# How Human-AI Interactions Shape Collaborative Learning: An Activity Theory Perspective

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**Abstract**

*The increasing proliferation of Generative Artificial Intelligence (GenAI) in society has the potential to reshape classroom ecology. Collaboration with GenAI enriches learners' AI knowledge and skills. However, it remains unclear whether GenAI-assisted tasks facilitate human-human collaborative learning. This study examines the interaction between two activity systems in GenAI-assisted assessment tasks—individual assessment and collaborative assessment—through the lens of the third-generation activity theory [1]. This theory provides valuable insights to better understanding the complex interplay among students and GenAI in individual-machine collaboration tasks [2,3].*
*Participants were 36 undergraduate students from the "Information Technology and Education" course. The experiment was divided into two parts: GenAI-assisted lesson plan assessment by text and collaborative lesson plan assessment by group dialogue. Participants were randomly assigned two-person groups to finish GenAI-assisted individual assessment and then collaborative assessment tasks. The study collected and analysed screen recordings of human-GenAI interactions and speech recordings during the collaborative learning activities. Thematic analysis was conducted [4]. The human-GenAI conversation history and students' responses to generated outputs from GenAI were thematically analysed to identify human-GenAI interaction profiles. Differences between individual and collaborative tasks were compared. The study identified fluctuations in tools and division of labour elements from GenAI-assisted individual learning to collaborative learning. As a result, 10 subthemes were identified in individual tasks while 26 subthemes were identified in collaborative tasks. Understanding the evolution of human-GenAI interaction from individual tasks to collaborative tasks can enable educators to tailor instructional strategies for optimal learning with GenAI as an assistant. This study contributes to the knowledge of integrating GenAI in education, exploring how GenAI can influence collaborative learning, and calls for considerations regarding the construction of GenAI-assisted classroom ecology.*

**Keywords:** *Activity Theory, Collaborative Knowledge Construction; Computer-Supported Collaborative Learning, Classroom Ecology, Human-GenAI Interaction*

## 1. Introduction

Collaboration and reflection are important components to support Generative artificial intelligence (GenAI) usage [5]. Interaction with GenAI stimulates the dynamic co-creation of thoughts [6]. Findings from [7, 8] demonstrate the evolution of interaction patterns with GenAI. Exploring the roles GenAI takes in collaborative learning would facilitate the understanding of the ecological context of integrating GenAI into authentic courses. However, there is a lack of research on how different human-GenAI interaction patterns evolve at multiple levels to reveal activity transitions from GenAI-assisted individual learning to collaborative learning. Targeting negotiated knotworking among multiple activity systems [9], the third generation of Activity Theory (AT) provides an ecological lens to analyze the interaction in GenAI-assisted collaborative learning.
In pre-service teacher education, lesson plan is time consuming. With the advance of GenAI, some articles have explored the potential of GenAI in automatic lesson plan generation [10, 11] Though the automated lesson plan generation reduce the labour and time invested in lesson plan design, some shortcomings are identified, such as vagueness of instruction and inability to provide external materials [10, 11]. Lesson plan assessment tasks are ill-defined problem-solving tasks, encompassing diverse challenges such as prior pedagogical knowledge and domain knowledge activation, problem representation, exploring a variety of revision solutions, and converging on the applicable revision suggestions. This process requires private information that commercial GenAI does not include, such as student profiles, prior teaching materials used, and the preparation of operational experimental materials. Integrating GenAI into human-led lesson plan evaluation tasks could combine the

advantages of both, the massive information stored by GenAI and the customized private data stored by humans in specific scenarios.
Therefore, this study utilizes GenAI as an assistant to support lesson plan assessment first in individual and then in collaborative settings. This would stimulate pre-service teacher students to think critically about when and how to use AI tools in the classroom. The findings from this study also contribute to the understanding of how human-GenAI interactions evolve between individual and collaborative tasks.

