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Empowering preservice teachers' pck development through resource folio pck development tools: Cores and pap-ers

Wiputra Cendana [1], Sean Patrick Kang [2*], Dea Deviani Pradhipta [3]

[1] Universitas Pelita Harapan, Tangerang, Indonesia, 15811
[2] National Sun Yat-sen University, Kaohsiung, Republic of China (Taiwan), 804
[3] National Dong Hwa University, Hualien, Republic of China (Taiwan), 974

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Abstract

Effective teaching entails PCK, enabling teachers to integrate different elements of instructional design in dynamic ways. The tacit nature of PCK poses challenges for novice teachers in understanding the reasons behind certain pedagogical approaches throughout the teaching-learning process. Resource Folio, as one of the PCK development tools that combines Content Representations (CoRes) and Pedagogical and Professional-experience Repertoires (PaP-eRs), is expected to be the solution for capturing teachers' implicit pedagogical reasoning embedded in instructional design. This study investigates the use of the Resource Folio in developing and refining topic-specific PCK. 27 4th- to 6th-grade teachers in Tangerang were surveyed. The analysis of CoRes and PaP-eRs across the additional files reveals that teachers consistently use CoRes as a forward-planning pedagogical tool to align content knowledge, instructional strategies, and anticipated student difficulties, and PaP-eRs highlight teachers' real-time decisions when students struggle, ask unexpected questions, or display alternative ways of thinking. The interaction between CoRes and PaP-eRs supports continuous pedagogical improvement rather than one-time lesson preparation. In conclusion, integrating CoRes and PaP-eRs fosters intentional instructional design, responsive teaching practices, and deeper student learning. This study provides a robust framework for developing reflective educators who can translate complex scientific concepts into meaningful, accessible learning experiences.

* Corresponding Author.
E-mail address: seanpatrickkang@g-mail.nsysu.edu.tw (Sean Patrick Kang)
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1. Introduction

Effective teaching requires more than mastery of content knowledge; it entails an iterative cycle of planning, teaching, and reflection. Meaning, teachers should meaningfully tailor the instructional design to transform learning materials into authentic, meaningful, and inclusive learning experiences that align with students' needs. Consequently, teachers need to acquire this professional skill known as pedagogical content knowledge (PCK). According to Shulman (1987), PCK serves as a framework that integrates learners' knowledge, content understanding, and topic-specific instructional strategies. Further, PCK is central to teachers' effectiveness in teaching that transforms content knowledge into authentic, practical, and meaningful subject matter for students (Kind & Chan, 2019; Shing et al., 2018). Teachers' PCK is continuously developed and refined through numerous instructional planning, teaching experiences, and reflections that incorporate students' learning experiences based on their backgrounds (Carlson et al., 2019; Gess-Newsome et al., 2019). However, preservice teachers experience difficulties understanding the pedagogical reasoning behind real-time classroom decision-making when unexpected conditions arise during their observed teacher mentors' lessons, who are seasoned teachers with years of professional teaching experience. This shows the tacit nature of PCK, often embedded in lesson plans and implied in teachers' minds during teaching sessions. Things such as interpreting student thinking, making dynamic adjustments to the classroom situation that might differ from the lesson plan, and other real-time decision-making are at work in experienced teachers' minds, which are usually unscripted in the lesson plan. Previous studies show that such challenges toward preservice teachers' PCK development highlight the need for structured planning instruments and teaching opportunities to internalize the reasoning of connecting content knowledge, students' knowledge, and pedagogical approaches (Conceição et al., 2021; Drollinger-Vetter et al., 2025; Hadas et al., 2023; Mahler et al., 2024; Sæleset & Friedrichsen, 2021; Yip, 2025).

