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Artificial intelligence assisted design of a novel cooperative learning technique for higher education

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Cooperative learning has long been recognized as an effective pedagogical strategy, yet the development of innovative techniques tailored to modern educational demands remains a challenge. This study introduces the Curriculum Concept Constellation Technique (CCCT), a novel cooperative learning technique developed with the support of artificial intelligence (AI). The CCCT employs a metaphorical and visual approach, wherein students collaboratively map key curriculum concepts into visual 'constellations,'[1] – a metaphor representing how individual ideas (like stars) interconnect to form meaningful patterns. This approach fosters deeper conceptual understanding through creativity, role-based collaboration, and peer interaction. Using a mixed-methods explanatory sequential design, the study examined the effects of CCCT on 67 prospective teachers enrolled in a "Curriculum Development in Education" course. Participants were divided into experimental (CCCT) and control (conventional lecture-based) groups. Quantitative results revealed statistically significant improvements in the experimental group's academic achievement (g = 0.839), co-regulation situations (g = 0.512), and attitudes toward cooperativeness (g = 0.751), with moderate effect sizes. Qualitative feedback highlighted CCCT's strengths in enhancing communication, teamwork, and engagement, though challenges such as unequal participation and time constraints were noted. The study demonstrates that AI can serve as a valuable generative tool in pedagogical innovation, producing structured cooperative learning techniques based on human-authored prompts. The findings suggest that AI-generated techniques can be effectively implemented in higher education contexts, offering a scalable model for developing tailored instructional methods.

Keywords Artificial intelligence in education, Conceptual mapping, Cooperative learning, Higher education, Pedagogical innovation

Cooperation is not a novel concept in the field of education. Its roots can be traced back thousands of years, as reflected in proverbs such as "two heads are better than one," "many hands make light the work," and "if you want to go fast, go alone; but

[1] Throughout this manuscript, references to 'constellations' should be understood as a pedagogical metaphor for conceptual relationships, not as an astronomical or literal representation.

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if you want to go far, go together"[1,2]. These expressions underscore the long-standing belief in the power of cooperation and its potential to enhance learning and productivity. However, the formalization of cooperative learning as an instructional strategy began in the late twentieth century and gained significant momentum during the 1970s, when a growing body of research and practical work began to solidify its theoretical and empirical foundations[3].

According to Ghaith and Awada, cooperative learning encompasses a range of pedagogical frameworks in which learners engage in structured, small-group interactions to collaboratively solve problems, complete tasks, or pursue common educational objectives[4]. This definition highlights the structured and goal-oriented nature of cooperative learning, distinguishing it from informal or unstructured group activities. While the concept of cooperation in education has existed for many years, it was not until the late 1960s and 1970s that cooperative learning was systematically studied and implemented in classrooms[5]. The research conducted laid the groundwork for understanding the psychological and social dynamics of cooperative environments, leading to the development of key principles and models that continue to guide practice today. Since the 1970s, a significant body of research has examined the outcomes of cooperative learning across diverse educational settings, from early childhood education to higher education and beyond. As Baloche and Brody emphasizes, "why champion and implement a pedagogy that does not demonstrate efficacy?"[6]. This question has driven numerous empirical studies, meta-analyses, and best-evidence syntheses, including those by Johnson et al., Slavin, and Qin et al.[7-11]. These studies have provided robust evidence of the effectiveness of cooperative learning in enhancing academic achievement, motivation, intergroup relations, critical thinking, and problem-solving skills.

Moreover, researchers have sought to provide theoretical frameworks to contextualize and evaluate cooperative learning practices. Slavin identifies four theoretical perspectives – motivationalist, social cohesion, cognitive developmental, and cognitive-elaboration – to explain the achievement effects observed in cooperative learning environments[12]. Similarly, Johnson and Johnson highlight four major theories – social interdependence, cognitive developmental, social-cognitive, and behavioral – that support the use of cooperative learning and have shaped both research and classroom practice[13]. These theoretical foundations have been instrumental in guiding the development and refinement of cooperative learning techniques over the decades.