## 2. Related Works

### *2.1 GenAI and Problem Solving*

In the fast-changing AI era, multiple capabilities are required for effective human-AI collaboration in problem solving, such as navigate one's own and others' views mediated by AI through engaging people in AI-mediated dialogue and group work [12]. For complex problem solving, GenAI can provide support to students in the iterative development of initial ideas, expanding these ideas in greater detail, enabling students to deeply explore the problem space and develop elaborate solutions [13]. Human and GenAI offer distinct and complementary roles which are essential for effective collaborative problem solving [14]. In lesson plan tasks in education, GenAI can rapidly generate course materials, saving time for instructors to start from scratch [11]. GenAI has demonstrate strengths in suggesting appropriate toolkits and materials as well as providing diverse instructional activities and assignments [10].

### *2.2 Activity Theory (AT)*

AT provides a sociocultural approach to analyse and present human activities as systematic and socially situated phenomena. Different from the prior generation, the third generation of AT support a dynamic perspective to interpret activity processes by combing the seven elements: subject, tools, object, rules, community, division of labour, and outcomes. The third generation provides conceptual tools to understand dialogue and networks of interacting activity systems [15]. Among the elements in AT, rules and division of labour are important elements for observing the dynamic process. Rules encompass explicit and implicit guidelines, norms, conventions, and standards that constrain actions within the activity system, while division of labour involves the distribution of tasks horizontally and the allocation of power and status vertically [9]. Compared to rules, division of labour demonstrates the dynamic operation status of the task completing process mediated by other elements. By ascending from abstract theory to concrete practice, interactions among the elements can be reconceptualized to allow for greater possibilities and flexibility than the prior pattern of activity [15].
With the penetration of GenAI in everyday life, GenAI has become a community member in teaching and learning scenarios. This involvement also shapes the classroom economy through the relationships among students, instructors, and tools. AT has been employed in prior studies to examine GenAI-assisted activities, such as students' attitudes to GenAI's role in problem-based learning and argument essay writing [2, 16]. For instance, [16] identified three main tensions in a GenAI involved university community: tension in the object mediation, tension between subject and micro-community, and tension between subject and rules. Supported by screen recordings of 5 English as foreign language learning students [2] revealed that the writing community was formed by humans and GenAI, including mediating tools, rules, and division of labour during the GenAI-assisted writing process. However, how GenAI triggers new relationships between humans and GenAI in lesson plan assessment tasks is still understudied.

### *2.3 This Study*

This study aims to reveal the characteristics of students' collaboration with GenAI and human partners in cognitive and regulative dimensions at two levels: individual and collaborative. In the context of Gen-AI assisted assessment, learners conceptualize a mediated activity system where students are subjects prosecuting their assessment tasks. Although the subject, object, and tool exist in the same community, students have different rules, and each activity system has its own division of labour. Simplified relationships among these elements can be seen in Figure 1. Considering rules are more related to guidelines such as ethical AI use, interaction protocols, or assessment criteria, while division of labour relates to how students, instructors, and AI systems contribute to the learning process in

practical implementation, this study use division of labour to interpret the human-AI, human-human, human-human-AI interactions in practical processes. The following research question (RQ) was proposed: How do tools and division of labour elements fluctuate from GenAI-assisted individual learning to collaborative learning?