In light of the challenges above, researchers in education (especially in STEM fields) have proposed development tools to empower teachers' PCK growth, especially to support preservice teachers by making PCK more tangible. Resource Folio is one of the tools that combines Content Representations (CoRes) and Pedagogical and Professional-experience Repertoires (PaP-eRs) (Loughran et al., 2004). Both CoRes and PaP-eRs aim to capture teachers' pedagogical decision-making behind instructional design and delivery to the extent of assessment (Loughran et al., 2012). The novelty of this study lies in its contribution to investigating the role of CoRes and PaP-eRs, which together function as a Resource Folio to support preservice elementary school teachers in primary science or Natural and Social Sciences (hereinafter, IPAS) teaching through iterative cycles of planning, teaching, and reflection. In particular, preservice teachers' revision results will be analyzed to assess the progress of their PCK development. This underscores the importance of this study, as primary school teachers need to transform multiple abstract science concepts and topics (e.g., states of matter, energy, electricity, sound, light, etc.) into meaningful experiences for young learners.

Current research on primary teacher education in Indonesia have examined lesson plans, problem-based learning, technology-enhanced learning, differentiated learning, and project-based learning from IPAS subject that shows significant improvement amongst preservice teachers' instructional design and teaching practice (Anggriani et al., 2024; Budiono et al., 2025; Damayanti et al., 2025; Ekasiswi, 2025; Guslinda et al., 2025; Muhajang et al., 2025; Mustika et al., 2025; Nugrahani et al., 2025; Nurhaliza et al., 2026; Safrizal et al., 2026; Saputra et al., 2025; Sari HS et al., 2025; Sitorus et al., 2025; Susilowati et al., 2025)

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However, researchers identify a gap in the evidence and an absence of an explicit evaluation of how preservice teachers document their iterative cycles to refine topic-specific PCK through the combined use of CoRes and PaP-eRs. Therefore, building on this background, this study investigates the use of Resource Folio (CoRes and PaP-eRs) tools to support the development of preservice primary science teachers' topic-specific PCK by analyzing how these tools guide instructional design with clear pedagogical reasoning through iterative cycles. This study is guided by the research questions below:

a) How do teachers create an instructional design that incorporates pedagogical strategies while highlighting potential student challenges using CoRes?
b) How do PaP-eRs visualize teachers' decision-making and adjustment throughout the teaching and learning process?
c) What changes are visible across the cycles of planning, teaching, and reflection in CoRes and PaP-eRs?

2. Literature review

The Pedagogical Content Knowledge (PCK) framework was developed to enable teachers to transform disciplinary content into meaningful forms for students, aligning with learning goals (Shulman, 1987, 1986). Specifically in science education, PCK highlights teachers' understanding of the integration of content knowledge, students' prior knowledge, students' learning challenges with common misconceptions, assessment methods, and teaching strategies in line with learning goals through multiple means of representations (Gess-Newsome et al., 2019; Shing et al., 2018). PCK is developed through cycles of refinement of planning, teaching, and reflection on student outcomes based on the learning goals (Van Driel et al., 1998). PCK is based on topic-specific content and is shaped by a specific teaching-learning context, such as students' background (e.g., class, performance record), subject-specific factors, and curriculum goals (Angeli et al., 2016; Kind & Chan, 2019). Hence, PCK is a complex construct that does not lend itself to a one-size-fits-all approach.

The Refined Consensus Model (RCM) is one of the most recent frameworks that emphasizes contextual implementations of PCK. The RCM views PCK into different representations, such as collective PCK (shared professional knowledge and resources in a particular institution), personal PCK (teacher's personal understanding based on experiences), and enacted PCK (applied knowledge that is visible through teaching practices) (Carlson et al., 2019). This strengthens the idea of using representation tools to capture both instructional design and real-time decision-making in teaching. Recent studies also support integrating components to examine teachers' PCK through representation tools rather than in isolation (Chan, 2022; Sarkar et al., 2024; Schiering et al., 2023; Şen et al., 2022). In relation to this study, such a distinction in PCK analysis aligns with the roles of CoRes, which reveal the personal PCK underlying the intended pedagogical approaches, and PaP-eRs, which reflect the refinement of PCK aspects.

