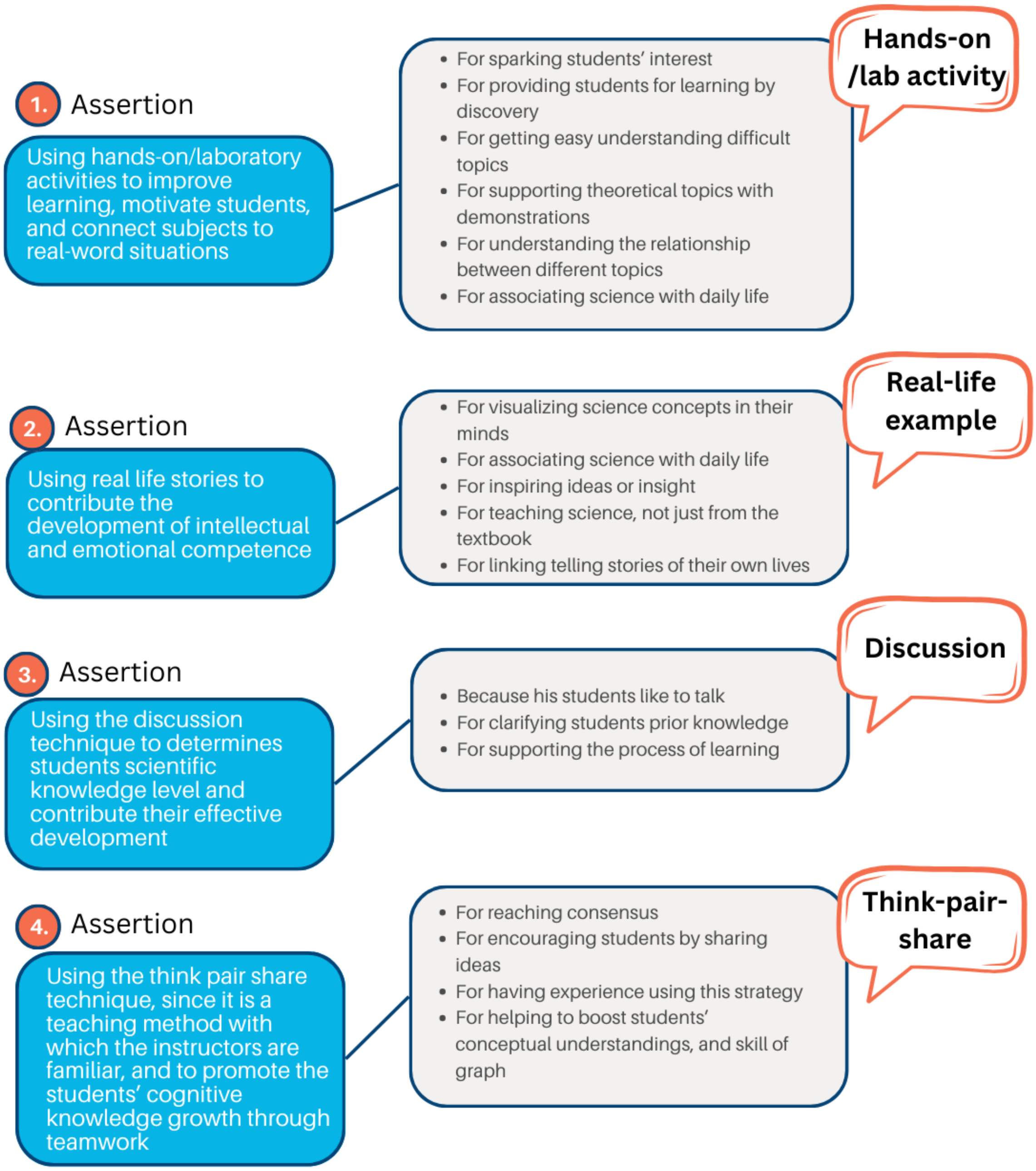

Figure 2. Relation of Assertion, Codes and Instructional Strategies

Lisa, Lee Ann, and Cathy chose hands-on activities to help their students understand difficult concepts. Lisa and Lee Ann, who took part in the same study, used the "tug of war" activity to explain balance forces. Lisa thought it would be easier for her students who experienced this game in real life to make sense of the balance force. Lee Ann also gave similar expressions to Lisa as the reason for using the same activity. Lee Ann said the following about hands-on activities: "...This activates student interest and allows them to use the common experience of a simple game to illustrate a difficult concept." (Gates, 2008, p.108). She chose games in which the students are active for teaching of the concepts that are difficult to understand. She also emphasized the importance of experiencing so that students can realize the relationship between concepts. Lena believes her students can connect theory and practice through their experiences: "I started out with theory and closed with the practical" (Sealeset & Friedrichsen, 2021, p.10). That's why, before instructing her students on the topic of energy, she had them design an electric circuit to test their theoretical understanding of the topic.