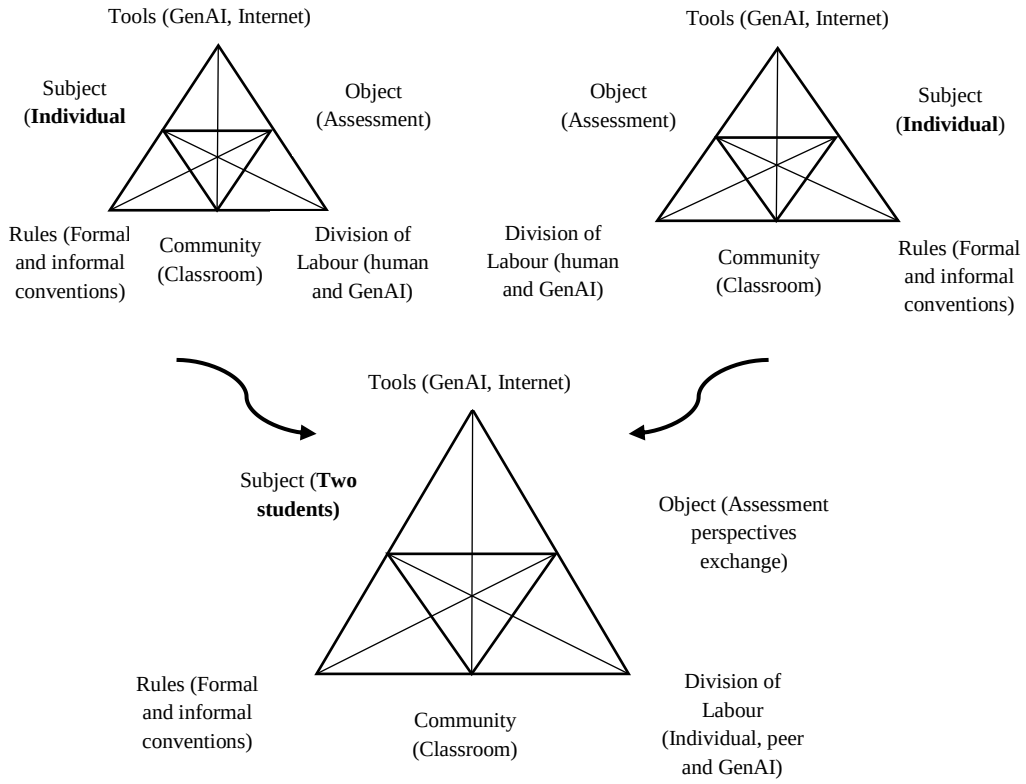


Figure. 1. GenAI-assisted assessment tasks based on Engeström's AT [9].

## 3. Methods

### *3.1 Participants and Context*

The participants were 36 undergraduate pre-service teachers from a teacher education course named "Information Technology and Education" in a public Chinese university. The course focused on integrating information technology into teaching and included a unit on evaluating lesson plans using digital tools. A local ERNIE driven GenAI tool, Wenxinyiyan was selected in the lesson plan assessment tasks because it provides multiple interaction modes, such as text-to-text, text-to-image, document as input.

### *3.2 Design*

The study was conducted in two phases: GenAI-assisted lesson plan assessment by individual students and then by groups. The detailed of the assessment activities design from a AT framework can be found in Table 1. Participants were randomly assigned to two-person groups to finish the assessment tasks.

Table 1. AT elements shown in the GenAI-assisted lesson plan assessment tasks.

| AT elements | Individual assessment task | Collaborative assessment task |
|---|---|---|
| Tools | WORD document (lesson plan), GenAI tool | WORD document (lesson plan), GenAI tool |
| Subject | Individual student | Students and their peers |

| | | |
|---|---|---|
| Object | Assess and revise the self-designed lesson plan and peer's lesson plan by text | GenAI-assisted lesson plan peer assessment task to facilitate the integration of GenAI in classroom and to stimulate pre-service teacher students critically thinking how to use GenAI in lesson plan design. |
| Rules | Individual students need to decide whether, and how to use and evaluate generated outputs from GenAI;<br>GenAI act as an assistant in lesson plan assessment. | Students need to decide to take turns as the feedback provider and receiver;<br>Students need to decide whether and how to use and evaluate generated outputs during group discussion;<br>GenAI act as an assistant in lesson plan assessment. |
| Division of labor | Individual students' inquiry GenAI to evaluate and revise lesson plan;<br>GenAI generates feedback to the inquiry;<br>Individual students either accept or reject the generated feedback. | As feedback provider, students need to provide give their comments and reasoning;<br>As feedback receivers, students need to response to the comments received and express their willingness and reasoning;<br>GenAI can be used to assist students with giving and response the feedback. |
| Community | Authentic classroom setting, instructor, GenAI, individual students | Authentic classroom setting, instructor, GenAI, individual students and their peers |
| Outcome | Revised lesson plans, screen recordings | Revised lesson plans, screen recordings, peer dialogue recordings |

