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Teaching biology and geology as reflective decision-making: designing an asynchronous online professional development course for in-service science teachers

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Professional development in discipline-specific pedagogy remains a persistent challenge in teacher education, particularly when addressed in fully online, asynchronous settings with in-service practitioners. This article describes and theorises the design of Specific Didactics of Biology and Geology, a 14-week professional development course offered at Universidade Aberta, Portugal's public open distance university, within the framework of the institution's Pedagogical Model. The course targets in-service Biology and Geology teachers enrolled in the first year of a teacher professionalisation programme. Rather than reporting a completed impact evaluation, the article offers a theoretically grounded, design-oriented practitioner inquiry account of course design, early implementation reflections, and transferable design principles for asynchronous online teacher professional development. Its conceptual core is the framing of teaching as didactic decision-making, integrating reflective practice, didactic transposition, and experiential learning theory into a coherent design philosophy that places participants' existing professional experience at the centre of learning. The article argues that subject-specific professional development can be meaningfully designed in a fully asynchronous online format, provided that the e-activity repertoire is epistemically varied, experientially anchored, and coherent with the pedagogical principles under study. Three structural features are discussed in detail: a two-tier activity design distinguishing non-assessed preparatory tasks from assessed e-activities; a deliberately diverse typology of digital activity formats, each serving a distinct cognitive and social function; and an integrative culminating task, the Professional Development and Pedagogical Action Plan, developed progressively across the final three weeks of the course. By describing the course design in sufficient detail to enable adaptation to comparable contexts, the article contributes to research-informed approaches to online teacher professional development. It highlights the pedagogical potential of asynchronous learning environments when they are designed not as simplified substitutes for face-to-face provision, but as coherent spaces for reflective, situated, and discipline-specific professional learning.

KEYWORDS
asynchronous e-learning, biology and geology education, community of practice, online learning, professional development, reflective practice, science education, science teacher education

1 Introduction

The professional development of in-service science teachers - particularly in the domain of subject-specific pedagogy - constitutes a persistent challenge in teacher education systems worldwide (Darling-Hammond et al., 2017; Garet et al., 2001). While considerable research has addressed the content and organisation of initial teacher education, far less attention has been devoted to the design of sustained, discipline-specific professional development opportunities for practising teachers, especially in fully online environments (Dede et al., 2009; Trust and Horrocks, 2016).

In Portugal, as in many European countries, in-service teacher professionalisation is a growing concern (European Commission/EACEA/Eurydice, 2015). Teachers who entered the profession through non-standard pathways - particularly in the sciences - frequently lack formal pedagogical training in subject-specific didactics. As a result, key pedagogical decisions - what to teach, how to sequence content, how to question students, how to design experimental work, how to respond to student diversity - are often made implicitly, without grounding in science education research.

At the same time, in-service teachers represent a distinctive kind of learner. Unlike pre-service students, they bring to professional development a substantial body of experiential knowledge: years of classroom decisions, accumulated observations of student behaviour, strategies developed through trial and error, and a professional identity shaped by real institutional contexts. Any effective professional development programme must take this accumulated experience seriously - not as background noise, but as the primary epistemic resource from which new understanding is constructed (Knowles, 1980; Kolb, 1984; Opfer and Pedder, 2011). Recent research confirms that professional development programmes which are contextually anchored, sustained over time, and aligned with teachers' own classroom realities consistently produce greater engagement, higher transfer rates, and more meaningful instructional change than those that are generic or decontextualised (Darling-Hammond et al., 2017; Obilana, 2025).

It is against this backdrop that this article is situated. Specific Didactics of Biology and Geology is a 14-week course offered at Universidade Aberta (UAb), Portugal, within the framework of its Pedagogical Model (MP-UAb), targeting in-service Biology and Geology teachers enrolled in a formal professionalisation programme. The course is delivered in a fully asynchronous online format - not as a mere response to logistical constraints, but as a principled pedagogical choice consistent with UAb's institutional commitment to fully online, asynchronous higher education, and grounded in the professional realities of its participants. This positioning is also consistent with recent arguments that asynchronous-first design in teacher professional development should be understood not as a compromise, but as an ethical response to the temporal conditions of in-service teachers' professional and personal lives (Albergaria-Almeida, 2026b). The course is offered here not merely as a case study, but as a worked example of design reasoning made explicit - described in sufficient detail to enable critical scrutiny, informed adaptation, and theoretical dialogue. In keeping with the format of a Curriculum, Instruction, and Pedagogy (CIP) article, the course is therefore presented not as an empirical impact study, but as a theoretically grounded account of pedagogical design, implementation rationale, and transferable instructional principles.

The article advances three interrelated arguments: that subject-specific pedagogical knowledge can be substantively developed in fully asynchronous online environments; that the design of professional development for practising teachers is itself a theoretical act, requiring explicit articulation of the epistemological assumptions underlying each design decision; and that the framing of teaching as didactic decision-making - integrating reflective practice, didactic transposition, and experiential learning - provides a coherent and generative conceptual architecture for science teacher professional development - one that the remainder of this article maps, justifies, and critically examines.

The course addresses a dual challenge: developing teachers' conceptual and practical knowledge of Biology and Geology didactics, while doing so through a pedagogical format coherent with the principles it teaches - placing the teacher-learner at the centre of informed, reflective decision-making.

2 Pedagogical framework

2.1 The teacher as didactic decision-maker

The conceptual spine of the course is the framing of teaching as a practice of pedagogical reasoning. This framework holds that every act of teaching - selecting content, choosing a pedagogical strategy, formulating a question, responding to a student's answer, designing an assessment task - constitutes a decision grounded (explicitly or implicitly) in assumptions about learning, knowledge, curriculum, and professional identity. Drawing on Schön's (1983) notion of the reflective practitioner and on the broader tradition of teacher professional knowledge (Shulman, 1986), the course aims not to transmit a fixed body of didactic knowledge, but to develop teachers' capacity to examine, justify, and refine their own pedagogical choices.

2.2 Didactic transposition

A second theoretical pillar is Chevallard's (1985) concept of didactic transposition - the process by which scholarly knowledge is transformed into teachable knowledge. This concept operates at a complementary level to Shulman's (1986) notion of pedagogical content knowledge (PCK): where PCK describes the specialised knowledge a teacher develops to make content comprehensible to specific learners (Carlson et al., 2019; Kind and Chan, 2019), didactic transposition foregrounds the broader institutional and curricular processes through which scientific knowledge is restructured before it even reaches the teacher. Together, these frameworks invite teachers to examine their role as active agents in the construction of school knowledge, rather than mere conduits of a prescribed syllabus.

2.3 Experiential learning and adult professional development

Following Kolb's (1984) experiential learning cycle - and a subsequent critical revisitation of its implications for adult professional learning in higher education contexts (Albergaria-Almeida, 2015) - and drawing critically on Knowles's (1980) principles of adult learning, the course treats participants' accumulated professional experience not merely as context but as content: every learning activity is anchored in a concrete professional situation that participants have already lived or are currently navigating.

