

When AI Becomes a Resource: AI-Supported Teacher Design Capacity in Mathematics Teacher Education

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Research Article

Keywords: Generative artificial intelligence, Mathematics teacher education, Pre-service teachers, Documentational Approach to Didactics, Teacher Design Capacity, Lesson design

Posted Date: September 10th, 2026

DOI: <https://doi.org/10.21203/rs.3.rs-10891387/v1>

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Additional Declarations: No competing interests reported.

Abstract

Generative artificial intelligence (AI) can produce apparently complete mathematics lesson plans within seconds, raising a central question for teacher education: how can pre-service teachers use AI-generated resources while remaining responsible for mathematical and pedagogical design? This qualitative study investigates AI-supported lesson design during an 11-week course at a Chinese university. Data comprised AI dialogues, reports, three lesson-plan versions, microteaching videos, and evaluation reports from 20 participants; three focal cases were examined through follow-up interviews. Drawing on the Documentational Approach to Didactics and Teacher Design Capacity, we propose AI-supported Teacher Design Capacity (AI-TDC) as an analytical construct characterising five interrelated dimensions of knowledge-in-action: Orienting, Verifying, Transforming, Regulating, and Collectivising. The focal cases revealed contrasting configurations in which AI became a mediating hub, a task-specific mediator, or a supplementary reviewing resource; these configurations could not be reduced to interaction volume. AI-generated resources became components of teaching documents through mathematical and didactical transformation: participants reorganised conceptual relations, constructed problem sequences, and selectively retained or rejected proposals according to intended mathematical trajectories for students. The course created opportunities for such work through cycles of individual design, collective scrutiny, enactment, and redesign. AI-TDC thus offers a framework for analysing and supporting documentational work with AI in mathematics teacher education.

1. Introduction

Generative AI can produce apparently complete teaching materials within seconds, creating new opportunities as well as new demands for teachers. AI can support lesson planning, task generation, feedback, and assessment design (Cardona et al., 2023; Kasneci et al., 2023; Tan et al., 2025), but it also raises concerns about over-reliance, ethical risks, and the weakening of professional judgement (OECD, 2026). The central issue is therefore not simply how teachers use AI, but how they retain responsibility for instructional design when working with AI-generated resources.

In mathematics education, a formally coherent lesson plan may still lack conceptual progression, sensitivity to students' reasoning, or an appropriate organisation of mathematical tasks (Simon, 1995; Stein et al., 1996). More generally, curriculum resources do not determine instruction by themselves: teachers interpret, adapt, combine, and redesign them in relation to mathematical goals, learners, and classroom contexts (Brown, 2009; Remillard, 2005). The National Council of Teachers of Mathematics (NCTM, 2024) accordingly argues that AI increases rather than diminishes the need for mathematical, pedagogical, and relational expertise. Artigue (2026) similarly suggests that generative AI reconfigures teachers' relationships with resources, knowledge, and agency.

Within mathematics education, the quality of generated responses varies with the model, task, and prompting strategy, and apparently convincing outputs may remain mathematically problematic (Schorcht et al., 2026). Teacher–ChatGPT interaction, especially in lesson planning and curriculum development, has emerged as a research strand (Pepin et al., 2025), with recent studies examining pre-service teachers' sustained lesson-planning use (Gurl et al., 2025; Ku, 2026). Less is known, however, about the documentational processes through which AI becomes integrated with teachers' other resources and through which generated outputs are transformed across successive mathematics lesson-plan versions.

This study addresses this gap by combining the Documentational Approach to Didactics (DAD) and Teacher Design Capacity (TDC). We propose *AI-supported Teacher Design Capacity (AI-TDC)* as an analytical construct for characterising the knowledge-in-action mobilised in AI-supported documentational work. Through a multiple-case study in mathematics teacher education, we examine how AI enters resource systems, how AI-generated resources contribute to lesson-plan development, and how AI-TDC is enacted during revision.

Section 2 develops the theoretical framework; Section 3 presents the educational setting; Section 4 describes the methodology; Sections 5 and 6 present the within- and cross-case analyses; and Section 7 discusses the study's contributions, implications, and limitations.

2. Conceptualising AI-supported teacher design capacity

This section combines two complementary perspectives—the Documentational Approach to Didactics (DAD) and Teacher Design Capacity (TDC)—to develop AI-supported Teacher Design Capacity (AI-TDC) as the analytical lens for this study.

2.1 GenAI in documentational genesis and resource systems

DAD (Gueudet & Trouche, 2009) conceptualises teachers' professional activity through their interactions with resources. Extending the instrumental approach (Artigue, 2002; VÉrillon & Rabardel, 1995), DAD considers resources not simply as material objects but as means for *re-sourcing* activity: teachers select, combine, transform, and create resources in relation to their professional goals.

Interactions with resources oriented towards a teaching goal progressively give rise to *documents* through *documentational genesis*. A document combines the resources mobilised by the teacher with the knowledge that supports—and develops through—their use. Like instrumental genesis, documentational genesis involves reciprocal processes of *instrumentation* and *instrumentalisation* (Artigue, 2002; Trouche, 2004): resources shape teachers' activity, while teachers assign functions to and transform resources.

These interactions do not involve isolated resources. Over time, the resources a teacher selects, combines, creates, and reuses become organised into a *resource system*: a structured and evolving set of resources and the relations established among them (Gueudet & Trouche, 2009). Its organisation reflects the mathematics involved, the forms of teaching activity, and the teacher's professional history and purposes. A resource can therefore become more structurally central by mediating relations among other resources without necessarily being used more frequently. Resource systems are also socially situated: resources may be shared, discussed, adapted, or jointly developed, making *collective documentational work* an important dimension of teachers' activity (Gueudet et al., 2013; Sabra, 2016).

GenAI intensifies some characteristics already present in interactions with digital resources. Its distinctive combination of dialogic generation, responsiveness, variable outputs, often opaque provenance, and capacity to propose new directions can make its influence on design activity particularly visible (NCTM, 2024; Walkington, 2026). Productive interaction therefore involves not only prompting but also recognising limitations and maintaining epistemic vigilance (Artigue, 2026). Pepin (2023) highlights the broader issue of *resource agency*: resources can shape attention and activity without possessing professional agency equivalent to that of teachers. Teacher agency is understood here relationally, emerging through teachers' professional histories and purposes in interaction with cultural and material conditions (Biesta & Tedder, 2007; Priestley et al., 2015). In AI-supported documentational genesis, *instrumentation* concerns how generated proposals shape emerging design activity, while *instrumentalisation* concerns how teachers assign functions, refine prompts, constrain AI, and transform or reject outputs.

In this paper, AI is used as the broader term, whereas GenAI refers specifically to systems that generate content through interaction. AI-generated resources include outputs such as suggestions, drafts, examples, and feedback; AI-supported activities mobilise AI alongside other resources.

DAD conceptualises the knowledge component of documents through *schemes*, whose relatively invariant organisation becomes visible through repeated activity. Reconstructing such schemes generally requires longer-term observation than the bounded lesson-design process studied here. We therefore complement DAD with TDC to characterise the knowledge-in-action visible as PSTs design and revise lessons.

2.2 Teacher Design Capacity: characterising knowledge-in-action in design

Teacher Design Capacity (TDC) concerns the knowledge teachers mobilise when designing instruction with resources. Building on Brown's (2009) *Pedagogical Design Capacity*, it conceptualises teachers as designers who interpret, adapt, and transform resources in relation to instructional goals and contexts rather than simply implementing them (Remillard, 2005).