### *3.3 Data Collection and Analysis*

Data sources included screen recordings of individual sessions, audio recordings of group discussions, and students' written lesson plan revisions. Audio recordings were manually transcribed and segmented for further analysis. We conducted thematic analysis [4] to identify patterns in interaction. Considering the research question proposed in this study, attention was mainly paid to the division of labour because this element refers to horizontal division of tasks and vertical division of power and status [9]. Two researchers independently coded the prompts extracted from the screen recordings and transcripts. One researcher coded 20% of the data while the other coded all the data. The agreement of coding results was 85%.

## 4. Results and Discussion

Besides the assumed tools and division of labour in task requirements, additional diverse divisions of labour actively emerged in both individual assessment tasks and collaborative assessment tasks. Comparatively, collaborative learning presents more diverse collaboration modes than individual settings. The emerged specific application scenarios can be visualized in Figure 2 and 3. More details can be found below. Clearer figure and examples of the subthemes can be found at the OSF link: https://osf.io/3rjgc/?view_only=9208c047f3a840b998a9de5e017d497b

### *4.1 GenAI-assisted Lesson Plan Assessment in Individual Tasks*

During individual tasks, besides the assigned tools, other related tools were utilized to enrich or verify the lesson plan during assessment, such as search engine and self-developed courseware.
As shown in Figure 2, 6 main themes and 10 subthemes were identified to describe the human-AI interaction in individual tasks. Most of them demonstrated a preference for generating text from text. For example, expanding lesson plan materials about physics domain knowledge in application scenarios, exercises examples, physics experiment design, and homework design. When the generated outputs didn't align with individual students' prior knowledge, they chose to use other search engines to verify the generated outputs. This suggests that students critically think about the generated outputs and build cognitive relationships among prior knowledge, generated outputs by GenAI, and online information.

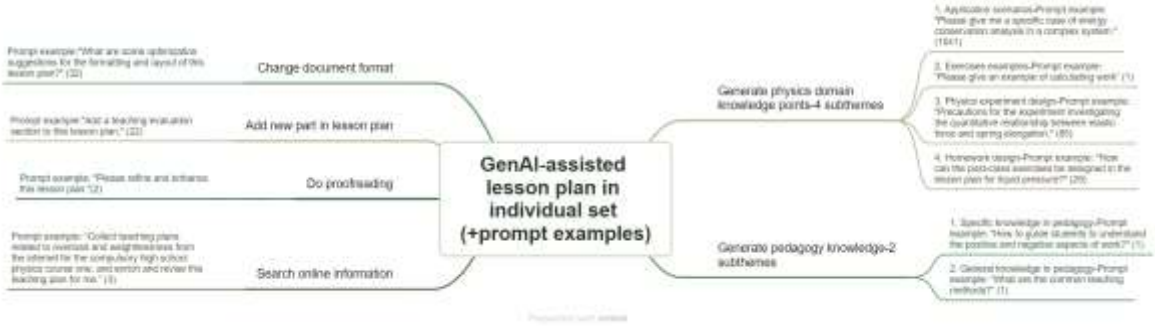


Figure 2. Division of labours themes in GenAI-assisted lesson plan assessment individual tasks.
Note: Examples are followed by the anonymized participant IDs like “(2)”.