Numerous studies in education have highlighted one driving factor of effective teaching: teachers' ability to address students' learning challenges by choosing appropriate pedagogical strategies that empower them to overcome those challenges (Eames, 2016; Gess-Newsome et al., 2019; Nilsson & Karlsson, 2019). Though the challenge arises for preservice teachers due to the tacit nature of PCK, they can only observe experienced teachers' decision-making during teaching sessions without fully understanding the pedagogical reasoning. PCK is implicitly embedded across instructional design and delivery, which are context-bound (Gess-Newsome et al., 2019; Rafiah & Winarti, 2024; Tal et al., 2021). Furthermore, the interpretation of students'

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thinking and the shifting pedagogical approaches throughout the teaching-learning activities occur simultaneously in the teacher's mind, which might differ from the instructional alignment (Han-Tosunoglu & Lederman, 2021; Nilsson & Elm, 2017). Realistically, teaching-learning activities may not fully align with the planned instructional design, posing real-time PCK challenges for preservice teachers who have fragmented content, students, and pedagogical knowledge (Nurmatin & Purwianingsih, 2017).

Preservice teachers may design engaging instruction based on what they have observed from experienced teachers on different occasions. However, without a clear structure, they will not be able to meaningfully connect such attractive learning activities to subject-specific big ideas, goals, and assessment methods. The importance of structure for preservice teachers' PCK is supported by current studies, which show that it helps them map out subject-specific activities, transfer tasks, and assessments (Buldu & Buldu, 2021; Conceição et al., 2021). Further, this helps preservice teachers to integrate students' cognitive growth (e.g., prior knowledge, thinking process during the lesson, and understanding at the end of the lesson) and instructional approaches with clear pedagogical reasoning (Bui et al., 2025; Dragnić-Cindrić & Anderson, 2025; Kramer et al., 2021; Mahler et al., 2024; Sæleset & Friedrichsen, 2021). The PCK development of preservice teachers is happening over time through numerous teaching experiences. Previous longitudinal studies highlight the gradual improvement of preservice teachers' ability to design lesson representations, anticipate students' learning difficulties, and align assessment results to instructional goals (Drollinger-Vetter et al., 2025; Koberstein-Schwarz & Meisert, 2022; Yip, 2025). Therefore, the findings support this study's aim to examine how the Resource Folio reveals preservice teachers' pedagogical growth across iterative cycles of planning, teaching, and reflection.

Loughran and colleagues developed the Resource Folio as a theoretically aligned development tool for teachers. Resource Folio helps teachers in PCK instructional design for a specific subject-related topic, carefully tailoring learning activities to the expected outcomes by applying Content Representations (CoRes) and Pedagogical and Professional-experience Repertoires (PaP-eRs) (Bertram, 2014; Bertram & Loughran, 2012; Loughran et al., 2004). Here, teachers name and analyze their specific pedagogical techniques with practice-based descriptions that standard instructional documentation does not precisely visualize (Nilsson & Elm, 2017). Resource Folio functions as a structured yet tangible PCK representation for a particular topic that combines both knowledge used in instructional alignment and applied in delivery (Kind & Chan, 2019; Lehane & Bertram, 2016).