Pepin et al. (2017) elaborated TDC for mathematics teachers working with digital curriculum resources, highlighting the coordination of mathematical, curricular, digital, and social resources in situated design decisions. TDC comprises three interacting components—*orientations, design principles, and reflection-in-action*—through which teachers frame goals, organise resources for mathematical activity, and revise decisions in response to possibilities, feedback, enactment, and constraints. Trgalová and Tabach's (2024) account of Digital Resource Design Capacity further emphasises iterative cycles of design, enactment, and redesign.

Because design capacity is situated, its enactment may be shaped by teachers' previous experiences and social settings. Prior teaching experience can inform interpretations of resources and classroom feasibility (Brown, 2009; Pepin et al., 2017; Remillard, 2005); familiarity with AI-supported design may shape engagement with generated outputs (Celik, 2023; Viberg et al., 2025); and collective work creates opportunities for resources and decisions to be shared, discussed, and revised (Gueudet et al., 2013; Voogt et al., 2011, 2016). These three contextual characteristics informed the construction of contrasting focal cases in Section 4.2.

DAD and TDC thus address complementary aspects of design: DAD traces the documentational genesis through which resources contribute to the development of teaching documents, while TDC characterises the knowledge mobilised in this process.

2.3 Constructing AI-supported Teacher Design Capacity

Within this study, *AI-supported Teacher Design Capacity (AI-TDC)* is an analytical construct for characterising knowledge-in-action during AI-supported documentational work. Its five dimensions were derived by relating DAD and TDC to features of generative AI that intensify particular demands of design. *Orienting*, grounded in TDC orientations, concerns purposeful framing when AI can generate many possible directions. *Verifying* combines epistemic vigilance (Sperber et al., 2010) and reflection-in-action to address outputs whose accuracy, relevance, and provenance may vary. *Transforming* follows DAD's resource–document distinction and concerns how generated outputs are incorporated—through adoption, adaptation, or more substantial reworking—into emerging teaching documents. *Regulating* draws on instrumentation and instrumentalisation to examine how teachers negotiate AI's influence and allocate authority. *Collectivising* extends collective documentational work by examining how peer resources enter AI-supported design and how AI-supported resources enter shared scrutiny.

Table 1 summarises the theoretical grounding and analytical focus of these dimensions without treating them as separate competencies. Their relations can vary across phases of design: for example, Orienting may provide criteria for subsequent Verifying and Transforming, while Regulating concerns the role granted to AI across these processes.

Table 1
Theoretical grounding and analytical focus of the five AI-TDC dimensions

Dimensions	Theoretical grounding	Analytical focus
Orienting	TDC orientations	Framing or reframing AI-supported activity in relation to mathematical, curricular, learner, and lesson goals
Verifying	Epistemic vigilance (Sperber et al., 2010) and TDC reflection-in-action	Judging the mathematical, curricular, pedagogical, and practical adequacy of generated resources
Transforming	DAD documentational genesis; TDC principles for organising resources	Incorporating generated resources into teaching documents through adoption, adaptation, or reworking
Regulating	Instrumentation–instrumentalisation and TDC reflection-in-action	Directing AI activity and allocating epistemic and pedagogical authority
Collectivising	DAD collective documentational work	Connecting AI-supported design with peer resources, shared scrutiny, and revision

The operationalisation of these dimensions is presented in Section 4 and Appendix 1. For each dimension, three *enactment levels* distinguish increasing coordination in the knowledge-in-action made visible in AI-supported interactions: Level 1 describes broad or surface enactment, Level 2 local or partial enactment, and Level 3 coordinated enactment. These levels are ordinal *within each dimension*, but they do not constitute a common metric across dimensions: for example, Level 2 in Verifying is not equivalent to Level 2 in Transforming. Nor are the levels intended to represent successive stages of teacher development or to be aggregated into an overall AI-TDC score. They provide analytical descriptors for characterising how a given dimension is enacted in particular interactions and phases of lesson design.

This framing leads to three research questions:

- RQ1. How does AI become integrated into PSTs’ resource systems during mathematics lesson design?
- RQ2. How do PSTs transform AI-generated resources into mathematics lesson-plan documents?
- RQ3. How do PSTs enact the five AI-TDC dimensions during lesson-plan development and revision?

3. An AI-supported lesson-design environment in teacher education

This section situates the study within the growing use of AI in Chinese education, describes the course and participants, and explains how the course organisation created successive opportunities for observing AI-supported documentational work.

3.1 AI-supported teaching and teacher education in China

The study was conducted in a context where AI is increasingly integrated into higher education and school teaching. Since the *Action Plan for Artificial Intelligence Innovation in Higher Education*, Chinese universities have been encouraged to strengthen AI-related curriculum development (Ministry of Education of the People's Republic of China [MOE], 2018). More recently, the national *Artificial Intelligence + Education* Action Plan extended these initiatives to teacher education (MOE et al., 2026). Pre-service teachers are therefore entering a profession in which engaging critically with AI-generated resources is becoming part of lesson preparation and teaching.

AI is also becoming part of everyday educational practice. Survey data indicate that Doubao, DeepSeek, and Qwen account for more than 80% of AI use among Chinese university students, mainly for summarisation, translation, language polishing, and writing support (MyCOS Research Institute, 2026). A national report based on more than 86,000 teachers documented expanding GenAI use across teaching and evaluation, including lesson preparation and personalised guidance (Educational Technology and Resources Development Center, Ministry of Education of the People’s Republic of

China, 2026). Teachers nevertheless reported difficulties related to prompting, unstable outputs, and the relevance of AI-generated resources.

Beyond lesson preparation, national guidance increasingly positions AI as a resource for teaching evaluation. The 2025 guidelines for generative AI use in primary and secondary schools encourage AI-assisted evaluation and human–AI collaboration while retaining human review and critical judgement (Basic Education Teaching Guidance Committee, Ministry of Education of the People's Republic of China, 2025). The participants were therefore preparing to enter a profession in which AI may support both lesson design and post-enactment evaluation.

3.2 Course setting and participants

The study was embedded in an 11-week compulsory professional-education course enrolling 21 PSTs at a leading teacher education university in China. Students had strong mathematical backgrounds but differed in their prior experience with educational theory, instructional design, classroom practice, and AI-supported lesson preparation.

The course aimed to develop capacities for mathematics lesson design and enactment through successive cycles of design, discussion, implementation, and revision. Students prepared lessons that could later be adapted for teaching demonstrations, competitions, or teacher-recruitment interviews. Because access to secondary classrooms was limited, enactment took the form of recorded microteaching sessions—scaled-down teaching episodes in which PSTs rehearsed selected aspects of teaching and received feedback (Allen & Eve, 1968; Fernández, 2010).

The course also incorporated an AI-based teaching-evaluation platform developed within the university (hereafter, the evaluation platform). After microteaching, students received AI-generated feedback on observable aspects of their teaching, including pacing, explanation patterns, questioning, and student engagement. This feedback constituted one resource among others for subsequent revision and could be compared with peer comments and personal reflection.

The first author taught the course with another experienced teacher trainer, Jian, and conducted the research with the second author.

3.3 AI-supported lesson design as iterative documentary work

The course was organised around a cycle of individual design, peer discussion, enactment, evaluation, and revision, making successive stages of students' documentary work accessible for analysis. Rather than producing a single lesson plan, students developed three versions while mobilising and transforming multiple resources (Fig. 1).

Before beginning lesson design, students studied principles of secondary mathematics instructional design, including lesson structure, concept development, mathematical tasks, worked examples, and task sequencing. They also formed groups of three to six students, reflecting collective lesson-design practices characteristic of Chinese mathematics teaching communities (Huang & Bao, 2006; Li & Huang, 2013).