Two teachers in Gates (2008), one teacher in Yalaki (2004), and one pre-service teacher in Hahn (2003) preferred activities that students were active in to attract the attention and interest of their students. Lisa emphasized that her students enjoyed doing pulleys in the simple machine lesson. For another lesson, she commented, "I noticed lots of missed opportunities. The children were bored. We certainly should have started with the phenomena first. This would have sparked their interest" (Gates, 2008, p.113). She observed that they were bored when they did not do any hands-on and lab activities, and therefore she thought that they missed many learning opportunities. Similarly, Lee Ann used activities in which students were active to attract their attention. Lee Ann also added that one reason for including hands-on activities is to make difficult concepts understandable. Sara asked her students to do rocket projects in one of her classes. She was happier than on other days while expressing her thoughts about this lesson. She also stated that her students had fun doing the hands-on activity: “It is so much fun when they do big messy projects” (Yalaki, 2004, p.98). She thinks the educational environment becomes more fun when her students engage in hands-on activities. Cathy stated that she observed that the interest of her students increased. They had fun in her lesson in which she did experiments with her students in the laboratory environment in her lesson in which she explained Newton's laws: “...Allowing students to work in groups for research and laboratory activities is a good idea to improve student interest…” (Hahn, 2003, p.84) and “...They really enjoyed that lab” (Hahn, 2003, p.177).

One pre-service teacher in Hahn (2003) emphasized that one of the reasons why students use active activities in teaching physics is the visualization of concepts and associating them with daily life. In her lectures, Cathy aimed to associate experiments with daily life so that students could understand difficult concepts. Instead of using the experiments given in Cathy textbooks, she prefers the experiments she designed herself. For example, she dropped items with different masses on gravity in one of her lectures. Cathy chooses to show students how concepts relate to everyday life through experiments.

Assertion 2: Using Real-Life Stories to Contribute to the Development of Intellectual and Emotional Competence

Real-life stories are used in teaching physics subjects. Telling stories in their own lives allows students to enjoy and combine scientific knowledge with their own experiences. They require students to present their own life stories and discuss the physics concepts in those stories.

Assertion 2a: Using Real-Life Stories to Generate Insights about Concepts. One participant in Hahn (2003) preferred real-life stories to enable her students to generate insights about the concepts. Cathy stressed that her students' talks should include examples from daily life during her lecture on force and motion. She thinks that students who give examples from their own lives during the lesson have inspired ideas in their minds and developed insight into the subject. It is the reality that students experience in their lives. When they share this reality in their classes, the transfer of concepts to daily life is realized, and they are made to see their experiences from a different perspective. Cathy thinks that when students share their own experiences with their classmates, they can visualize the concepts in their minds: “...Students actually could visualize a “force” even though that is a difficult concept to visualize.” (Hahn, 2003, 176).

Assertion 2b: Using Real-Life Stories as Students Like to Share Their Experiences. One participant in Hahn (2003) preferred real-life stories because their students like to present. Cathy stated that her students love daily life stories. Students are eager to share stories of their own lives in class and enjoy them. Cathy had the following to say about the real-life stories technique: “...With this strategy, the students are more willing to ask questions when confused and enjoy telling stories related to what we’re learning.” (Hahn, 2003, p.184).

Assertion 3: Using the Discussion Technique to Determine Students' Scientific Knowledge Level and Contribute to Their Affective Development

The discussion/question answer technique is used in teaching physics subjects. In this technique, students are provided with both asking questions to each other, and teachers ask them questions.

Assertion 3a: Using Discussion/Question-Answer (QA) Technique to Assess Students' Knowledge Levels at the Beginning and During the Learning Process. One participant, Gates (2008) preferred discussion/QA to determine her students' knowledge levels in the learning process. Lena2 used the discussion of terms to reveal students' prior knowledge of the subject. Lena2's lectures focused on observable facts and their interrelationships. She used questions to provide these connections. She stated the following expression about the discussion/QA technique: "...made sure each of our lessons had an intro, phenomena, and post phenomena - making sure each phenomenon had a relationship to the point of the activity as well as each post-phenomena. We tied each back to the driving question…"(Gates, 2008, p.109).