This has both motivational and epistemological implications: abstract didactic concepts are encountered as tools for re-reading problems participants already recognise from practice, and the course functions as a space for the progressive theorisation of experience - from tacit professional knowledge towards explicit, critically examined, and transferable didactic understanding.

2.4 Community of practice and the social dimension of professional learning

Beyond individual reflection, the course draws on Wenger's (1998) concept of communities of practice - and its subsequent elaborations in professional and digital contexts (Trust and Horrocks, 2016; Wenger-Trayner and Wenger-Trayner, 2015) - to justify its collaborative dimensions. In-service teachers often navigate challenges such as student misconceptions, tensions between curriculum prescriptions and classroom reality, and assessment uncertainties in relative isolation. The collaborative tools embedded in the course (forums, Padlets, Perusall) create shared spaces where such difficulties become visible as collective professional conditions rather than individual failings, contributing to the normalisation of professional difficulty and to a strengthened sense of belonging to a shared practice.

2.5 The UAb pedagogical model

The course is anchored in the Pedagogical Model of Universidade Aberta (MP-UAb), updated in 2026 to reflect the maturation of the institution's distance education practice and the pedagogical challenges of the post-digital era (Casanova et al., 2026). The model is built on three structural principles - interaction, inclusion, and flexibility - all grounded in a transversal commitment to student-centred learning. The 2026 revision reinforces activity-based design, continuous assessment, learner autonomy, authentic assessment, and competence development - dimensions directly enacted in the course described here.

Within this framework, the course both follows and enacts the MP-UAb. It follows the model's structural prescriptions - asynchronous delivery, continuous assessment, activity-based design - and enacts its underlying principles: the pedagogical values that participants study (learner autonomy, formative feedback, differentiation, reflective practice) are simultaneously the values that govern their own learning experience. This alignment between object of study and design of study is not coincidental; it is a deliberate expression of the MP-UAb's commitment to coherent, values-driven pedagogical design - and, more broadly, of UAb's institutional mission of open, distance, and lifelong education as a vehicle for professional inclusion and democratisation of access to knowledge.

The frameworks outlined above are not used as parallel theoretical references, but as mutually reinforcing lenses for course design. Reflective practice defines the professional stance expected of participants; didactic transposition specifies the disciplinary problem of transforming Biology and Geology knowledge into teachable school knowledge; experiential learning explains why teachers' prior classroom experience is treated as a central learning resource; and communities of practice justify the collaborative spaces through which individual reflections become available for collective professional interpretation. The MP-UAb provides the institutional and pedagogical conditions through which these principles are enacted in an asynchronous online environment. Figure 1 summarises this conceptual architecture.

3 Learning environment

3.1 Setting and context

The course is offered through UAb's Platform, a Moodle-based learning management system. It is delivered in fully asynchronous mode, with two optional synchronous sessions. All learning materials, e-activities, assessment tasks, and communication spaces are hosted within the platform. The course runs from April to July, spanning 14 weeks of active learning.

The course constitutes the subject-specific didactics unit (discipline-based pedagogy) of the second semester of the first year of UAb's In-Service Teacher Professionalisation Programme (Curso de Profissionalização em Serviço). Within the programme's curricular structure, this unit belongs to the subject-specific didactics group (16 ECTS total) and is designed to develop disciplinary pedagogical competence grounded in participants' professional practice. The work produced in this unit feeds directly into the Professional Development and Pedagogical Action Plan (PFAP), the central component of the second year of the programme.

3.2 Participants and teaching team

The course is designed for 32 in-service Biology and Geology teachers, including Natural Sciences teachers, enrolled in UAb's In-Service Teacher Professionalisation Programme. Participants are practising professionals who teach in Portuguese secondary schools (10th–12th grade) or middle schools (7th–9th grade), bringing diverse professional contexts, school realities, and levels of experience to the course.

The course was designed and delivered by the first author, a specialist in science education and teacher professional development, with the support and scientific coordination of the