A CoRe is an organized matrix derived from the topic's big idea to represent teachers' topic-specific content knowledge. This scaffolds teachers through prompts on the intended learning outcomes, related big conceptual ideas, possible student learning difficulties, teaching procedures, and varied assessment approaches aligned with learning goals (Lehane & Bertram, 2016; Loughran et al., 2012). CoRes scaffolds teachers to translate topic-specific concepts and justify instructional activities with strong pedagogical reasoning that connects the students' learning process to curriculum goals (Eames, 2016). This helps preservice teachers construct meaningful, activity-driven learning through goal-oriented assessments and other teaching representations (Nilsson & Karlsson, 2019). The instructional design will be carefully tailored to the relevant big conceptual ideas rather than mere content coverage (Kind & Chan, 2019). Recent studies on CoRes amplify its role as a scaffolding tool for lesson planning and a methodological framework to capture teachers' topic-specific PCK, instructional choices with pedagogical reasoning, teaching reflection, and refinement over time (Forsler et al., 2024a, 2024b; Nilsson & Karlsson, 2019; Sannert et al., 2026). Though CoRes should be complemented by an additional

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tool to capture all PCK components equally, thereby enriching reflection and teaching evidence. This strengthens the case for pairing CoRes with PaP-eRs for holistic teachers' PCK development.

CoRes is complemented with PaP-eRs to visualize PCK in action through descriptive teaching logs that highlight essential teaching and learning activities and embed theoretically aligned reasoning in those moments (Carpendale & Hume, 2019; Loughran et al., 2004). Pairing both CoRes and PaP-eRs aligns with previous studies on enacted PCK, teacher talk, and PCK mapping on topic-specific that argue the teachers' ability to adapt with the classroom dynamics beyond the intended practice is more crucial than just designing the lesson (Mapulanga et al., 2024; Mazibe, 2026; Ottogalli & Bermudez, 2024; Smets & Tuithof, 2024). Here, PaP-eRs document the missing record of teachers' decision-making based on their interpretation of students' thinking, classroom responses, and unexpected classroom conditions beyond the planned instructional strategies. PaP-eRs are connected to CoRes and grounded in practice to visualize teachers' PCK in the teaching and learning process (Nilsson & Elm, 2017). There are detailed prompts that incorporate teachers' detailed strategies with their explanations in responding to emerging ideas from students through particular classroom activities, interpreting students' tasks as evidence of understanding, and adapting teaching approaches in a real-time context. PaP-eRs created as the lesson progresses can provide a holistic and robust understanding of teachers' PCK development over time (Bertram & Loughran, 2012; Mulhayatiah et al., 2023). Further, this highlights how teachers' dynamic approach of PCK can be visualized and understood from collections of PaP-eRs narratives (Carpendale & Hume, 2019; Rafiah & Winarti, 2024).

In relation to primary education, especially in science or IPAS subject-specific contexts, CoRes and PaP-eRs tools are highly relevant to primary students' needs. Young learners need practical learning experiences, concrete representations (e.g., models, analogies, multimodal visual aids), and real-life examples or transfer tasks to understand abstract science concepts. Recent studies in primary education suggest young learners learn at their best through hands-on learning activities, connections to real-life context (e.g., project-based learning and problem-based learning), differentiated approaches based on their needs (e.g., instructions and assessments), and technology-enhanced learning (e.g., digital game-based learning and multimodal content representations) (Azzahra & Saleh, 2024; Mustika et al., 2025; Prayuda et al., 2025; Safrizal et al., 2026; Waluya et al., 2026). These findings mainly highlight instructional strategies, appropriate motivation, and multimodal teaching materials. Hence, this study provides greater coverage by focusing on teachers' pedagogical reasoning behind the chosen teaching strategies, their decisions to respond to students' challenges, and the development of PCK across iterative cycles.

Therefore, Resource Folio, with its CoRes and PaP-eRs, provides a complete theoretical and practical framework for representing topic-specific PCK from planning through teaching (Lehane & Bertram, 2016; Loughran et al., 2012). This supports teachers' PCK growth through structured reflection and a visualized matrix to represent the extent of teachers' content knowledge across planning, teaching, and refinement (Mulhayatiah et al., 2023; Nilsson & Elm, 2017). Thus, Resource Folio serves not only as a documentation tool but also as a developmental instrument, helping teachers refine their pedagogical approaches by grounding their PCK reasoning in knowledge of their students (Han-Tosunoglu & Lederman, 2021; Loughran et al., 2012). Consequently, this study addresses the conceptual gap in the literature, where few studies examine both roles of CoRes and PaP-eRs as a Resource Folio to support preservice primary teachers' topic-specific PCK development in the primary science subject. This study uses the

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Resource Folio as an analytical tool to examine preservice teachers' PCK progress from planned to enacted pedagogical strategies, supported by clear pedagogical reasoning.