AI use was expected but deliberately left open. Students could choose their preferred tools and decide how to use them; no prompt templates or predefined workflows were imposed. For research purposes, they were asked to save their AI dialogues and, when working on the same lesson, to continue in the same chat thread where possible. This made the evolution of AI-supported interactions traceable without prescribing a particular mode of use.

During *Version 1 (V1)*, students individually prepared an initial lesson plan and documented their AI interactions and reasons for adopting, adapting, or rejecting generated suggestions. Before *Version 2 (V2)*, peer review introduced a collective phase in which students discussed one another's plans, anticipated student difficulties, compared suggestions, and revised their work. Following microteaching, students considered platform-generated evaluation reports alongside peer feedback and personal reflection before producing *Version 3 (V3)*. These phases generated the main materials analysed in Sections 4–6.

The three phases did not prescribe a common trajectory of AI use. Rather, they created different opportunities for AI-supported design: initial exploration and production, collective scrutiny and revision, and post-enactment reflection and refinement. This structured but open environment made it possible to examine how AI occupied different positions within PSTs' resource systems and how AI-generated resources were transformed across successive lesson-plan documents.

4. Investigating AI-supported documentational work: a qualitative multiple-case study

This study adopted a qualitative multiple-case design informed by reflective investigation within DAD. Section 4.1 presents this methodological orientation, Section 4.2 describes the corpus, focal-case selection, and ethical safeguards, and Section 4.3 explains the analytical and trustworthiness procedures.

4.1 Reflective investigation as a methodological approach

The study was informed by *reflective investigation* within DAD (Trouche et al., 2020), which combines longitudinal follow-up, collection of resources and documents across settings, participants' accounts of their activity, and confrontation of these accounts with material traces. This approach was appropriate because AI-supported lesson design cannot be reconstructed from final lesson plans or retrospective accounts alone: it requires tracing how generated resources were produced, interpreted, transformed, combined with other resources, or rejected. Participants created retrospective resource-system representations using researcher-provided shapes representing resources and functions, and arrows representing relations; they chose the content and layout and checked the translated, digitised versions. Bold indicates resources or functions that the participant retrospectively identified as newly incorporated into her regular lesson-preparation system during the course.

4.2 Data corpus, focal-case selection, and ethical safeguards

Data collection was embedded in the course activities shown in Fig. 2. Although the course was compulsory, research participation was voluntary. Of the 21 enrolled PSTs, 20 consented to the research use of their materials. Students were informed in Week 1 that grades would depend only on the final lesson plan and microteaching video, assessed according to previously established criteria. Jian assigned the grades without reference to consent status or completeness of research records. Students could withhold detailed reports or AI dialogues without academic consequences. All participants provided informed consent, and research materials were pseudonymised before analysis.

Four complementary sources constituted the corpus:

- AI dialogue records, including prompts and responses when available;
- individual reports documenting AI use, collective interactions, lesson-plan revisions, and reasons for adopting, adapting, or rejecting suggestions;
- three successive lesson plans (V1–V3), providing material traces of changes in mathematical explanations, representations, tasks, and problem sequences;
- microteaching videos and platform-generated evaluation reports, providing enactment-related evidence.

All 20 consenting participants submitted individual reports and three lesson-plan versions, although reports differed in detail and in the extent of documented AI use. Eight participants volunteered; three were selected for follow-up interviews and focal analysis using a maximum-variation strategy based on three contextual characteristics identified in Section 2.2: prior teaching experience, prior use of AI for lesson preparation, and engagement in collective work. Selection preceded detailed trajectory analysis and prompt-level AI-TDC coding. The purpose was to construct analytically contrasting cases rather than representative types. Hu and Xin belonged to the same peer-review group but differed in their previous patterns of AI use and engagement with peer resources, providing a useful within-group contrast. Ya provided a

contrasting case with substantially greater teaching experience, less established AI use, and participation in a different peer-review group. Together, the three cases thus varied along the contextual dimensions expected to shape, without determining, AI-supported documentational work.

Table 2
Information about the three focal cases

Hu	Teaching experience	Self-reported prior use of AI for lesson preparation	Self-reported engagement in collective work
	Part-time secondary-school teaching	Frequent use across several lesson-preparation tasks	Actively sought peer input beyond required activities; same peer-review group as Xin
Xin	Brief secondary-school teaching placement	Regular use, mainly for analysing resources and refining selected lesson components	Participated in required peer review and incorporated selected feedback; same group as Hu
Ya	Three years of secondary-school teaching	Occasional use; AI was not part of her usual preparation routine	More comfortable in small-group discussion; different peer-review group

Interviews with the three focal participants took place after grades had been finalised and required additional consent. Stimulated recall drew on participants’ AI dialogues, reports, successive lesson plans, and evaluation reports. A common protocol addressed changes in the resource system, lesson-plan transformations across V1–V3, enactment of AI-TDC dimensions, and experiences of collective work.

The first author taught the course and later supervised the focal participants’ theses, providing substantial contextual knowledge but also requiring reflexive scrutiny. The second author was not involved in teaching or grading and contributed to calibration and critical examination of the interpretations.

4.3 Analytical procedures and trustworthiness

Analysis proceeded in three stages aligned with the research questions.

For **RQ1**, each focal participant’s interview-generated resource-system representation and explanation were examined alongside individual reports and AI dialogues. The analysis focused on AI’s structural position relative to other resources and on changes in relations within the resource system.

For **RQ2**, lesson-plan genesis was reconstructed across V1–V3 using lesson plans, reports, interviews, peer and platform feedback, and microteaching evidence. Comparisons focused particularly on changes in mathematical concepts and relations, explanations, representations, examples, task sequences, derivations, justifications, and anticipated student reasoning.

For **RQ3**, prompt-level coding was restricted to the focal participants’ AI dialogues. The five AI-TDC dimensions and their three within-dimension enactment levels are defined in Appendix 1. Dialogues were segmented into episodes centred on a coherent mathematical or pedagogical design task. Follow-up prompts remained within an episode while pursuing the same goal; a new episode began when the design task changed. Prompts constituted the coding unit and could receive more than one dimension code, with one enactment level assigned within each coded dimension (Appendix 2).

Both authors co-developed the dimensions and independently coded Hu’s V1. After the final codebook was established, they also independently coded one mathematically focused episode from Xin and one collective-review episode from Ya. Differences in episode boundaries or level assignments were resolved by reference to dialogue context, lesson-plan traces, and participant accounts. The additional calibration confirmed the final descriptors. The first author coded the remaining dialogues. Generative AI was used to produce preliminary English translations of pseudonymised Chinese

excerpts. All translations were checked against the Chinese originals by the first author; coding and interpretation remained the responsibility of the authors.

For each phase, N denotes the total number of recorded prompts and n the number coded for a given dimension. Tables 3–5 report n/N and the distribution of those coded prompts across Levels 1–3. Interaction volume, structural position, and AI-TDC enactment were analysed separately: prompt counts describe recorded interaction volume, resource-system representations indicate AI's structural position, and dimension/level coding characterises enactment within particular interactions. Prompt-level interpretations were corroborated against lesson-plan revisions, reports, interviews, videos, and feedback, although these sources were not independently coded for AI-TDC.

Each focal trajectory was consequently represented through an evolving resource-system diagram, a reconstruction of lesson-plan genesis, and a table combining interaction volume with within-dimension AI-TDC enactment.