While cooperative learning involves students working together in small groups, it differs significantly from other forms of group work due to its structured and intentional design. According to Johnson and Johnson, cooperative learning is characterized by five essential elements: (1) positive interdependence, (2) individual accountability, (3) face-to-face promotive interaction, (4) interpersonal and small group social skills, and (5) group processing[14,15].

Positive interdependence refers to the idea that students' success is linked to the success of their group. This creates a sense of shared responsibility and mutual support, ensuring that group members work together to achieve common goals. Individual accountability ensures that each student is responsible for contributing to the group's work and is assessed individually to prevent free-riding. Face-to-face promotive interaction encourages students to communicate, share ideas, and support one another in their learning. Interpersonal and small group social skills are developed through structured interactions that promote effective communication, conflict resolution, and teamwork. Finally, group processing allows students to

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reflect on their group's functioning and identify ways to improve cooperation and learning outcomes[16].

Baloche and Brody emphasize that merely placing students in groups does not guarantee effective cooperation or learning. Without intentional structuring of these five elements, group work may devolve into unproductive or even counterproductive interactions. Therefore, cooperative learning requires careful planning, clear expectations, and ongoing support to ensure that students engage in meaningful and productive collaboration[6].

Literature Review

Teaching profession, teacher education and cooperative learning

The importance of cooperative learning extends beyond student learning to encompass teacher education and professional development. Johnson and Johnson argue that effective teacher training must not only focus on subject matter expertise but also model the collaborative practices that teachers are expected to implement in their classrooms. Teacher education programs aim to ensure that educators master the content they teach, engage in long-term implementation of instructional procedures, develop appropriate attitudes and values, integrate new practices into their professional identity, and achieve membership in a community of practice[17].

The processes used during teacher education play a crucial role in achieving these goals. Johnson and Johnson emphasize that the attainment of these objectives is largely contingent upon the nature of the processes employed during teaching sessions. They further note that these processes should be grounded in theory, supported by empirical research, and operationalized into clear procedures for teacher educators to use. Cooperative learning provides an ideal framework for meeting these criteria, as it allows teacher candidates to experience firsthand the benefits of working interdependently, being accountable to peers, and reflecting on collective practice[18].

In addition to developing instructional competence, cooperative learning plays a vital role in shaping teachers' professional identity and commitment to their craft. As Johnson et al. point out, within educational settings, teachers are frequently required to work together in pursuit of shared objectives, uphold mutual accountability, support one another's professional success and well-being, develop and apply the interpersonal competencies necessary for effective teamwork, and engage in reflective practices to evaluate the efficacy of their cooperative processes. By engaging in cooperative learning experiences, teacher candidates are better prepared to collaborate with colleagues, support student learning, and contribute to a positive school culture[19].

Moreover, cooperative learning fosters the development of essential interpersonal and group skills that are critical for effective teaching. Teachers must be able to work collaboratively with students, parents, and other educators to create inclusive and supportive learning environments. Through cooperative learning, teacher education programs can model these skills and provide opportunities for reflection and growth. As Johnson and Johnson assert, cooperative pedagogy is considered the most suitable approach for socializing teachers into a professional community of practice, fostering the development of a teacher identity, cultivating a commitment to professional effectiveness, and achieving a range of other essential educational objectives[17].

The contemporary relevance and innovative nature of cooperative learning

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In today's rapidly evolving educational landscape, cooperative learning has emerged as a cornerstone of innovative pedagogy. Its relevance is closely tied to broader socio-economic conditions that emphasize the importance of human cooperation in fostering effective functioning at individual, community, and global levels[20]. Educational systems that incorporate cooperative approaches not only align with these societal needs but also contribute to addressing critical global challenges, including social inequality, cultural integration, and ethical development.