3. Method

This research adopted a qualitative design-based research (DBR) methodology to investigate how teachers make their tacit pedagogical content knowledge (PCK) explicit and communicable through the development of Resource Folios, which include Content Representations (CoRes) and Pedagogical and Professional-experience Repertoires (PaP-eRs). A DBR framework was selected because it supports iterative processes of planning, implementation, reflection, and revision—processes that mirror the evolving, context-specific character of PCK as a topic-bound, practice-embedded form of professional knowledge (van Driel et al., 1998; Gess-Newsome, 2015; Gess-Newsome et al., 2019).

The investigation examined PCK across three interrelated stages of teaching practice:

a) Instructional planning, as articulated in CoRes;
b) Instructional enactment and real-time adaptation, as documented in PaP-eRs, and
c) Reflective refinement of pedagogical reasoning across successive cycles.

27 participants completed a survey conducted in May 2026. This survey was conducted in Tangerang, Indonesia, among upper elementary (4th to 6th grade) subject teachers. Participants were preservice teachers responsible for teaching the same or closely aligned subject matter within a particular disciplinary domain. Purposeful sampling was employed to ensure the inclusion of individuals actively involved in both lesson preparation and classroom instruction, thereby providing access to their intended pedagogical reasoning as well as their enacted teaching decisions. The study was situated within an authentic educational environment. Within this setting, participants were encouraged to trial instructional approaches while systematically reflecting on student learning outcomes. This contextual embedding was essential for capturing the situated and dynamic nature of PCK, recognizing that instructional decisions are influenced by learners' characteristics, curricular expectations, institutional frameworks, and classroom interactions.

4. Results

4.1 Teachers' instructional planning through cores: pedagogical approaches and anticipation of student difficulties

The analysis of CoRes reveals that teachers consistently use CoRes as a forward-planning pedagogical tool to align content knowledge, instructional strategies, and anticipated student difficulties. Across grade levels and science topics, teachers structured instruction around big ideas rather than isolated facts, indicating a deliberate effort to promote conceptual understanding. Teachers demonstrated strong awareness of students' cognitive development. For example, in Grade 4 sound energy and Grade 6 electricity topics, abstract scientific concepts (e.g., vibration, free electrons, energy transformation) were intentionally translated into concrete experiences through experiments, demonstrations, analogies, and real-life examples. This suggests that CoRes function as a planning scaffold, helping teachers choose pedagogical approaches such as inquiry-based learning, discovery learning, constructivism, and hands-on activities to reduce conceptual complexity. Secondly, practical methods such as CoRes help

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students realize that what is taught in the theoretical process is not just theory, but also has real-world applications that help them in the workforce.

A recurring pattern across the CoRes is teachers' deliberate attention to students' existing misconceptions as a starting point for instructional planning. Teachers consistently recognize that many students enter the classroom with intuitive but scientifically inaccurate ideas formed from everyday experiences. For example, when learning about sound energy, students often assume that sound simply "appears," unaware that vibrations produce it. This misconception leads teachers to prioritize hands-on experiments that allow students to see and feel vibrations directly, helping them reconstruct their understanding through observation and inquiry.

Similarly, in topics related to electricity, teachers identify students' assumptions that all metals conduct electricity in the same way. This belief influences teachers to design comparative activities using different materials, enabling students to test conductivity and recognize that electrical properties vary across substances. In ecosystem-related topics, teachers note that students tend to think in linear terms, viewing food chains as simple, unchanging sequences rather than interconnected food webs within dynamic ecosystems. As a result, instructional strategies emphasize visual models, group discussions, and simulations to help students understand interdependence and change within ecosystems.