Assertion 3b: Using Discussion Technique Because It is an Activity That Students Like. One pre-service teacher in Hahn (2003) and one in-service teacher in Gates (2008) frequently used discussion/QA because it is an activity that students like in the learning process. Lena and Cathy stated that their students love discussion environments, and they try to create this environment as much as possible. Lena2 noted that students appreciated discussing their own experiences using the expression: "...and the kids liked it. They enjoyed making and discussing their previous work" (Gates, 2008, p.126). Cathy also stated that his students love to talk: "My students love to talk, so they are more than willing to let me know why something relates to them. Learning is always more interesting when you can relate what you're learning to you personally."(Hahn, 2003, p.179). Cathy emphasized that the learning experience is more interesting for students who share their own experiences.

Assertion 4: Using the think-pair-share technique, since it is a teaching method with which the instructors are familiar, and to promote the students' cognitive knowledge growth through teamwork

The think-pair-share technique is used in teaching physics subjects. In this technique, students work in groups. They are asked to think together and reach a common decision on a question, and then all groups are asked to present their ideas.

Assertion 4a: Using the Think-Pair-Share Technique to Develop Students' Conceptual Understandings by Working Collaboratively. Two teachers in Gates (2008) used the think-pair-share technique in teaching physics as a reason for their students to reach a consensus, to support them to share their ideas and to help to boost students' conceptual understandings and skills of graphs. Lisa and Lee Ann emphasized that this technique is useful in making it easier for students to express their thoughts and to feel comfortable. Lee Ann stated that "...It takes the pressure off of individual students to give an answer and it allows students to discuss ideas before presenting them to the class…"(Gates, 2008, p.117). She thought students' sharing their ideas with a small group lessens their anxiety. Lisa also emphasized the importance of students discussing and reaching a consensus on a topic with their group mates: "When you put them in groups, that forces the group to come up with something to put on that paper and then they don't feel so intimidated" (Gates, 2008, p.123). Lisa and Lee Ann chose this technique and focused on students' communication and collaborative working skills.

Assertion 4b: Using the Think-Pair-Share Technique Since Teachers are Familiar with It. The teacher Lisa in Gates (2008) preferred the think, pair share technique since she used it frequently before. She stated her thoughts with the following words: "...I have really done a lot more with that…" (Gates, 2008, p.126). Lisa has chosen to use this familiar technique in her lessons.

Discussion

This article is one of the first attempts to examine the rationale of the instructional strategies used by PaIST in teaching middle school physics subjects with retrospective analysis. According to these analyses, our study underscores the scarcity of research focused on PCK within the context of PAIST's instructional strategies and their rationales when teaching physics subjects. Despite not imposing constraints on the publication year, we identified a limited pool of only four studies that met our criteria for examining the teaching strategies employed by science teachers after delivering any physics topic and the rationales behind these strategies. These studies have provided valuable insights into the rationale behind instructional strategies employed by PAIST when delivering lessons on various physics topics. They also underscore the profound dearth of research in this critical area.

In light of the limited available research, it becomes evident that PAIST frequently resorts to hands-on and laboratory activities. These strategies are employed not only to ignite students' interest but also to facilitate experiential learning, simplify the comprehension of intricate subjects, and reinforce theoretical concepts with practical demonstrations, thereby bridging interdisciplinary connections and linking science to real-life scenarios. These rationales point to the development of affective and cognitive skills. Practical activities are emphasized to be critical for the development of individuals' attitudes and motivation toward science (Corter et al., 2011; Lago et al., 2017), which can have a positive effect on students in middle school age. Practical activities are one of the recommended strategies. Because they contribute to a better understanding of abstract concepts by concretizing them, understanding their relationship with other subjects, and also making the student more active in learning (Holstermann et al., 2010; Rutherford & Ahlgren, 1990, p. 186). A meta-synthesis study demonstrated the positive impact of practical activities on students' cognitive and affective development (Brown & Lan, 2013). Consequently, it becomes evident that PaIST aims to foster cognitive and affective development in their students through the effective integration of practical activities.

Furthermore, our findings indicate that PaIST frequently employs real-life stories to enable students to conceptualize scientific ideas, bridge the gap between scientific knowledge and daily life, stimulate creativity, and foster a sense of personal connection. They advocate that relying solely on textbooks for instruction is insufficient. These rationales signify the promotion of intellectual and emotional competence. Recognizing that science fundamentally constitutes the scientific explanation of individual experiences, it appears beneficial for middle school students that PaIST reinforce the teaching of physics topics with real-life narratives. In accordance with Clark and Moss's (2011) mosaic approach, sharing experiences perceived as 'individual tiles' by students significantly contributes to merging scientific and daily occurrences, fostering creativity and insight. This approach encourages students not merely to acquire information from textbooks, the internet, or the teacher but to actively apply the knowledge they gather from diverse sources to their lives. Similar to the teachers in McNeal's (2005) study, literature supports the idea that real-life narratives enhance students' comprehension and visualization by connecting them with practical activities (Hughes, 2010).