One of the key reasons cooperative learning is considered an innovative trend is its alignment with the competencies identified as essential for the 21st century. The European Commission and UNESCO have both underscored the importance of skills such as teamwork, cooperation, communication, problem-solving, and creative thinking[21,22]. In particular, the World Economic Forum ranks collaboration as one of the top workforce skills, emphasizing its relevance in preparing students for the demands of the modern workplace[23]. Cooperative learning serves as a powerful mechanism for cultivating these competencies by embedding cooperative practices into the learning process.

Furthermore, cooperative learning supports the broader goals of education, including the enhancement of the humanistic dimension of learning, the promotion of participatory and student-centered pedagogy, and the development of critical thinking and creativity[24]. It moves beyond traditional, teacher-centered instruction by encouraging students to take ownership of their learning, engage in meaningful dialogue, and work interdependently to achieve shared goals. As Gunn and Hollingsworth observe, cooperative learning encourages the use of instructional technology, assessment practices, and student-centered methods that are central to modern educational innovation[25].

In countries around the world, cooperative learning has earned recognition as a respected pedagogy with the potential to positively influence a wide range of educational outcomes[6]. Its effectiveness in promoting academic achievement, motivation, intergroup relations, and creative problem-solving has been well-documented across diverse educational contexts. As such, cooperative learning is not only a response to contemporary educational needs but also a forward-looking approach that prepares students for the complexities of the modern world.

The need for developing new cooperative learning techniques

Despite the existence of well-established cooperative learning models such as Jigsaw[26], Student Teams-Achievement Divisions[27], and Learning Together[28], the field continues to evolve with the development of new techniques. Slavin notes that while the core principles of cooperative learning remain consistent, implementation varies widely depending on the learning context. This variation is driven by several key factors, including diverse educational contexts, evolving learning theories, technological advancements, student diversity, and ongoing research[29].

Different subjects, age groups, and classroom dynamics require tailored cooperative learning approaches. For example, while the Jigsaw method[26], was originally designed to reduce racial tension in desegregated schools, Reciprocal Teaching[30] was developed to improve reading comprehension. Similarly, Peer-Assisted Learning Strategies[31] was created to support struggling readers, and Complex Instruction[32] promotes equitable participation in heterogeneous classrooms.

Technological advancements have also influenced the development of new cooperative learning techniques. Digital tools such as Google Docs, Padlet, and

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online discussion forums have necessitated adaptations of traditional models to support collaboration in blended and online environments[33]. Additionally, empirical research that identifies limitations in existing methods or reveals more effective practices refine cooperative learning techniques. For instance, Hattie's meta-analysis shows that structured interdependence (e.g., assigning roles) improves outcomes more than unstructured group work[34].

Challenges in developing new cooperative learning techniques

Creating new and original cooperative learning techniques is a complex and demanding task. As Jacobs et al. note, numerous scholars and practitioners have made, and continue to make, both significant and incremental contributions to the ongoing development and richness of the cooperative learning movement[1]. However, the development of effective techniques requires a deep understanding of pedagogical theory, contextual adaptation, equity considerations, and rigorous evaluation.

Educators must be well-versed in foundational theories such as social interdependence theory[35], zone of proximal development[36], and constructivist learning principles. Without a strong theoretical foundation, new techniques may fail to promote meaningful collaboration or produce desired learning outcomes. Additionally, new techniques must be adapted to specific subjects, student demographics, and curricular goals, which can vary significantly across educational settings.

Ensuring equity and inclusion is another major challenge. Ashman emphasize that without built-in mechanisms for inclusion, some students – particularly those who are shy, non-native speakers, or have learning disabilities – may be marginalized or disengaged[37]. Finally, evaluating the effectiveness of new techniques requires data collection, analysis, and comparison with existing methods, which can be time-consuming and technically challenging for many educators.