In life science topics, misconceptions also emerge in students' perceptions of microorganisms and animals. Teachers report that many students initially view bacteria solely as harmful, which shapes lesson planning to introduce the concept of beneficial bacteria through familiar contexts, such as digestion and food fermentation. Likewise, teachers recognize that students often categorize all animals kept by humans as pets, without distinguishing between livestock, ornamental animals, or animals raised for economic purposes. This awareness leads teachers to incorporate real-life examples, classification activities, and contextual discussions that help students develop more accurate biological and social understanding.

Overall, the CoRes narrative shows that identifying misconceptions is not incidental but central to teachers' pedagogical reasoning. By explicitly anticipating how students might misunderstand key concepts, teachers can select teaching approaches, representations, and activities that directly challenge and refine students' thinking, supporting bigger, more meaningful conceptual change. By documenting these misconceptions in CoRes, teachers proactively planned instructional interventions, such as guided experiments, visual media, role-play, and contextual discussions, to directly confront and reconstruct students' prior understanding. This indicates that CoRes supports not only what to teach, but also how and why specific pedagogical choices are necessary.

4.2 Visualization of teachers' decision-making and adaptation through pap-ers

PaP-eRs complement CoRes by making visible the situated and responsive nature of teaching. While CoRes capture teachers' intentions, PaP-eRs illustrate how those intentions are enacted, adjusted, and sometimes redefined during instruction. Across the additional files, PaP-eRs highlight teachers' real-time decisions when students struggle, ask unexpected questions, or display alternative ways of thinking. For instance, teachers reported modifying explanations, simplifying terminology, introducing analogies, or extending hands-on activities when students showed confusion. In topics such as the human digestive system or sound propagation, teachers shifted from verbal explanations to visual simulations or physical demonstrations after observing students' difficulty in imagining unseen processes.

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PaP-eRs also reveal adaptive pacing and strategy selection, particularly when time constraints or limited teaching resources emerged. Teachers demonstrated pedagogical flexibility by prioritizing core concepts, integrating multimedia resources, or redesigning activities to maintain student engagement. This adaptive decision-making reflects the development of pedagogical content knowledge (PCK), in which teachers continuously balance curriculum goals, student needs, and classroom realities. Overall, PaP-eRs function as reflective narratives that capture teaching as an evolving practice rather than a fixed implementation of lesson plans.

4.3 Changes across cycles of planning, teaching, and reflection in cores and pap-ers

Across iterative cycles, notable changes appear in both CoRes and PaP-eRs, reflecting professional growth and refinement of pedagogical reasoning. Initially, teachers' CoRes tend to emphasize content coverage and activity selection. However, over time, there is a clear shift toward deeper consideration of students' thinking, learning progression, and conceptual coherence.

Over time, teachers increasingly demonstrate refinement in their instructional planning and implementation, reflecting a growing sophistication in their pedagogical reasoning. One prominent development is the careful sequencing of big ideas, in which teachers become more intentional about arranging concepts from concrete, familiar experiences toward more abstract scientific understanding. Rather than treating topics as isolated units, teachers design learning progressions that help students gradually build coherent and connected knowledge.

Alongside this, teachers show stronger alignment between learning objectives and assessment practices. Learning goals are no longer framed solely around content coverage but are closely matched with assessment tasks that capture students' conceptual understanding and thinking processes. This alignment enables teachers to monitor learning progress better and use assessment outcomes to inform instructional adjustments. Teachers also refine their use of representations to bridge students' everyday experiences with scientific concepts. Visual models, simulations, hands-on experiments, analogies, and real-life examples are increasingly chosen not just for engagement but also for their ability to support conceptual understanding. These representations help students make sense of abstract ideas by anchoring them in observable phenomena and familiar contexts.