### *4.2 GenAI-assisted Lesson Plan Assessment in Collaborative Tasks*

Similar to the tools used in individual tasks, search engines and self-developed courseware were also employed in the collaborative setting. Unlike individual tasks, peers acted as data sources to customize the generated outputs and share prior usage experiences.
Regarding GenAI-assisted collaborative tasks, 5 main themes and 26 subthemes were identified, including Human group conversation, Combination of Human group+GenAI, Combination of Human group+other group, Combination of Human group+instructor, Search engines as other data sources (details seen in Figure 3). Compared to individual tasks, more interaction activities occurred. The 11 subthemes under the theme Human group+GenAI and 8 subthemes under Human group conversation suggested that the engagement of GenAI in collaborative learning triggered more human-human collaboration activities.

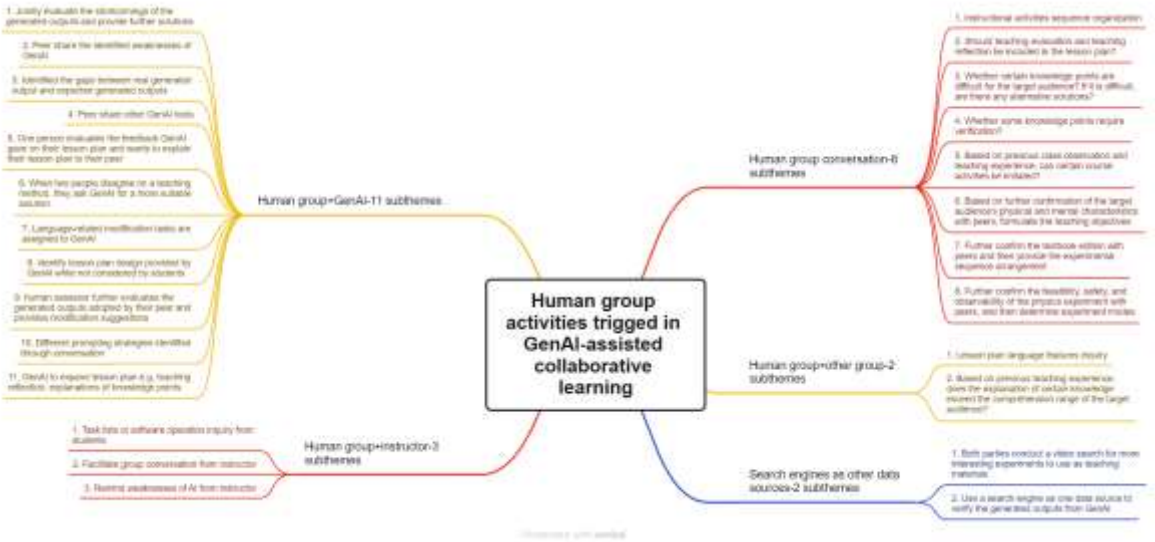


Figure 3. Division of labour themes in GenAI-assisted lesson plan assessment in collaborative tasks.

Here we demonstrate some dialogue episodes to exemplify subthemes under themes of Human group+GenAI and Human group conversation:

**Theme 1: Human group+GenAI (examples)**
1. *Jointly evaluate the shortcomings of the generated outputs and provide further solutions.*
Examples were found between participants 39 and 85: "39- Hmm, I feel like your teaching summary is a bit wordy. 85- Oh, I copied it from AI. 39- Alright, I'll help you revise it. 85- Yes, please help me revise it. Sharp eyes! 39- Well, how should I put it? I think I should still use AI to revise it, since I don't really know the key points of this lesson."
2. *Peer share the identified weakness of GenAI*.

Examples were found between participants 18 and 19:"18- Hmm, because earlier, I asked AI to design a blackboard layout for me, but when I looked at output, it seemed very Cyberpunk style.19- Same with mine—I asked it to format something, but it didn't really do much. 18- That shows AI is still just a reference tool. 19- A reference, a reference—it still relies on people."

3. *Identified the gaps between real generated output and expected generated outputs*.