5. Three trajectories of AI-supported documentational work

This section presents the within-case findings for three focal pre-service teachers. Each trajectory is examined through three distinct but related perspectives: AI's *structural position* within the participant's resource system (RQ1), the transformation of resources into successive lesson-plan documents (RQ2), and *AI-TDC enactment* in the recorded dialogues (RQ3). Interaction volume refers only to the number of recorded prompts; structural position concerns the relations AI establishes with other resources; and AI-TDC enactment concerns how the five dimensions are expressed within coded interactions.

Hu is presented first because her records make these three perspectives particularly visible. Xin and Ya then provide contrasting trajectories.

5.1 Hu: AI becoming a mediating hub within teacher-regulated design

Hu had some part-time teaching experience, frequently used AI before the course, and participated actively in peer exchange.

5.1.1 From sequential resource use to AI-mediated coordination

Figure 3 summarises Hu's retrospective account of changes in her resource system. Although the range of resources remained broadly stable, AI became more central because a wider variety of curriculum extracts, online materials, lesson examples, peer suggestions, and lesson-plan formats were channelled through AI-supported dialogue. Textbooks and curriculum standards nevertheless remained the principal reference points for mathematical and pedagogical decisions.

Structural centrality followed a different trajectory from recorded interaction volume: Hu's number of prompts decreased over the three versions, but AI increasingly connected heterogeneous resources that she had initially consulted more sequentially. Greater centrality therefore meant a broader mediating function within the resource system, not more frequent prompting or greater authority. Hu continued to judge AI outputs against curriculum standards, mathematical coherence, classroom feasibility, and anticipated student understanding.

5.1.2 Reorganising the lesson around the arithmetic–geometric analogy

Hu's lesson-plan genesis was marked by a decisive reorganisation between V1 and V2 (Fig. 4).

In V1, she asked AI to combine 12 papers into a complete lesson plan and then imposed a peer-provided format (Appendix 2). The resulting draft was formally complete but lacked a clear mathematical progression and gave limited attention to how students might develop the new concept. Peer review led Hu to identify the analogy between arithmetic and geometric sequences as a missing organising relation. She rebuilt the lesson around this analogy, aligning objectives and procedures with a progression from prior knowledge to the new concept and retaining AI suggestions that supported this route. V3 preserved the resulting architecture, with AI used mainly to synthesise feedback and refine practice tasks.

5.1.3 Decreasing interaction volume and phase-specific AI-TDC enactment

Hu’s recorded prompts decreased from 18 in V1 to 9 in V2 and 7 in V3 (Table 3). This describes interaction volume only; the level distributions characterise how each AI-TDC dimension was enacted within the prompts that occurred.

Table 3
Hu’s interaction volume and within-dimension AI-TDC enactment across V1–V3

	Orienting			Verifying			Transforming			Regulating			Collectivising		
	V1	V2	V3	V1	V2	V3	V1	V2	V3	V1	V2	V3	V1	V2	V3
n/N	11/18	9/9	4/7	12/18	6/9	5/7	15/18	6/9	6/7	18/18	9/9	7/7	1/18	3/9	1/7
L3	4	6	2	0	0	0	1	5	2	2	5	2	0	0	0
L2	6	3	1	11	6	4	14	1	4	14	3	5	1	3	1
L1	1	0	1	1	0	1	0	0	0	2	1	0	0	0	0

Orienting, Verifying, Transforming, and Regulating appeared in each version. Regulating was coded in every prompt, showing that the role allocated to AI—whether relatively AI-led, constrained, or explicitly teacher-directed—remained relevant throughout. Collectivising appeared only occasionally in the dialogues, although interview evidence indicated that Hu mobilised peer resources beyond the formally required V2 phase.

Within Orienting, Level 2 was modal in V1 and Level 3 in V2 and V3. Within Transforming and Regulating, Level 3 was modal only in V2; Level 2 predominated in V1 and V3. Verifying remained predominantly at its Level-2 descriptor, while Collectivising was coded at Level 2 whenever it appeared. V2 was the only version in which Level 3 was modal within Orienting, Transforming, and Regulating. The later reduction in prompting accompanied a shift from draft construction and whole-plan reworking to targeted refinement.

Hu’s trajectory therefore combines three distinct developments: decreasing interaction volume, increasing structural mediation by AI, and phase-dependent changes in AI-TDC enactment. The decisive document change was the V2 mathematical reorganisation around the arithmetic–geometric analogy.

5.2 Xin: AI as a task-specific mediator within a teacher-defined design

Xin had limited teaching experience, regularly used AI for selected lesson-preparation tasks before the course, and participated in the required peer-review activities within the same group as Hu.

5.2.1 AI supporting selected tasks within an established resource system

Figure 5 shows a resource system already structured by curriculum standards, textbooks, a personal lesson-plan template, and a design developed for an undergraduate teaching competition. AI occupied a task-specific position within this existing architecture.

Xin used AI to analyse resources, generate alternative contexts, organise peer suggestions, compare possibilities, and refine problem chains. Curriculum standards and textbooks continued to anchor the mathematical direction, while the template and prior design organised the sequence of work. She redirected or rejected suggestions that overloaded the lesson or did not support its established progression.

5.2.2 Transforming AI-generated derivations into a mathematical problem chain

Xin’s V1 lesson plan developed from her prior competition design (Fig. 6). AI proposed introductions, historical and cultural contexts, analogies with arithmetic sequences, and alternative derivation methods; Xin initially used these suggestions for local revisions.

The major change occurred in V2, when she transformed AI-generated derivations into a sequence of student inquiry. The analogy with arithmetic sequences supported conjecture about the sum formula; students were then asked to compare alternative derivations before applying the formula. In V3, she retained this structure but clarified the mathematical logic and conditions of the shift-and-subtract method, including why multiplication by q aligns terms for subtraction and why $q = 1$ requires separate treatment. AI-generated candidate solutions thus became resources for constructing and refining a teacher-defined problem chain.

5.2.3 Increasing interaction volume within a teacher-defined mathematical progression

Xin’s prompt volume increased from 2 in V1 to 3 in V2 and 6 in V3 (Table 4), but AI did not thereby acquire a broader structural position. The additional interactions concerned increasingly fine-grained mathematical work within a progression already defined by Xin.

Table 4

Xin’s interaction volume and within-dimension AI-TDC enactment across V1–V3

	Orienting			Verifying			Transforming			Regulating			Collectivising		
	V1	V2	V3	V1	V2	V3	V1	V2	V3	V1	V2	V3	V1	V2	V3
n/N	2/2	3/3	5/6	1/2	2/3	5/6	2/2	3/3	6/6	2/2	3/3	6/6	0/2	2/3	0/6
L3	0	1	4	0	0	0	0	1	4	0	1	4	0	0	0
L2	2	2	1	1	2	5	2	2	2	2	2	2	0	2	0
L1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Transforming and Regulating were coded in every recorded prompt, and Orienting in nearly all. Verifying appeared in a larger share of later prompts, which focused on more specific mathematical issues. Collectivising appeared only during the required V2 peer-review phase, suggesting that collective input entered her AI-supported work mainly when the course explicitly created that opportunity.

Level 2 was modal within Orienting, Transforming, and Regulating in V1 and V2. In V3, Level 3 predominated within Orienting, Transforming, and Regulating as Xin used AI to elaborate recurrence relations, derivation methods, and the problem chain while retaining control over selection and sequencing. All Verifying instances and, when present, all Collectivising instances were coded at Level 2.

Xin thus provides a useful contrast with Hu: interaction volume increased, but AI remained structurally task-specific. Her strongest recorded AI-TDC enactment concerned the refinement of a mathematical progression whose overall direction had already been established.