Furthermore, our investigation reveals that PaIST utilizes the discussion technique, driven by students' inclination towards interactive discussions and its utility in elucidating prior knowledge and enhancing the learning process. These rationales suggest that this technique effectively fosters students' cognitive and affective competencies. The discussion technique hinges on asking pertinent and well-timed questions, thereby achieving logical conclusions through iterative question-answer cycles. This method is often regarded as student-centred and meaningful (Osborne, 2014). Our findings align with other studies, indicating that PaIST prefers the discussion technique due to its ease of implementation, ability to elevate students' cognitive levels by promoting creative and critical thinking, and enhancement of student motivation (Jamil et al., 2021; Özder, 2011). Furthermore, several studies corroborate teachers' insights, demonstrating that the discussion technique has a positive influence on cognitive development (Galishnikova et al., 2019; Sepeng & Webb, 2012).

The final result is the rationale for using the think-pair-share technique, as it is familiar to pre-service science teachers and supports students' cognitive knowledge development through teamwork. This situation draws attention to teachers' self-efficacy beliefs (Evers et al., 2002; Jamil et al., 2021). Because familiar strategies boost their confidence and competence in teaching practices, highlighting the role of self-efficacy beliefs. Furthermore, due to their limited experience, pre-service teachers' concerns, such as ensuring classroom management, correctly maintaining and completing the implementation process, and using appropriate activities, may lead them to use the teaching strategies they have experienced. Therefore, it is natural for teacher candidates who have not yet gained much experience to use the strategies they feel safe and experienced (Bradbury, 2010; Kind, 2009).

Based on the findings of this research, a question arises: while there is evidence supporting the effectiveness of various external strategies such as STEM education, out-of-school learning, and project-based teaching on students, along with recommendations for their implementation, why do science teachers and teacher candidates seem hesitant to adopt these methods?

Conclusion

PaIST used macro and micro strategies such as hands-on, laboratory, real-life story, discussion, and think-pair-share techniques to provide students' cognitive development, support learning with visuals, and create motivation. Considering current findings, PaIST chooses experiments which they can relate to daily life in teaching physics subjects, hands-on activities, and strategies in which their students can create environments in which they can express themselves. However, these studies did not consider additional factors that stimulate the strategy decision-making process.

Limitations and Recommendations

This study utilized specific databases to identify research articles that met the inclusion and exclusion criteria. However, access to paid publications might have been limited, representing a constraint of this research. One limitation of this study is that it exclusively included studies published in English. This criterion may have resulted in the exclusion of relevant research published in other languages, potentially leading to a narrower understanding of the topic. Future studies could enhance comprehensiveness by including data from articles in multiple languages, provided access to paid publications is secured. Despite the high volume of studies retrieved through keyword searches, only four studies met the inclusion and exclusion criteria established for this research. This limited number of relevant studies restricts the generalizability of the findings and hinders a broader perspective on the topic. To enhance the search strategy in future research, including specific physics topics taught in middle school (e.g., force and motion, energy) along with the term "physics" in database queries may yield a more comprehensive dataset.

The findings of this study indicate the need for further research examining the decision-making processes of PaIST regarding their selection of instructional strategies for teaching physics. Such research could uncover both the constraining and facilitating factors in the choice of student-centered strategies. Additionally, it is worthwhile to explore why PaIST may hesitate to adopt external strategies, such as STEM education, out-of-school learning, and project-based teaching, despite evidence supporting their effectiveness and recommendations for their integration.

As a secondary analysis, this study relies on previously collected data. While we endeavored to access all articles meeting our criteria and relevant to our research focus, the findings are limited to the direct quotations presented in the original publications. Access to the complete datasets from these original studies could potentially yield different insights.

Acknowledgment

Ethics statement: In this study, we declare that the rules stated in the "Higher Education Institutions Scientific Research and Publication Ethics Directive" are complied with and that we do not take any of the actions based on "Actions Against Scientific Research and Publication Ethics". At the same time, we declare that there is no conflict of interest between the authors, which all authors contribute to the study, and that all the responsibility belongs to the article authors in case of all ethical violations.

Author Contributions: Ş.I. and D.Y.E contributed equally to the conceptualization, methodology, validation, formal analysis, investigation, resources, data curation, writing (original draft, review, and editing), visualization, supervision, project administration, and funding acquisition.

Funding: This research received no funding.