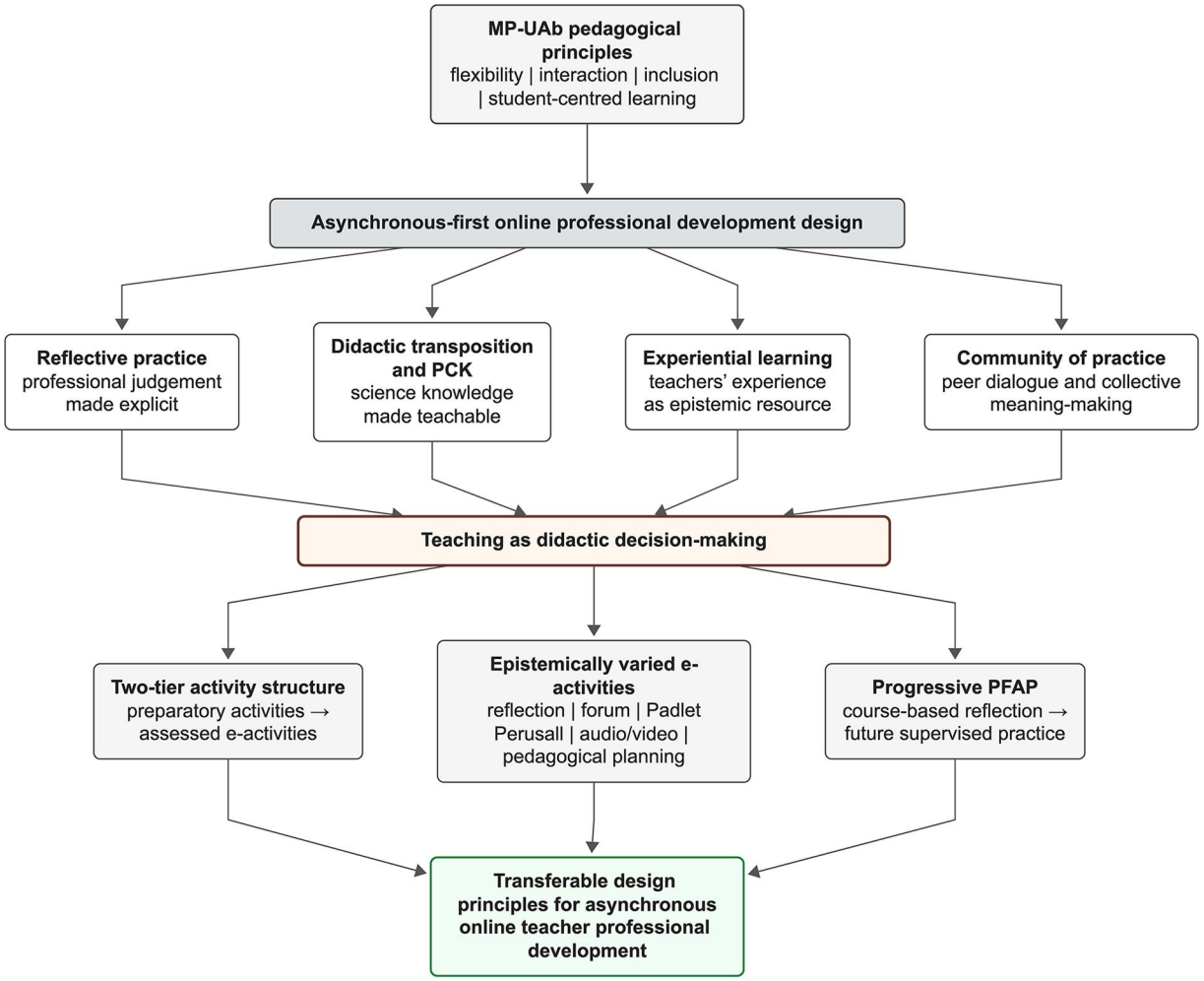

FIGURE 1
Conceptual architecture of the course design. The model represents the relationship between the MP-UAb pedagogical principles, the asynchronous-first design, the central framing of teaching as didactic decision-making, the four theoretical lenses informing the course, and the operational design features through which the framework is enacted.

second author. Both authors have disciplinary and pedagogical expertise in Biology and Geology education and Didactics.

The thematic architecture of the course reflects an established research-based orientation in science education. The selection of classroom questioning (Weeks 6–7), fieldwork in Biology and Geology (Week 5), and approaches to learning and differentiation (Weeks 8–9) as discrete thematic units is grounded in published empirical research in each of these areas (Albergaria-Almeida, 2010, 2013, 2015; Almeida and Neri de Souza, 2010; Barros et al., 2012; Martinho et al., 2025; Pedrosa de Jesus et al., 2006). In this way, the course design is informed by a cumulative research tradition rather than by generic pedagogical prescription. Technical support for the pedagogical transposition to the Moodle platform was provided by an instructional designer.

3.3 Estimated workload

The course entails an estimated weekly workload of approximately 6–7 h over the 14-week period, combining engagement with learning materials, preparatory activities, assessed e-activities, and independent study.

3.4 Learning objectives

By the end of the course, participants are expected to:

- Critically analyse the teaching of Biology and Geology as a practice of situated pedagogical choice, recognising the complexity of choices involved in planning, conducting, and assessing learning;
- Interpret structuring curricular documents (Student Profile at the End of Compulsory Schooling; Essential Learning outcomes), identifying their didactic implications;
- Understand conceptual learning processes in science, including the role of alternative conceptions, cognitive conflict, and scientific language;
- Analyse the role of questioning, discourse, and interaction in science classrooms, interpreting student responses - including errors and silences - as evidence of thinking;

- Understand the contribution of experimental and fieldwork in Biology and Geology education, distinguishing different typologies and levels of didactic intentionality;
- Problematise diversity in science learning, including differentiated pedagogy and support strategies for students with Portuguese as a non-native language;
- Critically analyse assessment and feedback practices and their role in regulating learning;
- Plan coherent annual teaching sequences and design a comprehensive Professional Development and Pedagogical Action Plan.

3.5 Research approach and analytic procedure

Consistent with the Curriculum, Instruction, and Pedagogy (CIP) article format, this article adopts a design-oriented practitioner inquiry approach. The unit of analysis is not participant learning outcomes, but the pedagogical design of the course itself: its rationale, structure, activity sequence, assessment architecture, and alignment with the institutional pedagogical model. The purpose is therefore analytic rather than evaluative: to make visible the reasoning through which a fully asynchronous course in Biology and Geology Didactics was designed for in-service teachers. In this sense, the course designer is positioned both as practitioner and as reflective analyst of the design process, an orientation that is consistent with design-based and practitioner inquiry traditions in education (McKenney and Reeves, 2012).

The analysis draws on a bounded corpus of design documentation produced during course development and early implementation: (a) the official curricular description and learning objectives of the unit; (b) weekly planning documents; (c) Moodle activity descriptions and assessment guidelines; (d) design rationale notes written during the construction of the course; (e) reflective implementation notes produced by the course teacher during the first weeks of delivery; and (f) the institutional principles of the Universidade Aberta Pedagogical Model. These materials were selected because, taken together, they document the movement from institutional requirements and curricular aims to concrete pedagogical decisions, activity design, assessment structure, and early implementation reflection. Table 1 summarises the sources included in this corpus and the analytic function of each source within the study.

These materials were not treated as evidence of participant impact, but as traces of pedagogical reasoning through which the course design could be reconstructed, interpreted, and theorised.

The analytic procedure involved three stages. First, design decisions were identified across the course documentation, including decisions about sequencing, activity format, assessment weighting, feedback moments, and the relationship between preparatory learning activities and assessed e-activities. Second, each decision was interpreted in relation to the conceptual frameworks mobilised in the course: reflective practice, didactic transposition, experiential learning, communities of practice, and the MP-UAb principles of interaction, inclusion, flexibility, and student-centred learning. Third, recurring patterns across these decisions were synthesised into transferable design principles. A design feature was retained as a principle when it met three criteria: it recurred across more than one course component, it could be theoretically justified through the framework, and it had potential relevance beyond the specific institutional context of the course.

TABLE 1 Sources and analytic function of the design-oriented practitioner inquiry.

Source of evidence	Analytic function
Official course description and learning objectives	To identify intended learning outcomes and institutional constraints
Weekly planning documents	To reconstruct sequencing, thematic progression, and workload distribution
Moodle activity descriptions	To analyse the relationship between learning activities, e-activities, digital tools, and assessment
Assessment guidelines and weighting	To examine coherence between pedagogical aims, assessment criteria, and the continuous assessment structure
Design rationale notes	To identify the reasoning underpinning key design decisions
Teacher reflective implementation notes	To interpret early feasibility, tensions, adjustments, and constraints during delivery
MP-UAb institutional model	To situate the course within the principles of interaction, flexibility, inclusion, and student-centred learning

This procedure may be characterised as abductive and interpretive. Rather than applying theory mechanically to a pre-existing course, the analysis moved iteratively between theory, design documentation, and early implementation reflections. The resulting principles are therefore not presented as empirically validated predictors of effectiveness, but as theoretically grounded design claims that can guide adaptation, critique, and future empirical investigation. This dual positioning carries its own epistemological weight: the practitioner-researcher brings to the analytical process not only professional expertise but a situated and institutionally embedded form of knowledge, whose legitimacy rests on depth of engagement with the pedagogical context as well as on theoretical interpretation (Albergaria-Almeida, 2026a).

Because the present article analyses course design documentation and does not report identifiable participant data, formal ethical approval was not sought for this design-oriented account. Any future empirical analysis of participant productions, feedback, interaction patterns, or engagement data will be subject to the relevant ethical and institutional procedures. This methodological positioning defines the scope of the article: it offers a transparent and theoretically grounded account of pedagogical design, while leaving the systematic empirical evaluation of participant learning, engagement, and classroom transfer to future research.