5.3 Ya: AI as a supplementary reviewing resource within an established preparation routine

Ya had three years of secondary-school mathematics teaching experience and had used AI only occasionally before the course. She belonged to a different peer-review group from Hu and Xin.

5.3.1 AI entering the resource system as a supplementary reviewing resource

Figure 7 represents Ya's retrospective account of a resource system organised around curriculum standards, textbooks, online lesson plans, materials shared by former colleagues, exemplary lesson designs, and her own teaching experience. Before the course, she occasionally consulted AI but did not regard it as a stable component of this system. During the course, AI acquired a supplementary role, mainly after she had drafted a lesson from other resources.

Her established routine was to compare available lesson plans, select one close to her intended design, and adapt it to curriculum requirements and classroom experience. She then used AI mainly as a reviewer, comparing its suggestions with textbook content, mathematical relevance, and classroom feasibility. AI therefore entered the resource system without reorganising its core relations.

5.3.2 Selective uptake within a stable mathematical route

Ya compared three online lesson plans, selected the one closest to her intended design, and consulted AI for individual components (Fig. 8).

Across V1–V3, she rejected generic examples and a complete AI-generated lesson plan when they were redundant, exceeded available lesson time, or diverted attention from curricular priorities. She retained one derivation strategy because separating the radicals before squaring made the correspondence between algebraic steps and line segments in the geometric representation more explicit while fitting the planned sequence. Peer review later broadened the learner analysis and exploratory questions in V2, while microteaching and course input contributed to a misconception-focused variation task in V3; neither revision altered the established mathematical route.

5.3.3 Limited interaction with experience-informed Verifying and Regulating

Ya's recorded prompts fell from 9 in V1 to 2 in V2 and 2 in V3 (Table 5). With such small numbers, prompt counts indicate only the amount of recorded interaction; the coded distributions characterise the particular interactions that occurred.

Table 5
Ya's interaction volume and within-dimension AI-TDC enactment across V1–V3

	Orienting			Verifying			Transforming			Regulating			Collectivising		
	V1	V2	V3	V1	V2	V3	V1	V2	V3	V1	V2	V3	V1	V2	V3
n/N	9/9	2/2	2/2	3/9	2/2	2/2	5/9	0/2	2/2	9/9	2/2	2/2	1/9	2/2	0/2
L3	0	0	0	3	2	0	1	0	0	3	2	1	0	0	0
L2	8	2	2	0	0	2	4	0	1	4	0	1	1	2	0
L1	1	0	0	0	0	0	0	0	1	2	0	0	0	0	0

Orienting and Regulating appeared in every recorded prompt. Verifying was present in both V2 prompts and both V3 prompts. Transforming was absent in V2 because these interactions concerned reviewing peers' lesson plans rather than revising Ya's own document. Collectivising was concentrated mainly in V2, with one instance in V1. The later phases therefore provide evidence of targeted enactment rather than stable phase-wide patterns.

Ya's trajectory shows AI moving from occasional consultation to a supplementary reviewing resource while curriculum materials and teaching experience continued to organise her decisions. AI-generated suggestions were taken up selectively and locally when they clarified a relation central to the intended derivation and fitted the intended lesson sequence. Her reduced interaction volume, supplementary structural position, and experience-informed Verifying and Regulating therefore describe different aspects of the trajectory rather than points on a single scale of AI engagement.

6. Cross-case comparison: configurations and conditions

This section compares the three focal trajectories by distinguishing recorded interaction volume, AI's structural position, document transformation, and AI-TDC enactment, and then considers contextual conditions and course affordances.

6.1 Contrasting configurations of AI-supported documentational work

The three trajectories show that interaction volume, AI's position in the resource system, document transformation, and AI-TDC enactment are related but distinct aspects of AI-supported design (Table 6).

Table 6
Cross-case comparison of interaction volume, AI position, document transformation, and AI-TDC enactment

Hu	Recorded interaction volume	Structural position of AI (RQ1)	Dominant document transformation (RQ2)	Distinctive AI-TDC enactment (RQ3)
	Decreased: 18 → 9 → 7 prompts	Mediating hub connecting heterogeneous resources	AI-organised draft reorganised around the arithmetic–geometric analogy	Level 3 modal within Orienting, Transforming, and Regulating in V2
Xin	Increased: 2 → 3 → 6 prompts	Task-specific mediator within a pre-existing design	AI-generated derivations transformed into inquiry tasks and a coherent problem chain	Level 3 modal within Orienting, Transforming, and Regulating in V3
Ya	Decreased: 9 → 2 → 2 prompts	Supplementary reviewing resource within an established routine	Selective local uptake without reorganisation of the mathematical route	Targeted Verifying and Regulating; Collectivising mainly in V2

Interaction volume and structural position followed different trajectories. Hu's prompting decreased while AI became more structurally central by mediating relations among curriculum, online, peer, and lesson-plan resources. Xin's prompting increased, but AI remained task-specific within an architecture already organised by curriculum resources and a prior design. Ya's interaction became sparse and AI remained supplementary. Recorded interaction volume therefore describes neither AI's structural position nor the authority granted to it.

The document transformations also differed. Hu reorganised an initially AI-compiled draft around the arithmetic–geometric analogy. Xin transformed AI-generated derivations into a mathematical problem chain supporting conjecture and comparison. Ya retained her established mathematical route and integrated suggestions selectively for local purposes. Across all three cases, generated outputs became components of teaching documents through mathematical and pedagogical reworking.

AI-TDC provides a further perspective. Hu's strongest coordination of Orienting, Transforming, and Regulating occurred during the V2 whole-plan reorganisation; Xin's occurred mainly in V3 while refining an already established progression. Ya's more selective interactions foregrounded Verifying and Regulating. These trajectories therefore represent contrasting configurations responding to different documentational problems rather than successive stages of a common development.

6.2 Contextual conditions and course affordances

The three characteristics used for focal-case selection—prior teaching experience, previous AI-supported lesson preparation, and engagement in collective work—help contextualise these differences.

Ya's greater teaching experience was visible in the practical criteria she mobilised when assessing AI suggestions, including curricular relevance, lesson time, anticipated student responses, and classroom feasibility. Hu's more extensive prior AI use accompanied a broader mediating role for AI across heterogeneous resources, whereas Xin's prior use for selected tasks was consistent with a more focused role. Collective engagement was most visible in Collectivising: Hu mobilised peer resources beyond the prescribed peer-review phase, Xin incorporated collective feedback selectively, and Ya's collective AI-supported work was concentrated mainly in V2.

The course nevertheless provided common opportunities. Individual preparation of V1 foregrounded framing and transformation; peer review before V2 made lesson plans and some AI-generated suggestions objects of collective scrutiny; microteaching and subsequent feedback before V3 confronted planned designs with enactment-related evidence. These phases created opportunities for different AI-TDC dimensions without prescribing how participants would mobilise them. Their uptake depended on existing resource systems, prior designs, mathematical problems, and professional experience. The course thus supported varied forms of AI-supported documentational work rather than a uniform trajectory.

7. Discussion and conclusion

This study contributes to understanding how generative AI becomes part of pre-service mathematics teachers' documentational work. GenAI entered existing resource systems in different ways, while its generative, responsive, and potentially agentic properties created particular demands for framing, verification, transformation, regulation, and collective scrutiny. AI-supported Teacher Design Capacity (AI-TDC) provides a framework for characterising the knowledge-in-action mobilised in meeting these demands. The three trajectories further show that AI-supported design cannot be understood through the amount of AI use alone: interaction volume, AI's structural position within the resource system, and AI-TDC enactment capture different aspects of teachers' work.