Examples were found between participants 02 and 32: "32- Hey, I just let it beautify my text. 02- What did it refine exactly? 02- No way. If you want refinement, it can only be done piece by piece. 32- I asked it to beautify, but it directly changed my content. (02 and 32 laugh together) 02- It shortened your text, alright, it summarized it. 32- It directly modified what I wrote. I didn't ask it to change my content, I wanted it to adjust the formatting."

4. *Peers share other GenAI tools*.

Examples were found between participants 02 and 32: "02- Does the WORD office software have AI? 32- Not sure. 02- WPS's WORD seems to have AI."

*5. One person evaluates the feedback GenAI gave on their lesson plan and wants to explain their lesson plan to their peer*.

Examples were found between participants 14 and 22: 14- Yes, yes, I'm here! AI gave me some suggestions, such as saying that the student's central role is not prominent enough, the experiment design lacks innovation, the connection between knowledge points is not tight enough, and the cultivation of scientific attitude and responsibility is not specific enough, etc. Now, I have some thoughts. For example, regarding the first point—AI mentioned that the student's central role is not prominent enough. However, I have already designed a teacher-led demonstration experiment to guide students. Since it is difficult for middle school students to independently conduct the buoyancy experiment, the design focuses more on the teacher guiding students to observe the demonstration and ask questions, allowing them to gain a deeper understanding."

…

*11. GenAI to expand lesson plan*.

Like human-AI interaction in individual tasks, GenAI was also utilized in collaborative learning to expand lesson plan materials. For example, to provide explanations of knowledge points participants 08 and 45 had conversations like "08- Understanding the fundamental cause of resonance—I think you should mention this. When I read through it, my biggest impression was that you didn't explain why. If I were a student, I would also be very curious. 45- Thank you for your suggestion. I think this is indeed a great improvement, and I will incorporate it into my lesson plan. 08- You can also use AI to find an explanation for the fundamental cause of resonance.". One different point from individual tasks was to extract specific content from a specific document. To quick find related text, groups tried to use AI to extract details. One example can be found in between participant 36 and 38: "38- How about you just send AI all—Word and PPT? 36- Send the PPT to AI, can AI handle it? Oh, PPT, it seems to have a way to extract text. 36- I remember AI has a function called 'Outline.' Where does PPT extract text? I remember there's a function called 'Outline.'"

**Theme 2: Human group conversation (examples)**

*1. Instructional activities sequence organization*.

Teaching activities reflect the logical sequence of knowledge points, such as first exploring a knowledge point and then understanding it. Examples can be found between participants 09 and 43 the number is not sure: 09 "Oh, wait, that's not right. It might mean that this is part of the new lesson, and since the new lesson's knowledge has already been covered, this part is more like self-exploration or review."

*2. Should teaching evaluation and teaching reflection be included in the lesson plan?*

Examples can be found between participants 14 and 22: "14- Then, later on, in the teaching reflection section, there's a part about post-class discussion with students. However, since the lesson plan is designed before the class, this process likely wouldn't happen. 22- Right, but... 14- This was generated by AI, right? 22- Yes. 22- But isn't teaching evaluation done after the class? 14- I think my teaching evaluation is more about identifying potential issues in the lesson plan. 22- Oh, I see. 14- Since the lesson plan is prepared before the class, this process wouldn't be included. 22- Yes, the lesson plan is pre-class preparation. 14- Then this part can be removed, right?"

*3. Whether certain knowledge poitns are difficult doe the targeted audience?*

Based on previous schooling and teaching experience, is a certain knowledge point relatively difficult for the target audience? If it is difficult, are there any alternative solutions? "1009- But there's a problem—middle school students haven't learned about molecular density. 10- We can expand on it.

1009- Would expanding on it be too difficult? 10- Just let them take a simple look—like identifying which is a gas and which is a liquid and then observing how gas transitions into liquid."