Institutional Review Board Statement: This research is based on secondary data analysis and does not involve research conducted on live subjects. The data has been previously collected from publicly available data sources. Therefore, no ethical approval from an ethics committee is required for the compliance with ethical standards of this research.

Data Availability Statement: All data generated or analyzed during this study are included in this published article. Therefore, no additional data are available from the authors.

Conflict of Interest: Authors should declare that there is no conflict of interest among authors.

References

(Studies included in the systematic review are marked with an asterisk (*))

Abell, S.K. (2008). Twenty years later: Does pedagogical content knowledge remain a useful idea? *International Journal of Science Education, 30*(10), 1405-1416. doi:10.1080/09500690802187041

American Educational Research Association. (2006). Standards for reporting on empirical social science research in AERA publications. *Educational Researcher, 35*(6), 33–40. https://www.academia.edu/32050123/Standards_for_Reporting_on_Empirical_Social_Science_Research_in_AERA_Publications?from=cover_page

Auerbach, C., & Silverstein, L. B. (2003). *Qualitative data: An introduction to coding and analysis.* NYU Press.

Barendsen, E., & Henze, I. (2019). Relating teacher PCK and teacher practice using classroom observation. *Research in Science Education, 49*(5), 1141-1175. doi:10.1007/s11165-017-9637-z

Benabentos, R., Hazari, Z., Stanford, J. S., Potvin, G., Marsteller, P., Thompson, K. V., ... & Kramer, L. (2021). Measuring the implementation of student-centered teaching strategies in lower-and upper-division STEM courses. *Journal of Geoscience Education, 69*(4), 342-356. doi:10.1080/10899995.2020.1768005

Bender, W. N., & Ukeje, I. C. (1989). Instructional strategies in mainstream classrooms: Prediction of the strategies teachers select. *Remedial and Special Education, 10*(2), 23-30. doi:10.1177/07419325890100020

Bielik, T. and Yarden, A. (2016). Promoting the asking of research questions in a high-school biotechnology inquiry-oriented program. *International Journal of STEM Education, 3*(15), 2-13. doi:10.1186/s40594-016-0048-x

Bradbury, L. U. (2010). Educative mentoring: Promoting reform-based science teaching through mentoring relationships. *Science Education, 94*(6), 1049-1071. doi:10.1002/sce.20393

Brown, C. P., & Lan, Y. C. (2013). The influence of developmentally appropriate practice on children's cognitive development: A qualitative meta-synthesis. *Teachers College Record, 115*(12), 1-36. doi:10.1177/016146811311501207

Chiang, F. K., Diao, S., Ma, H., & Wang, Y. (2017). Effects of hand-on inquiry based learning using LEGO® materials on the learning of eighth-grade physics students. *International Journal of Engineering Education, 33*(3), 1098-1103.

Chou, P. N. (2013). Effect of instructor-provided concept maps and self-directed learning ability on students online hypermedia learning performance. *Journal of College Teaching & Learning (TLC), 10*(4), 223-234.

Clark, A., and Moss, P. (2011). *Listening to young children: The mosaic approach* (Second edition). National Children's Bureau.

Cook, D., Mulrow, C., & Haynes, R. (1997). Systematic reviews: synthesis of best evidence for clinical decisions. *Annals of Internal Medicine, 126*(5), 376. doi:10.7326/0003-4819-126-5-199703010-00006

Corter, J. E., Esche, S. K., Chassapis, C., Ma, J., & Nickerson, J. V. (2011). Process and learning outcomes from remotely-operated, simulated, and hands-on student laboratories. *Computers & Education, 57*(3), 2054-2067. doi:10.1016/j.compedu.2011.04.009

Engström, S., & Carlhed, C. (2014). Different habitus: different strategies in teaching physics? Relationships between teachers' social, economic and cultural capital and strategies in teaching physics in upper secondary school. *Cultural Studies of Science Education, 9*, 699-728. doi:10.1007/s11422-013-9538-z

Evers, W. J. G., Brouwers, A., & Tomic, W. (2002). Burnout and self-efficacy: A Study on teachers' beliefs when implementing an innovative educational system in the Netherlands. *British Journal of Educational Psychology, 72*, 227-243. doi:10.1348/000709902158865

Faikhamta, C. (2013). The development of in-service science teachers' understandings of and orientations to teaching the nature of science within a PCK-based NOS course. *Research in Science Education, 43*(2), 847-869. doi:10.1007/s11165-012-9283-4

Ford, C. (2018). Effective practice instructional strategies: Design of an instrument to assess teachers' perception of implementation. *Studies in Educational Evaluation, 56*, 154-163. doi:10.1016/j.stueduc.2017.12.004

Galishnikova, E. M., Baklashova, T. A., & Khafizova, L. V. (2019). *Didactic potential of discussion technique in teaching foreign language for pedagogics students*. In & R. Valeeva (Ed.), Teacher Education - IFTE 2017, vol 29. European Proceedings of Social and Behavioural Sciences (pp. 206-214). Future Academy. doi:10.15405/epsbs.2017.08.02.25

*Gates, H. A., (2008). *Middle school science teachers' perspectives and practices of teaching through inquiry*. (Publication No. 3332245) [Doctoral dissertation, University of South Carolina]. ProQuest Dissertations and Theses Global.