Finally, teachers more deliberately integrate safety, ethical considerations, and real-world implications into their instruction. Topics such as electrical safety, ecosystem conservation, and healthy lifestyles are embedded within scientific explanations, helping students see science as relevant to their daily lives and responsible decision-making. This integration reflects a shift toward teaching science not only as a body of knowledge but also as a means of fostering awareness, responsibility, and informed action in real-world contexts. Reflection documented in PaP-eRs informs subsequent planning, thereby improving clarity in CoRes. This cyclical process shows how teaching decisions become more intentional, student-centered, and evidence-informed. The interaction between CoRes and PaP-eRs thus supports continuous pedagogical improvement rather than one-time lesson preparation.

5. Discussion

The fact that students actually learn better through practical methods rather than theoretical methods demonstrates that CoRes (Content Representations) and PaP-eRs (Pedagogical and Professional-experience Repertoires) function as complementary tools that

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make preservice primary teachers' pedagogical reasoning visible, structured, and progressively refined. CoRes documented the instructional strategies with clear pedagogical reasoning from lesson planning, while PaP-eRs captured the implemented instructional deliveries and reflective thinking throughout the teaching. The findings align with the main purpose of Resource Folios, which is to visualize the pedagogical reasoning implicit in teaching (Bertram & Loughran, 2012; Loughran et al., 2004). Drawing conceptually from Lee Shulman's notion of pedagogical content knowledge (PCK), the findings show how teachers integrate content knowledge, knowledge of students, and instructional strategies into coherent planning and responsive enactment. Across grade levels and science domains, teachers used CoRes not merely as lesson templates but as cognitive scaffolds to anticipate learning challenges, select representations, and align instruction with conceptual goals.

The analysis indicates that teachers consistently organized instruction around "big ideas" rather than discrete facts. This emphasis reflects an orientation toward conceptual coherence and aligns with constructivist views of learning, in which learners actively construct knowledge through interaction with experiences and social mediation. By foregrounding core scientific principles—such as vibration in sound energy, energy transformation in electricity, and interdependence in ecosystems—teachers demonstrated awareness that meaningful understanding depends on conceptual integration rather than memorization. Importantly, CoRes supported teachers in translating abstract scientific ideas into developmentally appropriate learning experiences. In upper elementary contexts, where students are transitioning from concrete operational to more formal reasoning, teachers deliberately employed experiments, analogies, simulations, and real-life examples to reduce cognitive load and make invisible processes observable. This suggests that CoRes operate as mediating artifacts that help teachers bridge disciplinary knowledge and learners' cognitive readiness.

A key contribution of the findings is the central role of anticipated misconceptions in shaping instructional planning. Teachers' identification of common intuitive beliefs—such as sound "appearing" without vibration, all metals conducting electricity equally, ecosystems functioning as linear chains, or bacteria being exclusively harmful—served as entry points for pedagogical decision-making. Rather than treating misconceptions as incidental classroom errors, teachers incorporated them as predictable starting points for conceptual change. This anticipatory stance reflects a sophisticated form of PCK, where teachers recognize that students' prior knowledge is both a resource and a constraint. By designing comparative experiments, classification tasks, visual modeling, and contextual discussions, teachers intentionally created cognitive conflict and guided reconstruction of understanding. The findings, therefore, align with conceptual change frameworks, which hold that learning involves restructuring existing mental models rather than simply adding new information.

CoRes, in this regard, extends beyond planning "what to teach" and explicitly addresses "why this approach is necessary." The documentation of likely misunderstandings compels teachers to justify their pedagogical choices in relation to learners' thinking, reinforcing the epistemic dimension of science teaching. While CoRes articulate teachers' intended reasoning, PaP-eRs reveal the dynamic and responsive character of classroom practice. The narratives show that teaching unfolds as a series of situated decisions shaped by students' reactions, time constraints, and resource availability. Teachers modified explanations, shifted modalities (e.g., from verbal to visual), extended hands-on activities, or simplified terminology when students showed confusion.