7.1 AI-TDC as a conceptual contribution to DAD and TDC

AI-TDC connects DAD's concern with resource–document transformations and TDC's attention to the knowledge mobilised in instructional design. Its five dimensions make visible complementary aspects of teachers' work with generative resources. Orienting frames the purposes towards which AI is mobilised; Verifying establishes criteria for judging generated proposals; Transforming concerns their incorporation into teaching documents through adoption, adaptation, or reworking; Regulating addresses the functions and authority allocated to AI; and Collectivising connects AI-supported design with shared resources and professional scrutiny.

The cases also show that these dimensions operate in configurations rather than independently. Orienting can provide criteria for subsequent Verifying and Transforming; Regulating concerns how responsibility and authority are distributed across these processes; and Collectivising can relocate them from individual teacher–AI interaction to collective scrutiny. This extends the analysis of TDC to design with resources capable of generating and reformulating proposals during interaction, while enriching DAD's analysis of instrumentation and instrumentalisation under conditions of increased resource agency (Artigue, 2026; Pepin, 2023). It also complements work on Digital Resource Design Capacity by foregrounding the demands associated with generative resources (Trgalová & Tabach, 2024).

7.2 From AI-generated resources to mathematical trajectories for students

The mathematical specificity of AI-supported documentational work lies not only in verifying whether generated content is correct, but in transforming generated resources into coherent mathematical trajectories for students. This requires deciding which mathematical relations should organise a lesson, how tasks should be sequenced, which representations and derivations should be connected, and how students may progressively encounter the intended ideas.

The three cases make this visible in different ways. Hu transformed an initially AI-organised collection of materials by making the analogy between arithmetic and geometric sequences the conceptual organiser of the lesson. Xin converted AI-generated derivations into a progression involving conjecture, comparison of methods, and subsequent application. Ya retained or rejected generated suggestions according to whether they clarified a relation central to the intended derivation and fitted the intended lesson progression. In each case, the contribution of AI depended on teachers' mathematical and didactical work on its outputs.

This extends studies concerned with the variable mathematical quality of AI-generated responses (Schorcht et al., 2026) and with AI as a lesson-planning assistant (Gurl et al., 2025). Recent review-level evidence similarly emphasises that mathematical correctness alone does not ensure the pedagogical quality, conceptual appropriateness, or curricular relevance of AI-generated resources (Schindler et al., 2026). Our cases add that teachers must reorganise generated mathematics into a teachable progression.

7.3 Designing teacher education for AI-supported documentational work

The course suggests that teacher education can support AI-TDC by organising environments in which generated resources are used in design, discussed, tested through enactment, and reconsidered. Individual preparation created space for exploration and transformation; peer review made lesson plans and AI-supported decisions available for collective examination; and microteaching confronted planned designs with enactment-related evidence before further revision.

Collective work is particularly important because AI-supported design can otherwise remain confined to private teacher–AI dialogue. Peer discussion can expose weak mathematical relations, question plausible-looking suggestions, and introduce alternative interpretations grounded in anticipated student reasoning or classroom experience (Gueudet et al., 2013; Sabra, 2016). Teacher education should therefore create occasions not merely for using AI collectively, but for

making AI-generated resources and the decisions surrounding them objects of shared mathematical and pedagogical scrutiny.

The aim is to develop teachers' capacity to position generative resources productively within broader resource systems while retaining responsibility for the mathematical trajectories offered to students.

7.4 Limitations and directions for future research

The study concerns one compulsory course and three purposively selected focal trajectories. Microteaching provided enactment-related evidence but did not reproduce ordinary classroom conditions. The resource-system representations were retrospective, and recorded prompt counts captured documented interaction rather than total AI use.

Longitudinal research is needed to examine whether the knowledge-in-action identified through AI-TDC becomes stabilised within professional schemes and how it develops through classroom experience. Further studies should compare mathematical domains, educational systems, AI models, and forms of collective work, while testing and refining the five-dimensional framework.

Generative AI changes the ecology of resources available for mathematics teaching. The challenge for teacher education is to help future teachers transform its outputs into mathematically purposeful teaching documents. AI-TDC offers one way to analyse—and support—that work while keeping teachers' responsibility for mathematical design at its centre.

Declarations

Funding

The first author's research was supported by a scholarship from the China Scholarship Council (CSC).

Data availability

The data are not publicly available because they contain confidential participant-generated course materials, AI dialogue records, interview data, and micro-teaching videos. De-identified excerpts supporting the analysis are included in the manuscript and appendices.

Ethics approval

Ethical approval for this study was granted by the Ethics Committee of the Faculty of Education, Beijing Normal University. The committee did not assign an approval number.

Consent to participate

All 20 participants provided informed consent for the research use of their course materials. The three focal participants provided additional informed consent for follow-up interviews.

Author contributions

Chongyang Wang contributed to the study design, data collection, translation, analysis, and drafting. Luc Trouche contributed to the study design, analysis, and critical revision. Both authors approved the final manuscript.

Competing interests

The authors have no relevant financial or non-financial interests to disclose.

Acknowledgement

We thank Michèle Artigue and Paul Drijvers for their careful review of an earlier version of this article and for their helpful advice.