Gess-Newsome, J. (2015). A model of teacher professional knowledge and skill including PCK. In A. Berry, P. Friedrichsen, & J. Loughran (Eds.), *Re-examining pedagogical content knowledge in science education* (pp. 28-42). Routledge Press.

Goodnough, K., & Hung, W. (2009). Enhancing pedagogical content knowledge in elementary science. *Teaching Education, 20*(3), 229-242. doi:10.1080/10476210802578921

Grossman, P. L. (1990). *The making of a teacher: teacher knowledge and teacher education*. Teachers College Press.

Günther, S. L., Fleige, J., zu Belzen, A. U., & Krüger, D. (2019). Using the case method to foster preservice biology teachers' content knowledge and pedagogical content knowledge related to models and modelling. *Journal of Science Teacher Education, 30*(4), 321-343. doi:10.1080/1046560X.2018.1560208

*Hahn, L. L. (2003). *Interpretive case studies on the influence of a pre-service contextual science research course on novice science and mathematics teachers.* (Publication No. 3156077) [Doctoral dissertation, The Florida State University]. ProQuest Dissertations and Theses Global.

Hanuscin, D. L., Lee, M. H., & Akerson, V. L. (2011). Elementary teachers' pedagogical content knowledge for teaching the nature of science. *Science Education, 95*(1), 145-167. doi:10.1002/sce.20404

Heaton, J. (2008). Secondary analysis of qualitative data: An overview. *Historical Social Research, 33*(3), 33-45. doi:10.12759/hsr.33.2008.3.33-45

Higgins, J. P., & Green, S. (2011). *Cochrane handbook for systematic reviews of interventions*. The Cochrane Collaboration. London, UK.

Holstermann, N., Grube, D., & Bögeholz, S. (2010). Hands-on activities and their influence on students' interest. *Research in Science Education, 40*(5), 743-757. doi:10.1007/s11165-009-9142-0

Hughes, S. W. (2010). A practical example of a siphon at work. *Physics Education, 45*(2), 162-166. doi:10.1088/0031-9120/45/2/006

Jamil, M., Muhammad, Y., & Qureshi, N. (2021). Critical thinking skills development: secondary school science teachers' perceptions and practices. *SJESR, 4*(2), 21-30. doi:10.36902/sjesr-vol4-iss2-2021(21-30)

Jonassen, D. H., Grabinger, R. S., & Harris, N. D. C. (1991). analyzing and selecting instructional strategies and tactics. *Performance Improvement Quarterly, 4*(2), 77-97. doi:10.1111/j.1937-8327.1990.tb00456.x

Kersting, M., Schrocker, G., & Papantoniou, S. (2021). 'I loved exploring a new dimension of reality'– a case study of middle-school girls encountering Einsteinian physics in the classroom. *International Journal of Science Education, 43*(12), 2044-2064. doi:10.1080/09500693.2021.1950943

Kıncal, R. Y., Ergül R., & Timur, S. (2007). Effect of cooperative learning method to student achievement in science teaching. *Hacettepe Üniversitesi Eğitim Fakültesi Dergisi, 32*, 156-163.

Kind, V. (2009). Pedagogical content knowledge in science education: perspectives and potential for progress. *Studies in Science Education, 45*(2), 169-204. doi:10.1080/03057260903142285

Ladachart, L. (2020). Thai first-year preservice science teachers' orientations toward teaching science. *The Asia-Pacific Education Researcher, 29*(5), 455-471. doi:10.1007/s40299-019-00498-6

Lago, A., Masiero, S., Bramuzzo, S., Callegaro, E., Poloni, E., Corrà, F., & Santovito, G. (2017, March). *Exploring microbiology and biotechnologies: a laboratory approach to the study of yeasts and bacteria in primary school*. [Paper presentation]. 11th International Technology, Education and Development Conference 2017, Valencia, Spain. doi:10.21125/inted.2017.0992