4 Course structure and pedagogical format

4.1 Thematic organisation

The course is structured into five thematic clusters, developed over 14 weeks:

4.1.1 Theme 1 - teaching science as didactic decision-making (weeks 1–2)

Participants are invited to problematise the teaching of Biology and Geology as a professional practice of informed choice. Week 1 focuses on teachers' professional identity and decision-making in real classroom contexts; Week 2 examines didactic transposition and the construction of school knowledge.

4.1.2 Theme 2 - conceptual learning and knowledge construction (weeks 3–5)

This theme addresses the processes by which students construct scientific knowledge, with particular attention to alternative conceptions, cognitive conflict, and conceptual change (Week 3); the foundations, typologies, and didactic intentionality of experimental work (Week 4); and the epistemological specificity of fieldwork in Biology and Geology (Week 5).

4.1.3 Theme 3 - interaction, discourse, and questioning (weeks 6–7)

The focus shifts to classroom interaction: the role of questioning as a pedagogical tool (Week 6) and the analysis of student discourse, participation patterns, and interpretation of student responses - including errors and silence - as diagnostic evidence (Week 7). The selection of questioning as a discrete thematic unit is supported by research demonstrating the centrality of questioning patterns in shaping science classroom dynamics and the significant gap between teachers' espoused beliefs about questioning and their actual classroom practices (Albergaria-Almeida, 2010; Almeida and Neri de Souza, 2010; Martinho et al., 2025).

4.1.4 Theme 4 - diversity, language, and inclusion (weeks 8–9)

This theme explores learner diversity in science education, including different approaches to learning (Week 8) and the specific challenges of teaching Biology and Geology to students with Portuguese as a non-native language, within a framework of cognitive demand and pedagogical differentiation (Week 9).

4.1.5 Theme 5 - analysing, planning, and integrating didactic decisions (weeks 10–14)

The final five weeks constitute an integrative, professionally-oriented phase. Participants deepen their reflection on assessment and formative feedback (Week 10), reflective planning of teaching sequences (Week 11), and progressively develop their PFAP: from annual planning and class management design (Week 12), through a curricular intervention or research project (Week 13), to a consolidated final submission (Week 14).

4.2 The two-tier activity structure: learning activities and E-activities

A structural feature of the course that deserves explicit attention is the systematic distinction between two types of learning tasks: learning activities and e-activities.

Learning activities are non-assessed preparatory tasks – typically individual reading, viewing, annotation, or comparative analysis – designed to activate prior knowledge and build the conceptual basis for the subsequent assessed task. They are not submitted or graded and are explicitly positioned as serving the learner's preparation rather than institutional evaluation. In this low-stakes epistemic space, participants can encounter new ideas and start connecting theoretical frameworks to their professional experience without the pressure of assessment. Research on scaffolded and formative learning consistently supports the value of such preparatory structures in adult professional development contexts (Black and Wiliam, 1998; Lei and Lei, 2026).

E-activities, by contrast, require the production and submission of a tangible outcome: a written reflection, a forum contribution, a Padlet entry, an audio/video recording, or an element of the PFAP. Their assessment is continuous - distributed across the full 14-week period rather than concentrated in terminal examinations - and their criteria value the quality of argumentation, the depth of reflection, and the coherence between theoretical frameworks and professional experience.

This two-tier structure is consistent across all 14 weeks of the course, ensuring that every assessed task is preceded by at least one non-assessed preparatory engagement. The result is a pedagogical rhythm alternating between exploration and consolidation - well-suited to adult learners managing the competing demands of professional and personal life alongside postgraduate study.

4.3 E-activity typology

The course employs a deliberately varied repertoire of e-activity formats, each serving a distinct epistemic and social function. This variety reflects the range of cognitive operations that a course on pedagogical reasoning demands, including analysis, narration, argumentation, observation, comparison, and synthesis. At the level of course design, it also enacts the very principle of differentiation that participants are asked to study. The deliberate diversity of formats is not merely a preference for variety: research on approaches to learning consistently shows that different pedagogical formats activate distinct cognitive modes and accommodate different learning orientations, making format diversity a pedagogical act in itself rather than a technical convenience (Albergaria-Almeida, 2015; Pedrosa de Jesus et al., 2006).

Individual Written Reflections are the most frequent format, ranging from 300 to 1,000 words depending on the week. Participants write structured reflective texts anchored in both

theoretical frameworks and their own professional experience. These are not summative exercises: they function as externalisations of emerging didactic thinking, making tacit professional knowledge visible for examination and critique. Depending on the week, written reflections are either submitted privately to the course teacher or shared in asynchronous forums - a design choice that serves distinct pedagogical purposes. Private submissions create a protected space for genuine professional vulnerability, allowing participants to articulate uncertainties or difficulties without the exposure of public posting. Forum-based reflections, by contrast, open that thinking to peer dialogue, enabling the co-construction of knowledge, the normalisation of shared professional concerns, and the emergence of a collective reflective culture across the cohort.

Asynchronous Forums are used for collaborative, dialogic knowledge construction, in line with research on the potential of online forums and Moodle-based environments to foster questioning and dialogic engagement in science education (Martinho et al., 2014). Each prompt is framed as a professional challenge rather than a generic discussion question: participants share a teaching decision, a problematic situation, or a topic-specific transposition strategy, and are required to engage substantively with at least one peer contribution. Forum participation is assessed on the quality of argumentation and critical interaction, not on mere presence.

Perusall (Annotated Collaborative Reading) is employed in Week 3 for social annotation of a text on alternative conceptions. Participants comment on passages that provoke interest, doubt, or disagreement and connect the text to their professional experience, transforming individual reading into a shared epistemic event.

Padlet (Shared Digital Boards) is used across multiple weeks for rapid, low-stakes sharing: questions participants wish to explore (Week 1), alternative conceptions encountered in practice (Week 3), photographs and field notes from micro-fieldwork (Week 5), classroom questioning examples (Week 6), and reflections on learning diversity (Week 8). These shared boards function as a social mirror of professional practice, making visible the diversity of participants' teaching realities.

Audio/Video Reflections are introduced in Week 7, where participants record a brief oral reflection on a classroom interaction episode, introducing a multimodal register into an otherwise text-dominant environment.

The Professional Development and Pedagogical Action Plan (PFAP) constitutes the course's integrative culminating task and its most substantial assessment element, accounting for 50% of the final grade. Developed progressively across Weeks 12–14, the PFAP is not a terminal examination but a professionally situated production process: participants are required to design a coherent annual teaching sequence for a Biology or Geology class of their choice (Week 12), develop either a curricular intervention project or an action research proposal grounded in their own classroom context (Week 13), and submit a consolidated, reflective final plan (Week 14). Each stage builds on the previous one, and formative feedback from the course teacher is planned to be provided between stages, allowing for revision and deepening before the final submission.