Cooperative learning and the potential of artificial intelligence

The development of innovative cooperative learning techniques presents significant challenges, but emerging technologies such as artificial intelligence (AI) offer promising avenues to support educators in overcoming these barriers. By leveraging AI, educators can address some of the theoretical and practical obstacles associated with the creation of novel pedagogical methods. Furthermore, AI has the potential to serve as a generative tool in the development of cooperative learning techniques, assisting educators by producing novel instructional designs based on specified parameters. This human-AI collaboration, where educators provide the pedagogical framework and AI generates creative implementations, can enhance both creativity and efficiency in pedagogical innovation. As noted by Holmes et al., AI is increasingly being utilized across various domains of education, including personalized learning, data mining, automated assessment, and intelligent tutoring systems. These applications enable the analysis of large datasets to identify effective group dynamics, personalize learning experiences, and simulate instructional strategies[38]. Recent research has also begun exploring the integration of AI into cooperative learning environments, shedding light on its transformative potential.

In their study, Youssef et al. investigated the methodological aspects of a collaborative Intelligent Tutoring System (ITS), focusing on the integration of IMS Learning Design (IMS-LD). The research aimed to evaluate the effectiveness of IMS-LD in designing and managing ITS while addressing the challenges posed by modern

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education systems. By integrating IMS-LD with advanced learning models, the study sought to enhance personalization and efficiency, thereby fostering a more student-centered approach. Although no experimental applications were conducted to test the developed model, the findings underscored the potential of intelligent tutoring systems to deliver adaptive and personalized learning experiences, promote effective communication and cooperation among participants, and improve overall educational quality through innovative technological integration[39].

Sheoran and Kaur examined traditional models of cooperative learning and explored the transformative role of AI within these frameworks, emphasizing its impact on the educational landscape. According to their analysis, the integration of AI into education is reshaping the roles of both educators and students by fostering personalized, inclusive, and effective learning experiences. Educators are empowered to create dynamic learning environments, while students benefit from tailored learning paths, instant feedback, and engaging educational tools. As AI continues to evolve, its capacity to enhance education in the digital age and meet the diverse needs of learners becomes increasingly evident, heralding a future where education is more accessible, adaptable, and enriching for all. By incorporating AI into cooperative learning, educators can design more dynamic, personalized, and effective learning environments that cater to the varied needs of students[40].

Martens conducted a study to examine the impact of an AI-powered conversational agent designed to enhance behavioral engagement during pair discussions, on students' responsiveness, active participation in cooperative learning activities, attention, and willingness to participate. The research involved 18 students who participated in an online experiment consisting of two stages: one with and one without the collaborative AI tool. Despite the absence of statistically significant differences between the two stages, the study provided valuable insights and a foundation for further exploration into the potential changes that conversational agents could introduce in cooperative learning settings[41].

Javed et al. investigated how AI facilitates cooperation, minimizes conflict, and enhances cooperative learning among university students and instructors working on group projects. Analyzing data collected from 250 students and 150 instructors, the study revealed strong correlations between the use of AI and improvements in cooperation (r = 0.76), communication (r = 0.72), task coordination (r = 0.78), conflict reduction (r = 0.80), and learning outcomes (r = 0.75). These findings highlight the significant potential of AI to optimize group dynamics and enhance the overall quality of cooperative learning experiences[42].

Yeon et al. conducted an experimental study to assess the effects of a chatbot integrated into a messaging application during online teamwork. Participants were divided into three conditions based on communication methods and interfaces: AI Assistant in Chat Room, AI Assistant in Web Page, and Search Engine. Among the 44 participants, perceived helpfulness during the team process varied significantly across the three conditions. Notably, the AI Assistant in Chat Room demonstrated the highest level of perceived helpfulness, underscoring its potential to enhance team interactions in online cooperative learning environments[43].