Largan, C. & Morris, T. (2019). *Qualitative secondary research: A step-by-step guide*. Sage.
Lee, O., Hart, J. E., Cuevas, P., & Enders, C. (2004). Professional development in inquiry-based science for elementary teachers of diverse student groups. *Journal of Research in Science Teaching, 41*(10), 1021-1043. doi:10.1002/tea.20037
Loughran, J. J., Berry, A., & Mulhall, P. (2006). *Understanding and developing science teachers' pedagogical content knowledge*. Brill.
Lune, H., & Berg, B. L. (2017). *Qualitative research methods for the social sciences*. Pearson.
Magnusson, S., Krajcik, J., & Borko, H. (1999). Nature, sources and development of pedagogical content knowledge for science teaching. In J. Gess-Newsome & N. G. Lederman (Eds.), *Examining pedagogical content knowledge: The construct and its implications for science education* (pp. 95-133). Kluwer Academic.
Mansour, N. (2009). Science teachers' beliefs and practices: Issues, implications and research agenda. *International Journal of Environmental and Science Education, 4*(1), 25–48.
Martin, W., Silander, M., & Rutter, S. (2019). Digital games as sources for science analogies: Learning about energy through play. *Computers & Education, 130,* 1-12. doi:10.1016/j.compedu.2018.11.002
McNeal, K. (2005). The influence of a multicultural teacher education program on teachers' multicultural practices. *Intercultural Education, 16*(4), 405-419. doi:10.1080/14675980500304405
Miranda, R. J. (2010). Urban middle-school teachers' beliefs about astronomy learner characteristics. *Astronomy Education Review, 9*(1), 1-9. doi:10.3847/AER2010030
Melo, L., Cañada-Cañada, F., González-Gómez, D., & Jeong, J. S. (2020). Exploring pedagogical content knowledge (PCK) of physics teachers in a Colombian secondary school. *Education Sciences, 10*(362), 2-15. doi:10.3390/educsci10120362
Moher, D., Liberati, A., Tetzlaff, J., Altman, D. G., & PRISMA Group*. (2009). Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *Annals of internal medicine, 151*(4), 264-269.
Morine-Dershimer, G., & Kent, T. (1999). The complex nature and sources of teachers´ pedagogical knowledge. In J. Gess-Newsome & N. G. Lederman (Eds.), *Examining pedagogical content knowledge: The construct and its implications for science education* (pp. 21-50). Kluwer Academic
Nilsson, P., & Karlsson, G. (2019). Capturing student teachers' pedagogical content knowledge (PCK) using CoRes and digital technology. *International Journal of Science Education, 41*(4), 419-447. doi:10.1080/09500693.2018.1551642
Nilsson, P., & Vikström, A. (2015). Making PCK explicit—Capturing science teachers' pedagogical content knowledge (PCK) in the science classroom. International *Journal of Science Education, 37*(17), 2836-2857. doi:10.1080/09500693.2015.1106614
Oliver, M., McConney, A., & Woods-McConney, A. (2019). The efficacy of inquiry-based instruction in science: a comparative analysis of six countries using pisa 2015. *Research in Science Education, 51*(S2), 595-616. doi:10.1007/s11165-019-09901-0
Osborne, J. (2014). Teaching critical thinking? New directions in science education. School Science Review, 352, 53-62.
Özder, H. (2011). Self-efficacy beliefs of novice teachers and their performance in the classroom. *Australian Journal of Teacher Education, 36*(5), 1-15. doi:10.14221/ajte.2011v36n5.1
Park, S., & Oliver, J. S. (2008). Revisiting the conceptualization of pedagogical content knowledge (PCK): PCK as a conceptual tool to understand teachers as professionals. *Research in Science Education, 38*, 261-284. doi:10.1007/s11165-007-9049-6
Petticrew, M., & Roberts, H. (2008). *Systematic reviews in the social sciences: A practical guide*. John Wiley & Sons.
Porter, A. C., & Osthoff, E. (1994). *External strategies for stimulating and supporting school restructuring.* Madison, WI: Wisconsin Center for Educational Research.
Rollnick, M., Bennett, J., Rhemtula, N. D., & Ndlovu, T. (2008). The place of subject matter knowledge in pedagogical content knowledge: A case study of South African teachers teaching the amount of substance and chemical equilibrium. *International Journal of Science Education, 30*(10), 1365- 1387. doi:10.1080/09500690802187025

Ruggiano, N., & Perry, T. E. (2019). Conducting secondary analysis of qualitative data: Should we, can we, and how?. *Qualitative Social Work, 18*(1), 81-97. doi:10.1177/14733250177007

Rutherford, F. J., & Ahlgren, A. (1991). *Science for all Americans*. Oxford University Press.