The PFAP operationalises the full range of concepts and frameworks addressed in the course - didactic transposition, conceptual learning, questioning strategies, diversity, formative assessment, and reflective planning - anchoring them in the participants' own professional reality. Its progressive, three-stage structure is a deliberate design choice: it distributes cognitive demand over time, models the kind of iterative, reflective planning that the course advocates as professional practice, and transforms the culminating assessment from a test of learning into an act of professional development in its own right. Crucially, the PFAP is not a contained academic exercise: it constitutes the foundational document for the second year of the professionalisation programme, in which participants are assessed on their actual teaching practice in school contexts. The plan developed in this course thus becomes the working instrument for the professional development and classroom intervention work that follows in the subsequent academic year. In this sense, the plan serves a supervisory function in the broadest sense of the term: it is the instrument through which the first-year course connects to the practicum supervision of the second year, bridging theoretical preparation and observed professional practice.

4.4 Optional synchronous moments

Two optional synchronous sessions (April 23 and July 7, 2026, 18:00–18:30) are integrated into the course as non-compulsory supplements to the otherwise fully asynchronous design. No course content is communicated exclusively through these sessions, ensuring that participation has no bearing on assessment outcomes. The first serves a relational function - establishing a visible, embodied connection between course teacher and participants at the outset of the course (Garrison and Vaughan, 2008); the second, positioned at the onset of the PFAP phase (Week 12), provides a space for real-time dialogue at the moment of highest cognitive demand. Both are brief (30 min) and scheduled for late afternoon, in recognition of participants' professional constraints. Participation in the first session reached approximately one third of enrolled participants - a figure discussed further in Section 6.2.

4.5 Illustrated example: week 5 - fieldwork in biology and geology

Week 5, dedicated to fieldwork in Biology and Geology, illustrates how the course's design principles are operationalised in a fully asynchronous environment. The week was selected because it brings together the two-tier activity structure, the experiential orientation of the course, the use of shared digital spaces, and the movement from concrete professional action to didactic theorisation.

The week begins with a non-assessed preparatory reading on the epistemological specificity of geological fieldwork (Marques and Praia, 1997). Participants are then asked to conduct a short micro-fieldwork observation in an accessible everyday location, such as a street, garden, park, beach, riverbank, or urban geological exposure. They share one or two photographs on a class Padlet, accompanied by a brief caption identifying the location and its didactic potential. A subsequent individual written reflection asks participants to analyse the micro-visit through the distinction between observation, interpretation, and inference, and to consider what transforms an outdoor observation into a didactically intentional fieldwork activity.

The pedagogical value of this sequence lies less in the field visit itself than in the transformation of a familiar environment into a site of didactic reasoning. The task reduces common barriers to fieldwork, such as distance, cost, equipment, and time, while preserving the epistemic structure of field-based science education. It also makes didactic transposition visible: participants must decide what counts as relevant scientific knowledge in a local setting, how that knowledge could be made accessible to students, and what forms of questioning or scaffolding would be needed to support learning. The Padlet board functions as a collective repertoire of possible fieldwork contexts, while the written reflection requires each participant to move from experience to conceptual analysis. In this sense, the sequence enacts Kolb's (1984) experiential cycle within an asynchronous design and exemplifies the course's broader framing of teaching as didactic decision-making.

5 Assessment design and preliminary observations

5.1 Assessment design

Assessment in the course is continuous and formative in orientation, aligning with the MP-UAb's principle of embedding assessment within the learning process itself (Casanova et al., 2026). Research consistently demonstrates that distributing assessment across multiple tasks - rather than concentrating it in terminal examinations - reduces cognitive overload, supports deeper engagement with course content, and is particularly effective in professional development contexts where participants need to integrate new knowledge with existing practice (Lei and Lei, 2026; Parmigiani et al., 2024). Table 2 presents the distribution of assessment components across the course.

This distribution reflects the course's commitment to continuous, diversified and professionally situated assessment.

5.2 Coherence between pedagogy and assessment

A deliberate design principle of the course is the coherence between the pedagogical practices being studied and the forms of assessment employed. Teachers who are invited to reflect on the role of formative feedback in student learning are themselves assessed through a process that values progressive elaboration, peer dialogue, and professional contextualisation over summative performance. This alignment between object of study and learning experience is a distinctive feature of the course design, and constitutes what Biggs (2003) termed constructive alignment at the level of the professional development programme itself.

TABLE 2 Distribution of assessment components across the course.

Format	Weeks	Weight
Individual reflections (written and audio/video)	1, 3, 4, 5, 6, 7, 10	25%
Critical comment	11	5%
Forum contributions + Perusall annotation	2, 3, 8, 9	10%
Padlet	1, 3, 5, 6, 8	10%
PFAP (3 progressive stages)	12, 13, 14	50%
Total		**100%**

Bold values indicate the percentage weight of each assessment component in the final course grade.

The distribution of assessment weight across multiple small tasks - rather than concentrated in terminal assignments - reduces the stakes of any individual submission, encouraging participants to take intellectual risks and share genuinely uncertain reflections. This is particularly significant for practising professionals, for whom admitting uncertainty in a formal academic context may represent a considerable psychological threshold (Desimone, 2009). It should be noted, however, that the PFAP accounts for 50% of the final grade - a weight that reflects not a contradiction of this principle, but its logical extension: the PFAP is not a terminal test of memorised content, but an integrative professional product developed progressively over three weeks, with formative feedback at each stage. Its weight signals the primacy of professional application over declarative knowledge, and is consistent with the course's overall commitment to assessment as a process of professional development rather than institutional certification.

5.3 Current status and preliminary observations

The current edition of the course is in progress (April–July 2026), with 32 enrolled participants, and represents the first delivery of the course in its present form. The observations reported in this section are not presented as empirical findings or evidence of learning outcomes, but as bounded practitioner reflections generated during early implementation. They draw on the course teacher's design diary, implementation notes, and non-identifiable observations of participation patterns. Accordingly, the claims made in this CIP article concern design coherence, implementation feasibility, and the theoretical grounding of the pedagogical architecture, rather than demonstrated impact.

Early implementation suggests that the opening e-activities are functioning in the way intended by the design. The Week 1 individual reflection, which asked participants to revisit a recent didactic decision from their own classroom practice, elicited professionally situated forms of self-examination rather than generic statements about teaching. This observation supports the design assumption that beginning from teachers' own classroom decisions can serve as both a motivational entry point and an epistemological bridge between experiential knowledge and formal didactic theory.

The first optional synchronous session, held on April 23, 2026, was attended by approximately one third of enrolled participants. Within a conventional attendance logic, this proportion might be read as limited engagement. Within an asynchronous-first design for in-service teachers, however, it confirms the importance of not making synchronous presence structurally necessary. The session

served its intended relational function for those able to attend, while the course design ensured that no participant was disadvantaged by non-attendance. This early observation reinforces the distinction between synchronous moments as optional relational and navigational supports, and asynchronous e-activities as the core structure of participation and assessment.