**Compared to other empirical studies about GenAI-assisted tasks using AT as analysis framework**

Similar to the tensions identified from [16], our study also found these tensions. Furthermore, our study provides additional empirical evidence to exemplify these tensions. For tension in the object mediation, based on prior individual usage experience and the GenAI usage in collaborative learning, more epistemic and pragmatic events were triggered. For example, generated feedback as shared targeted artifact, student groups shared their usage experiences of the identified weakness of GenAI in lesson plan design. The generated feedback served as an evaluation reference, students actively evaluating the generated feedback from GenAI and critically explaining their lesson plans to their peers. Regarding the tension between subject and micro-community, reflecting divergent views on which tasks should be delegated to AI, one example can be found between participants 34 and 37. They expressed different preferences about whether to use GenAI for lesson plan design. Here is one dialogue episode: 37 - "Why do you use AI to help you write this lesson plan?" 34 - "Because it saves time." 37 - "What if you write it entirely by yourself?" 34 - "Writing it completely on my own would take a lot of time."

Different from the small samples in GenAI-assisted individual tasks by [2], our study identified a more complex division of labour, esp. in collaborative learning tasks (26 subthemes identified as shown above). Agreeing with their statement, we also recommend a dynamic activity system perspective in human-AI interaction to analyse how students encountered challenges during their collaboration with GenAI.

**Compare to other studies in GenAI-assisted problem solving tasks**

Like the affordances provided by GenAI in the study by [13], we also found that the involvement of GenAI facilitated the deep exploration of the problem space and the development of more elaborated solutions. Furthermore, this phenomenon not only emerged in human-AI individual tasks but also in human-AI collaborative tasks (more details seen in part Theme 1: Human group+GenAI).

## 5. Conclusion and Implications

This study explores the integration of GenAI in a lesson plan assessment environment both individual and collaborative modes. It examines the emerging practices students develop individually and in groups, as well as the tensions they navigate in response to the affordances and limitations of GenAI. Compared to the 10 subthemes identified in the GenAI-assisted individual tasks phase, 26 subthemes were found in the GenAI-assisted collaborative tasks phase. During the collaboration process, multiple formal and informal rules and division of labour evolved to frame the GenAI use in classroom ecology. Evidence shows that GenAI-assisted tasks facilitate human-human collaborative learning. The examples of division of labour we found in this study could provide some practical application scenarios for instructions in authentic classrooms to facilitate GenAI-assisted collaborative learning, esp. for non-AI experts.

For future studies, educators, curriculum designers, or educational technology developers need to pay attention to:

*1. Metacognition and task decomposition support in GenAI-assisted problem solving.*

Integrating AI outputs into human knowledge systems requires humans' technical and conceptual skills to assess the outputs of AI systems, making knowledge practices like sense making and meaning making important [12]. During work with GenAI, metacognitive flexibility and task decomposition play significant roles. Metacognitive flexibility refers to adaptively shifting cognitive strategies when realizing a current strategy is not effective, while task decomposition invloves breaking down a task into actional subtasks [17].

For general problem solving processes in GenAI-assisted collaborative learning, the subthemes (10 in individual tasks and 26 in collaborative tasks) found in this study could serve as scaffolding examples for metacognition and task decomposition to facilitate the depth of elaboration of initial solutions in GenAI-assisted complex problem solving. For specific problem solving in lesson plan assessment tasks, the task design of GenAI-assisted lesson plan assessment tasks has the potential to facilitate the integration of GenAI in classroom and to stimulate pre-service teacher students know when and how to use AI tools critically in classroom. And the subthemes found in this study could be used as

coding scheme reference to categorize behaviors of GenAI-assisted collaborative learning in lesson plan assessments.

*2. Teacher AI literacy development*.

For pre-service teacher students education, the proliferation of AI in many aspects of human life requires teachers to develop AI literacy. This necessitates equipping teachers with fundamental AI knowledge. By integrating this understanding with their pedagogical expertise, educators can effectively design curricula that incorporate AI-driven learning and instruction [18]. The mode in this study, combing individual tasks and collaborative tasks, would be suggested to stimulate pre-service teacher students to critically think about what and how AI can be used in the classroom.

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