Sağdıç, A. (2024). Shedding light on pre-service science teachers' instructional preferences and hurdles in teaching phases of the moon. *Kastamonu Education Journal, 32*(2), 201-214. doi:10.24106/kefdergi.1473470

Saldaña, J. (2013). *The coding manual for qualitative researchers*. Sage.

*Sæleset, J., & Friedrichsen, P. (2021). Pre-service Science Teachers' Pedagogical Content Knowledge Integration of Students' Understanding in Science and Instructional Strategies. *Journal of Mathematics, Science and Technology Education, 17*(5), 1-18. doi:10.29333/ejmste/10859

Scheuch, M., Panhuber, T., Winter, S., Kelemen-Finan, J., Bardy-Durchhalter, M., & Kapelari, S. (2018). Butterflies & wild bees: biology teachers' PCK development through citizen science. *Journal of Biological Education, 52*(1), 79-88. doi:10.1080/00219266.2017.1405530

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher, 15*(2), 4-14.

Shein, P. P., & Tsai, C. Y. (2015). Impact of a scientist–teacher collaborative model on students, teachers, and scientists. *International Journal of Science Education, 37*(13), 2147-2169. doi:10.1080/09500693.2015.1068465

Smith, (2008). Pitpalls and promises: the use of secondary data analysis in educational research. *British Journal of Educational Studies, 56*(3). 323-339. doi:10.1111/j.1467-8527.2008.00405.x

Sepeng, P., & Webb, P. (2012). Exploring mathematical discussion in word problem-solving. *Pythagoras, 33*(1), 1-8.

Szabo, V. and Strang, V. (1997). Secondary analysis of qualitative data. *Advances in Nursing Science, 20*(2), 66-74. doi:10.1097/00012272-199712000-00008

Tafrova-Grigorova, A., Boiadjieva, E., Emilov, I., & Kirova, M. (2012). Science teachers' attitudes towards constructivist environment: a Bulgarian case. *Journal of Baltic Science Education, 11*(2), 184-193.

Tytler, R. (2003). A window for a purpose: Developing a framework for describing effective science teaching and learning. *Research in Science Education, 33*(3), 273–298. doi:10.1023/A:1025423704068

Ültay, E. (2017). Examination of context-based problem-solving abilities of pre-service physics teachers. *Journal of Baltic Science Education, 16*(1), 113-122.

Van Driel, J. H., Verloop, N., & De Vos, W. (1998). Developing science teachers' pedagogical content knowledge. *Journal of Research in Science Teaching, 35*(6), 673-695. doi:10.1002/(SICI)1098-2736(199808)35:6<673::AID-TEA5>3.0.CO;2-J

Walan, S. (2020). Embracing digital technology in science classrooms—secondary school teachers' enacted teaching and reflections on practice. *Journal of Science Education and Technology, 29*(3), 431-441. doi:10.1007/s10956-020-09828-6

Walan, S., Nilsson, P., & Ewen, B. M. (2017). Why inquiry? Primary teachers' objectives in choosing inquiry-and context-based instructional strategies to stimulate students' science learning. *Research in Science Education, 47,* 1055-1074. doi:10.1007/s11165-016-9540-z

Wang, L. C., & Chen, M. P. (2012, July). *The effects of cognitive-affective interaction strategy on novices' creative performance in game design project*. In 2012 IEEE 12th International Conference on Advanced Learning Technologies (pp. 549-553). IEEE

Wongsopawiro, D. S, Zwart C. R, & Van Driel, J. H. (2017). Identifying pathways of teachers' PCK development. *Teachers and Teaching: Theory and Practice, 23*(2), 191-210. doi:10.1080/13540602.2016.1204286

Williams, G., & Clement, J. (2015). Identifying multiple levels of discussion-based teaching strategies for constructing scientific models. *International Journal of Science Education, 37*(1), 82-107. doi:10.1080/09500693.2014.966257

Van Driel, J. H., De Jong, O., & Verloop, N. (2002). The development of preservice chemistry teachers' pedagogical content knowledge. *Science Teacher Education, 86,* 572-590. doi:10.1002/sce.10010

Vikström, A. (2014). What makes the difference? Teachers explore what must be taught and what must be learned in order to understand the particulate character of matter. *Journal of Science Teacher Education, 25*(6), 709-727. doi: 10.1007/ s10972-014-9397-9

*Yalaki, Y. (2004). *Science teachers' worldviews: a way to understand beliefs and practices.* (Publication No. 3156258) [Doctoral dissertation, The Florida State University]. ProQuest Dissertations and Theses Global.