These observations remain preliminary and deliberately modest. They do not establish effectiveness, but they indicate that the first implementation of the course is generating the kinds of participation conditions anticipated by the design: engagement anchored in teachers' own professional experience, flexible access for participants with constrained schedules, and early movement from practical classroom situations toward explicit didactic reasoning. A systematic analysis of participant productions, interaction patterns, feedback processes, and post-course outcomes is planned for the post-course evaluation phase.

6 Discussion

6.1 Practical implications

The contribution of the course design lies not in claiming that asynchronous online professional development is, in itself, novel. Existing research has already established the potential of online and blended teacher professional development when it is sustained, collaborative, content-focused, and connected to practice (Dede et al., 2009; Desimone, 2009; Trust and Horrocks, 2016). The specific contribution of the present design is more focused: it shows how discipline-specific didactics in Biology and Geology can be organised around teachers' didactic decision-making in a fully asynchronous environment. Three features are particularly distinctive in the present design: first, the use of didactic transposition and pedagogical content knowledge as organising disciplinary lenses; second, the systematic two-tier distinction between preparatory learning activities and assessed e-activities; and third, the progressive PFAP, which connects weekly conceptual work to a professional plan that will inform participants' subsequent supervised practice. The optional synchronous moments are therefore not the defining feature of the model; rather, they function as selective relational and navigational supports within an asynchronous-first architecture.

First, the course illustrates how subject-specific pedagogy - typically associated with face-to-face mentoring and observation - can be meaningfully addressed in a fully asynchronous online environment, provided that the e-activity design is sufficiently varied, contextually anchored, and epistemically demanding. The diversity of formats (forum, Padlet, Perusall, audio/video, written reflection, PFAP) mirrors the diversity of pedagogical approaches that participants are simultaneously studying, creating a metalevel coherence between content and method.

Second, the course illustrates the productive tension between structure and flexibility that characterises effective asynchronous online professional development (Dede et al., 2009). Weekly thematic progression provides a shared scaffold; individual e-activities allow participants to draw on their own school contexts, student populations, and professional challenges. This combination of shared content and personalised application is particularly well-suited to a diverse cohort of in-service teachers working in different school contexts across Portugal.

Third, the course contributes to questioning the assumption that asynchronous formats are inherently less rigorous than face-to-face modalities. The estimated workload of 6–7 h per week, the requirement for substantive written production, and the integrative demands of the PFAP position this course firmly within the tradition of research-informed professional development (Desimone, 2009). Crucially, the optional integration of two brief synchronous moments into an otherwise fully asynchronous course is consistent with recent research suggesting that bichronous designs - combining the flexibility of asynchronous delivery with targeted synchronous interactions - can enhance both relational quality and cognitive outcomes in online professional development contexts (Martin et al., 2024). More broadly, designing an asynchronous-first course for in-service teachers is not merely a pedagogical preference - it is an ethical acknowledgement that professional learning for practising teachers happens, necessarily, in the interstices of an already-full professional and personal life (Albergaria-Almeida, 2026a, 2026b). The ethical imperative of asynchronous-first design lies precisely in this recognition: that the structural conditions of participants' lives are not an obstacle to be overcome, but a reality to be respected and built around.

6.2 Design decisions: reflective notes

Drawing on the course design and early practitioner reflections, six transferable design principles can be identified for asynchronous online professional development in discipline-specific teacher education.

6.2.1 Principle 1: start from teachers' situated professional experience

A central design decision was to position participants' existing professional experience not as background information, but as the starting point for learning. Rather than asking in-service teachers to "suspend" their classroom knowledge in order to receive theoretical input, the course invites them to reinterpret their own decisions, routines, dilemmas, and observations through the conceptual lenses of science education, didactics, and reflective practice. This principle is particularly important in professional development programmes for teachers who already teach, but whose experiential knowledge may not yet be formally recognised within institutional qualification frameworks.

6.2.2 Principle 2: distinguish preparatory learning activities from assessed e-activities

The systematic distinction between non-assessed preparatory activities and assessed e-activities is one of the most consequential structural decisions of the course design. By ensuring that every assessed task is preceded by a low-stakes preparatory engagement with the relevant content, the course creates the conditions for deeper, better-grounded production in the e-activities themselves. Participants who have already encountered a concept through a preparatory reading, video,

annotation task or exploratory prompt, and who have had the opportunity to begin connecting it to their experience without the pressure of assessment, are better positioned to produce the kind of critical, contextualised reflection that the e-activities demand.

6.2.3 Principle 3: diversify digital formats according to epistemic function

The course deliberately employs a wide repertoire of e-activity formats - individual written reflections, collaborative forums, social annotation, shared digital boards, audio/video responses, and the progressive PFAP. This diversity is not a technological ornament. A course centred on pedagogical reasoning requires participants to think, compare, narrate, annotate, argue, observe, plan and synthesise; no single activity type can adequately mediate all of these cognitive operations. The alternation between formats creates structured variation in epistemic demand and addresses participant diversity not only as a topic of study, but as a constitutive principle of the learning design itself. In this sense, the diversity of strategies functions as pedagogical modelling: participants are not only asked to value intentional, differentiated teaching; they are themselves placed in a learning environment that enacts those principles.

6.2.4 Principle 4: align assessment with the pedagogical principles being taught

The course design seeks coherence between what is taught and how learning is assessed. If teaching is framed as reflective decision-making, assessment cannot be limited to reproduction of theoretical content. The e-activities require participants to interpret classroom situations, analyse curricular documents, formulate questions, respond to student diversity, plan sequences, and justify pedagogical choices. This alignment between conceptual framework and assessment architecture is central to the course's internal coherence. Assessment becomes not only a means of verifying learning, but also a space in which participants rehearse the professional reasoning that the course seeks to cultivate.

6.2.5 Principle 5: use an integrative professional plan as a culminating synthesis

The Professional Development and Pedagogical Action Plan functions as the culminating integrative device of the course. Its progressive construction across the final three weeks, rather than as a single terminal task, distributes cognitive demand over time and allows for formative feedback at intermediate stages. The PFAP requires participants to mobilise previous course themes - curriculum, learning difficulties, questioning, classroom interaction, diversity, assessment and planning - in a coherent professional proposal. In this way, the final task is not simply an assessment product, but a transition from course-based reflection to future professional action.

6.2.6 Principle 6: use synchronous moments selectively in asynchronous-first designs

The optional synchronous moments in the course illustrate the value of a deliberately asynchronous-first design. Approximately one third of participants attended the first synchronous session, a proportion that reinforces a core principle in professional development for in-service teachers: synchronous participation cannot be assumed and should not be structurally required. The value of these sessions lies not in attendance figures but in function. The first serves a relational purpose at the outset of the course; the second provides navigational support at the threshold of the PFAP phase. Together, they suggest a typology of synchronous function in asynchronous courses - relational and navigational - that may be useful for designers of comparable programmes.