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Figures

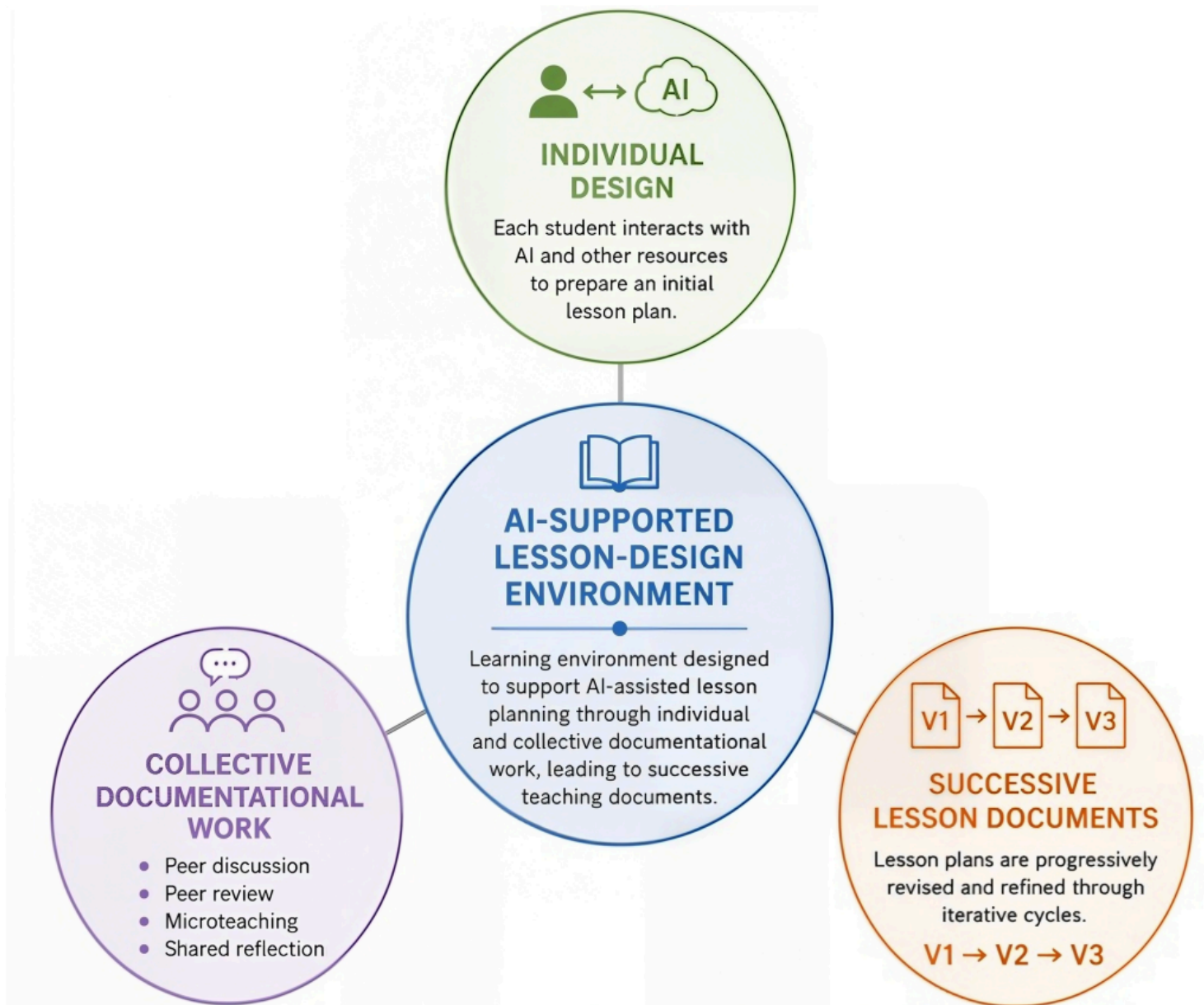


Figure 1

Didactical organisation of the AI-supported lesson-design environment, highlighting how individual AI-supported lesson design progressively becomes collective documental work, leading to successive teaching documents (V1–V3)