This responsiveness highlights teaching as adaptive expertise rather than procedural implementation. In particular, the movement from planned representation to enacted

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representation underscores the iterative negotiation between curriculum goals and classroom realities. PaP-eRs capture this process as reflective accounts, illustrating how teachers evaluate the effectiveness of their strategies and recalibrate accordingly. Such adaptive decision-making is central to mature PCK. It reflects the capacity to balance disciplinary integrity, developmental appropriateness, and contextual constraints in real time. The documentation of these micro-decisions provides empirical visibility to the often tacit dimension of professional judgment. Across cycles of planning, teaching, and reflection, both CoRes and PaP-eRs reveal developmental progression in teachers' pedagogical reasoning. Initially, planning focused more on activity selection and content coverage. Over time, however, teachers demonstrated:

a) Improved sequencing of big ideas, moving from concrete experiences to abstract generalizations in a more intentional learning progression.
b) Stronger alignment between objectives and assessment, indicating greater coherence between intended learning outcomes and evidence of understanding.
c) More purposeful use of representations, selected not merely for engagement but for conceptual clarity.
d) Integration of safety, ethical, and real-world implications, positioning science as socially relevant and responsibility-oriented.

These changes suggest that engagement with CoRes and PaP-eRs supports reflective practice and professional learning. Reflection documented in PaP-eRs informs subsequent CoRes planning, creating a feedback loop that strengthens instructional intentionality. Teaching thus becomes an evolving, evidence-informed practice rather than a static execution of lesson plans. The interaction between CoRes and PaP-eRs illustrates how structured planning and reflective narration together can scaffold the development of PCK. For professional development programs, particularly in elementary science education, these tools provide:

a) A shared language for discussing instructional reasoning
b) A mechanism for anticipating and addressing misconceptions
c) A structure for aligning objectives, strategies, and assessments
d) A reflective framework for analyzing classroom decision-making

By making pedagogical reasoning explicit, CoRes and PaP-eRs shift professional discourse from describing activities to examining underlying conceptual and epistemic considerations. This has implications for teacher education, collaborative lesson study, and curriculum design, where the goal is not merely effective delivery but principled and responsive instruction.

6. Conclusion and implications

CoRes enable teachers to plan instruction systematically by organizing big ideas, selecting appropriate pedagogical approaches, and anticipating student difficulties grounded in knowledge of learners' cognitive development and misconceptions. PaP-eRs, in turn, make the dynamic nature of teaching visible by documenting how teachers interpret classroom interactions and adapt instruction to students' needs. Together, CoRes and PaP-eRs reveal teaching as a reflective, adaptive, and evolving practice rather than a linear delivery of content.

These changes highlight the value of CoRes and PaP-eRs not only as instructional planning tools but also as professional learning instruments that support continuous growth. In conclusion, integrating CoRes and PaP-eRs fosters intentional instructional design, responsive teaching practices, and deeper student learning.

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Declaration and Statement

CRediT Authorship Contribution Statement

Wiputra Cendana: Conceptualization, Methodology, Investigation, Project Administration, Writing - original draft, review and editing, Formal Analysis. Sean Patrick Kang: Conceptualization, Publication administration, Writing - original draft, review and editing, Literature Framework, Supervision, Formal Analysis. Dea Deviani Pradhipta: Writing - review and editing, Formal Analysis. All authors reviewed and approved the final manuscript

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Aggregated data supporting the findings may be made available by the corresponding author upon reasonable request, subject to ethical restrictions and protection of participant confidentiality.

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During the preparation of the revised manuscript, the authors did not use Generative AI and AI-Assisted Technologies to support language refinement, editorial organization, and consistency checking. The authors independently reviewed and edited the content and took full responsibility for the publication's content.

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