6.3 Constraints and limitations

Several constraints merit honest acknowledgement, both as indicators of the boundaries of this article's claims and as pointers for future research.

6.3.1 Generalisability

The course was designed for a specific institutional framework (the MP-UAb), a specific national curricular context, and a specific professional population (Portuguese secondary and middle school science teachers enrolled in a formal professionalisation programme). While the pedagogical architecture - the two-tier activity structure, the e-activity typology, the progressive PFAP, and the asynchronous-first architecture with selective synchronous support - is in principle transferable, its adaptation to other contexts requires equivalent curricular anchoring and institutional negotiation.

6.3.2 Absence of outcome data

The current edition of the course is ongoing, and formal data on participant learning outcomes, assessment quality, and classroom transfer are not yet available. This article describes a designed and theoretically justified course rather than a fully evaluated one. The claims advanced here are claims of design coherence and theoretical grounding, not of demonstrated impact. Follow-up reporting of outcome data - drawing on participant assessment products, end-of-course feedback, and, where feasible, classroom observation - is planned and will constitute the empirical counterpart to this design-oriented account.

6.3.3 Constraints of asynchronous-first professional learning

The asynchronous-first design also entails pedagogical risks that should not be minimised. Flexibility can support access for in-service teachers, but it can also intensify experiences of isolation if interaction is not deliberately structured. For this reason, the course includes forums, shared Padlets, Perusall

annotation, and optional synchronous moments; however, the existence of these tools does not guarantee equitable or equally meaningful participation. Participants differ in confidence, time availability, digital fluency, writing fluency, and willingness to make professional uncertainty visible to peers. Asynchronous participation may therefore reproduce inequalities unless prompts, deadlines, feedback, and assessment criteria are carefully designed to value substantive engagement rather than frequency of posting.

6.3.4 Feedback quality constitutes a further constraint

In asynchronous courses, feedback is often delayed, text-heavy, and dependent on the teacher's capacity to respond meaningfully across multiple submissions. The progressive PFAP is designed to mitigate this risk by distributing feedback across stages, but it also increases the workload and interpretive responsibility of the course teacher. The quality of the design therefore depends not only on the architecture of activities, but also on the sustainability of teacher feedback practices during implementation.

6.3.5 Interaction in asynchronous environments requires ongoing pedagogical maintenance

Forums and shared boards can become spaces of genuine professional exchange, but they can also become repositories of parallel monologues if participants do not respond critically to one another. The course addresses this through prompts that ask participants to engage with peer contributions and through assessment criteria that value argumentation and interaction. Even so, the depth of peer dialogue remains an empirical question for future analysis. These constraints do not invalidate the asynchronous-first model; rather, they define the conditions under which such a model must be designed, supported, and studied.

6.3.6 Teaching-team configuration and first-edition effects

The course was designed by the first author with the support and scientific coordination of the second author, and is delivered in its current edition by the first author. The design documentation and early implementation reflections on which this article draws therefore emerge from a close insider position: the main course designer is also the teacher responsible for implementation. This positioning is consistent with practitioner inquiry methodology (McKenney and Reeves, 2012), but introduces a risk of confirmation bias that future external evaluation will need to address. With 32 participants, the cohort is sufficient to generate meaningful collaborative dynamics, but cohort-specific factors and first-delivery effects will inevitably require some design revision - a process consistent with the iterative logic of design-based research.

6.4 Future directions

The modular architecture of the course - five thematic clusters, each with its own conceptual framework, e-activity sequence, and assessment component - suggests a natural pathway toward micro-credential design. Topics currently addressed in a single week, such as fieldwork, classroom questioning, diversity and inclusion in science education, carry sufficient theoretical depth and practical complexity to sustain standalone eight-to-ten-week professional development units. Such units could serve in-service teachers who wish to pursue deeper engagement in specific areas without committing to a full programme, and could equally support professionals whose career trajectories do not map straightforwardly onto traditional academic or institutional pathways - including those entering, re-entering, or repositioning themselves within formal professional development after periods of interruption, career reorientation, or parallel professional lives (Albergaria-Almeida, 2026a).

In this sense, micro-credentials may be understood not only as instruments of continuing professional development, but also as spaces of personal and professional re-articulation. For teachers and other professionals with non-linear trajectories, flexible, asynchronous, and experientially anchored learning environments can create opportunities to reconnect accumulated experience with formal knowledge, rebuild professional confidence, and make prior, dispersed, or institutionally under-recognised forms of expertise more visible. This constitutes a promising direction for future work at the intersection of science education, teacher development, lifelong learning, and personal development.

7 Conclusion

This article has presented the design of a fully asynchronous online professional development course in Biology and Geology didactics as a theoretically grounded response to the needs of in-service science teachers enrolled in a professionalisation programme. Rather than treating online delivery as a logistical constraint, the course positions asynchronous design as a pedagogical and ethical choice that recognises the professional and personal conditions under which practising teachers pursue further qualification. Its central contribution lies in the articulation of teaching as didactic decision-making and in the translation of that principle into a coherent course architecture. The two-tier distinction between preparatory learning activities and assessed e-activities, the epistemically varied repertoire of digital formats, and the progressive construction of the PFAP illustrate how subject-specific pedagogy can be addressed through reflective, experiential, and professionally situated online learning.

The contribution of the article is therefore deliberately bounded. It does not demonstrate that the course improves teacher learning outcomes, nor does it claim that asynchronous delivery is universally preferable to face-to-face or blended professional development. Instead, it offers a transparent and theoretically grounded account of how an asynchronous-first course can be designed to support discipline-specific pedagogical reasoning among practising science teachers. By making the

design logic explicit, the article provides a basis for adaptation, critique, and future empirical evaluation.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Author contributions

PA-A: Methodology, Conceptualization, Writing – original draft, Investigation, Writing – review & editing, Resources. MA: Writing – review & editing, Supervision.

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Conflict of interest

The author(s) declared that this work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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References

Albergaria-Almeida, P. (2010). Questioning patterns and teaching strategies in secondary education. *Proc. Soc. Behav. Sci.* 2, 751–756. doi: 10.1016/j.sbspro.2010.03.096

Albergaria-Almeida, P. (2013). Fieldwork in geology: teachers' conceptions and practices. *Int. J. Sci. Soc.* 4, 83–97. doi: 10.18848/1836-6236/CGP/v04i01/51365

Albergaria-Almeida, P. (2015). "Kolb's experiential learning theory revisited", in *Advances in Psychology Research, Vol. 102*, ed. A. M. Columbus (New York: Nova Science Publishers), 63–76.