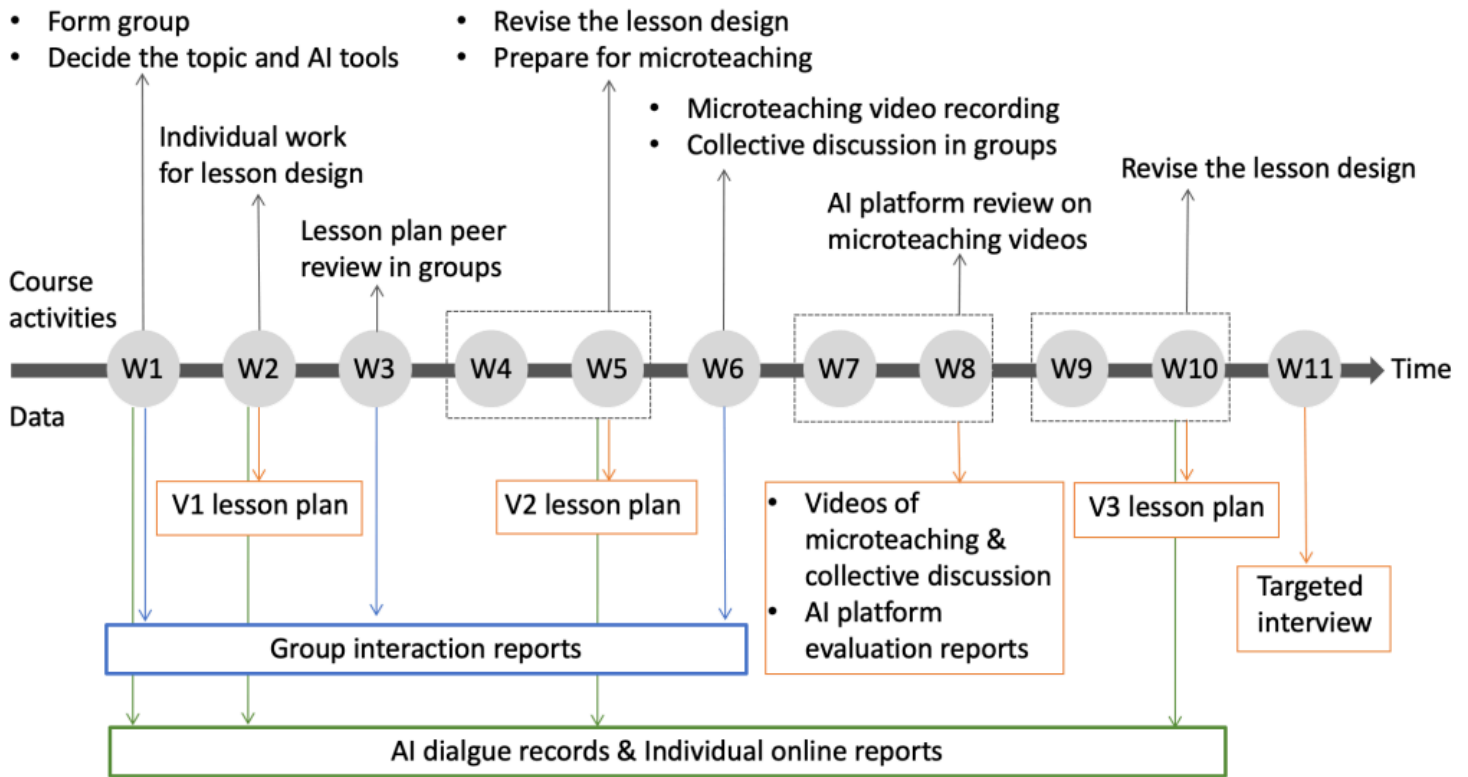


Figure 2

Timeline of course activities and data collection

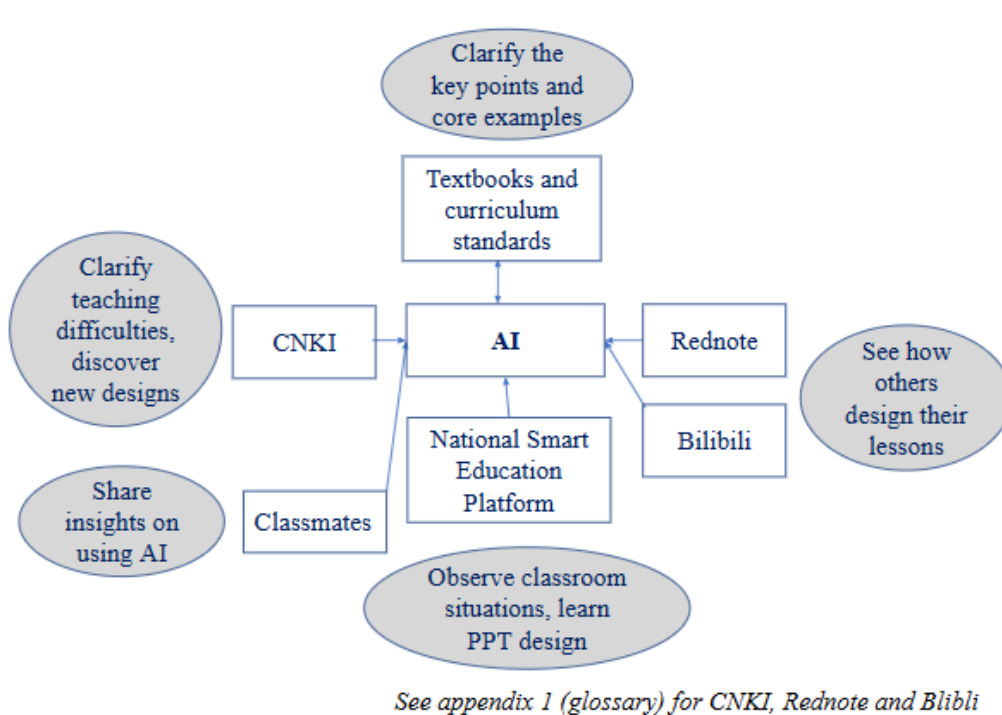


Figure 3

Hu's retrospective representation of her evolving resource system

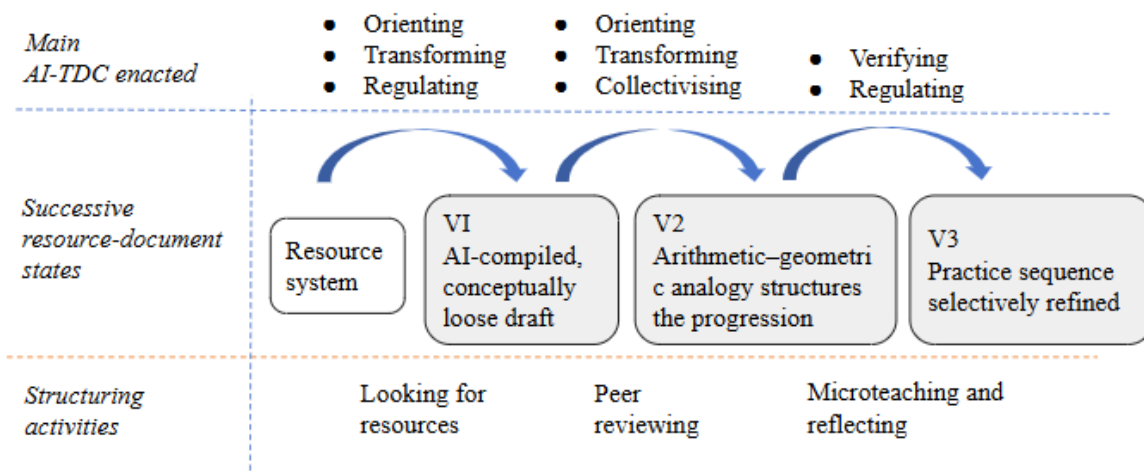
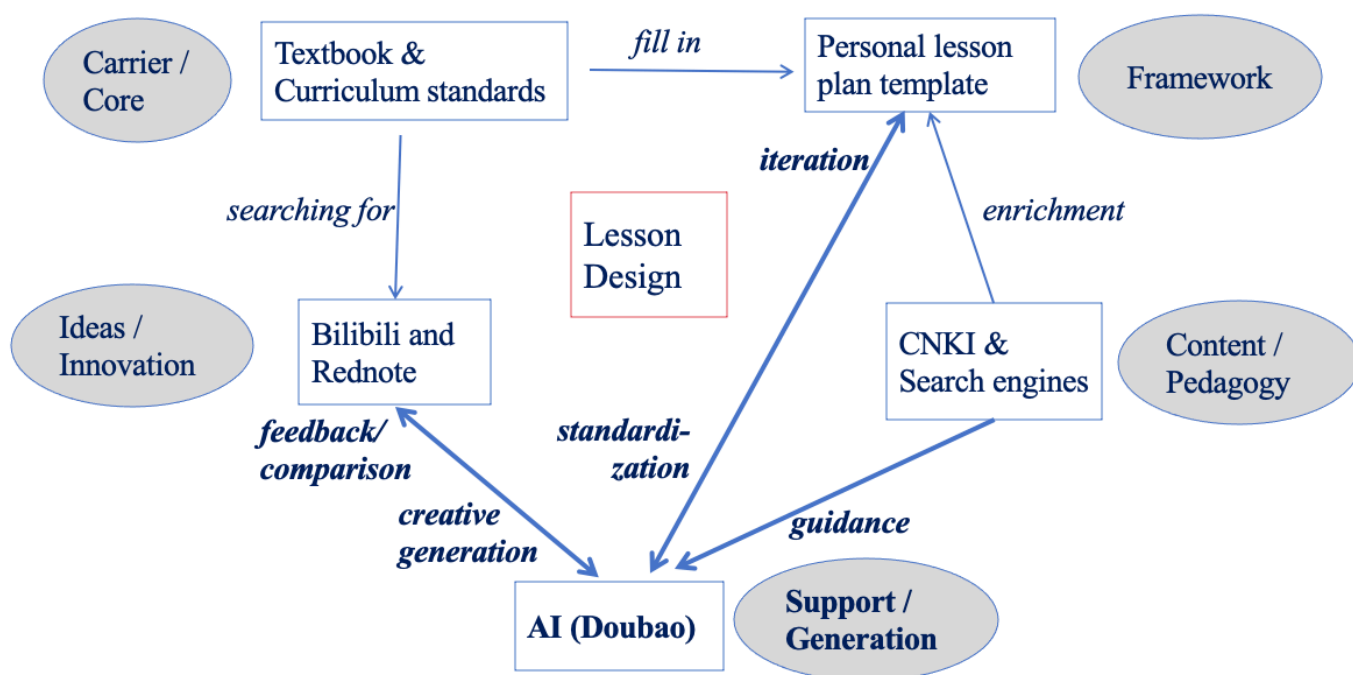


Figure 4

Hu's lesson-plan genesis and the main AI-TDC dimensions implicated in each transition



In bold: what has been added at the end of the course (final interview)

Figure 5

Xin's retrospective representation of her evolving resource system

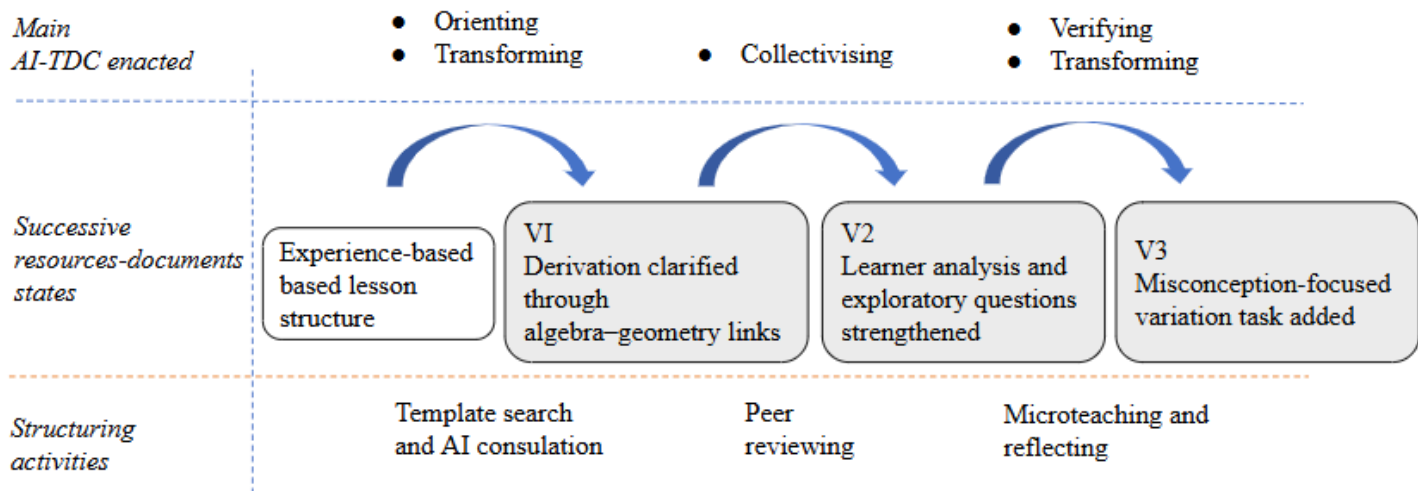


Figure 8

Ya’s lesson-plan genesis and the main AI-TDC dimensions implicated in each transition

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