Albergaria-Almeida, P. (2026a). Suspended, not absent: radical reflexivity, institutional legibility and interrupted academic lives. *Int. Rev. Qual. Res.* doi: 10.1177/19408447261434522

Albergaria-Almeida, P. (2026b). Asynchronous-first as an ethical imperative: Rethinking time, presence, and equity in teacher professional development. Preprints.org. doi: 10.20944/preprints202605.0656.v1

Albergaria-Almeida, P., and Abelha, M. (2026). Teaching Biology and Geology as reflective decision-making: Designing an asynchronous online professional development course for in-service science teachers. Preprints.org. doi: 10.20944/preprints202605.0648.v1

Almeida, P., and Neri de Souza, F. (2010). Questioning profiles in secondary science classrooms. *Int. J. Learn. Chang.* 4, 237–251. doi: 10.1504/IJLC.2010.035833

Barros, J., Albergaria-Almeida, P., and Cruz, N. (2012). Fieldwork in geology: teachers' conceptions and practices. *Proc. Soc. Behav. Sci.* 47, 829–834. doi: 10.1016/j.sbspro.2012.06.743

Biggs, J. (2003). *Teaching for Quality Learning at University*. 2nd ed. Buckingham: Society for Research into Higher Education and Open University Press.

Black, P., and Wiliam, D. (1998). Assessment and classroom learning. *Assess. Educ. Princ. Policy Pract.* 5, 7–74. doi: 10.1080/0969595980050102

Carlson, J., Daehler, K. R., Alonzo, A. C., Barendsen, E., Berry, A., Borowski, A., et al. (2019). "The refined consensus model of pedagogical content knowledge in science education," in *Repositioning Pedagogical Content Knowledge in Teachers' Knowledge for Teaching Science*, eds. A. Hume, R. Cooper, and A. Borowski (Singapore: Springer), 77–94. doi: 10.1007/978-981-13-5898-2_2

Casanova, D., Montalvo Machado, Â., Quintas Mendes, A., Dias Ferreira, C., Aires, L., Martins, M., et al. (2026). *Modelo Pedagógico da Universidade Aberta*. Lisboa: Universidade Aberta. doi: 10.34627/s45f-nn11

Chevallard, Y. (1985). *La Transposition Didactique: Du Savoir Savant au Savoir Enseigné*. Grenoble: La Pensée Sauvage.

Darling-Hammond, L., Hyler, M. E., and Gardner, M. (2017). *Effective Teacher Professional Development*. Palo Alto, CA: Learning Policy Institute.

Dede, C., Jass Ketelhut, D., Whitehouse, P., Breit, L., and McCloskey, E. M. (2009). A research agenda for online teacher professional development. *J. Teach. Educ.* 60, 8–19. doi: 10.1177/0022487108327554

Desimone, L. M. (2009). Improving impact studies of teachers' professional development: toward better conceptualizations and measures. *Educ. Res.* 38, 181–199. doi: 10.3102/0013189X08331140

European Commission/EACEA/Eurydice. (2015). *The Teaching Profession in Europe: Practices, Perceptions, and Policies. Eurydice Report*. Luxembourg: Publications Office of the European Union. doi: 10.2797/63946

Garet, M. S., Porter, A. C., Desimone, L., Birman, B. F., and Yoon, K. S. (2001). What makes professional development effective? Results from a national sample of teachers. *Am. Educ. Res. J.* 38, 915–945. doi: 10.3102/00028312038004915

Garrison, D. R., and Vaughan, N. D. (2008). *Blended Learning in Higher Education: Framework, Principles, and Guidelines*. San Francisco: Jossey-Bass. doi: 10.1002/9781118269558

Kind, V., and Chan, K. K. W. (2019). Resolving the amalgam: connecting pedagogical content knowledge, content knowledge and pedagogical knowledge. *Int. J. Sci. Educ.* 41, 964–978. doi: 10.1080/09500693.2019.1584931

Knowles, M. S. (1980). *The Modern Practice of Adult Education: From Pedagogy to Andragogy*. 2nd ed. New York: Cambridge Adult Education.

Kolb, D. A. (1984). *Experiential Learning: Experience as the Source of Learning and Development*. Englewood Cliffs, NJ: Prentice Hall.

Lei, W., and Lei, Z. (2026). Formative assessment literacy: a systematic review. *Lang. Test. Asia* 16, 7. doi: 10.1186/s40468-025-00418-0

Marques, L., and Praia, J. (1997). Trabalho de campo em Geologia, Enseñanza de las Ciencias, Número Extra V Congreso Internacional.

Martin, F., Swapna, K., Ritzhaupt, A., and Polly, D. (2024). Bichronous online learning: perspectives, best practices, benefits, and challenges from award-winning online instructors. *Online Learn.* 28, 1–27. doi: 10.24059/olj.v28i2.3945

Martinho, M., Albergaria-Almeida, P., Lopes, B., and Moreira, A. (2025). The in-class questions of science and engineering students: a gender-based perspective. *Soc. Sci.* 14, 689. doi: 10.3390/socsci14120689

Martinho, M., Albergaria-Almeida, P., and Teixeira-Dias, J. (2014). Fostering students questioning through moodle: does it work? *Proc. Soc. Behav. Sci.* 116, 2537–2542. doi: 10.1016/j.sbspro.2014.01.607

McKenney, S., and Reeves, T. C. (2012). *Conducting Educational Design Research*. London: Routledge.

Obilana, A. A. (2025). "Sustainable professional teacher development programs," in *Education and Human Development*, eds. F.G. Paloma, P.A. di Tore, and G.R.J. Mangione. London: IntechOpen. doi: 10.5772/intechopen.1009375

Opfer, V. D., and Pedder, D. (2011). Conceptualizing teacher professional learning. *Rev. Educ. Res.* 81, 376–407. doi: 10.3102/0034654311413609

Parmigiani, D., Nicchia, E., Murgia, E., and Ingersoll, M. (2024). Formative assessment in higher education: an exploratory study within programs for professionals in education. *Front. Educ.* 9, 1366215. doi: 10.3389/feduc.2024.1366215

Pedrosa de Jesus, H., Almeida, P., Teixeira-Dias, J. J., and Watts, M. (2006). Students' questions: building a bridge between Kolb's learning styles and approaches to learning. *Educ. Train.* 48, 97–111. doi: 10.1108/00400910610651746

Schön, D. A. (1983). *The Reflective Practitioner: How Professionals Think in Action*. New York: Basic Books.

Shulman, L. S. (1986). Those who understand: knowledge growth in teaching. *Educ. Res.* 15, 4–14. doi: 10.3102/0013189X015002004

Trust, T., and Horrocks, B. (2016). 'I never feel alone in my classroom': teacher professional growth within a blended community of practice. *Prof. Dev. Educ.* 43, 645–665. doi: 10.1080/19415257.2016.1233507

Wenger, E. (1998). *Communities of Practice: Learning, Meaning, and Identity*. Cambridge: Cambridge University Press.

Wenger-Trayner, E., and Wenger-Trayner, B. (2015). "Learning in landscapes of practice: a framework," in *Learning in Landscapes of Practice: Boundaries, Identity, and Knowledgeability in Practice-based learning*, eds. E. Wenger-Trayner, M. Fenton-O'Creevy, S. Hutchinson, C. Kubiak, and B. Wenger-Trayner (London: Routledge), 13–29.