Msambwa et al. conducted a comprehensive review of 148 articles published between 2021 and 2024, revealing that AI tools significantly enhance personalized learning, assessments, communication, engagement, scaffolding performance, and motivation. Additionally, AI fosters cooperative learning environments by facilitating

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peer-to-peer learning opportunities, enhancing student-content interaction, and providing robust support for collaborative activities[44].

A review of the existing literature indicates that research at the intersection of cooperative learning and AI generally falls into two categories. The first category comprises theoretical discussions that lack empirical application, focusing on how AI can be integrated into cooperative learning environments. The second category explores the impact of AI tools on communication and interaction among group members in online cooperative learning implementations. In this context, the current study distinguishes itself by utilizing AI to develop a novel cooperative learning technique. The incorporation of AI in the creation of unique and tailored learning techniques represents a significant advancement, enabling educators to design specific strategies for particular student groups and topics within their courses.

This research aims to investigate the effectiveness of a novel cooperative learning technique, the Curriculum Concept Constellation Technique (CCCT), developed with the support of artificial intelligence. Specifically, the study examines the impact of CCCT on prospective teachers' academic achievement, co-regulation situations, and attitudes towards cooperativeness within the context of a course titled "Curriculum Development in Education." The research employs a comparative analysis between experimental and control groups and seeks to address the following research questions:

- RQ 1. Is there a statistically significant difference between the pre and post-test scores of prospective teachers in the experimental group regarding their academic achievement?
- RQ 2. Is there a statistically significant difference between the pre and post-test scores of prospective teachers in the control group regarding their academic achievement?
- RQ 3. Is there a statistically significant difference between the post-test scores of prospective teachers in the experimental and control groups regarding their academic achievement?
- RQ 4. Is there a statistically significant difference between the pre and post-survey scores of prospective teachers in the experimental group regarding their co-regulation situations?
- RQ 5. Is there a statistically significant difference between the pre and post-survey scores of prospective teachers in the experimental group regarding their attitudes towards cooperativeness?
- RQ 6. What are the opinions of prospective teachers in the experimental group regarding the implemented cooperative learning technique?

Methodology

Research Design

The current study employed the explanatory sequential mixed-methods design, a prominent approach within mixed-methods research frameworks. In this design, quantitative data were collected first, followed by qualitative data to provide additional insights and explanations that deepen the understanding of the quantitative findings. By integrating both methodologies, this approach capitalizes on the strengths of quantitative and qualitative research while mitigating their respective limitations, thereby enhancing the overall rigor and depth of the research process[45,46].

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During the quantitative part, the study focused on evaluating the impact of the CCCT intervention on the academic achievement, co-regulation situations, and attitudes toward cooperativeness among prospective teachers. To achieve this, a quasi-experimental pre-test and post-test design with a control group was implemented. In the qualitative part, semi-structured interviews were conducted with participants in the experimental group to gather in-depth perceptions and opinions about their experiences with the CCCT intervention. The overall design of the study is summarized in Table 1.

Group	Pre-measure	Experimental procedure	Post-measure	Interview
EG	AT, CS, CLQ	Operation with cooperative CCCT	AT, CS, CLQ	SSI
CG	AT, CS, CLQ	Operation with conventional learning	AT	

EG: Experimental group, CG: Control group, AT: Achievement test, CS: Cooperativeness scale, CLQ: Co-regulated learning questionnaire, SSI: Semi structured interview.

Table 1. The research design.

Participants

The study participants consisted of 67 sophomore students enrolled in the "Curriculum Development in Education" course during the spring semester of the 2024-2025 academic year at Hakkari University's Faculty of Education. These students were drawn from two departments: Primary School Mathematics Teaching (n = 36) and Guidance and Psychological Counseling (n = 31). The Guidance and Psychological Counseling department was randomly assigned as the experimental group, while the Primary School Mathematics Teaching department served as the control group.

In the experimental group, which comprised 31 prospective teachers, 19 were female and 12 were male. Of these participants, 17 reported prior experience with cooperative learning activities, while 14 had no such prior exposure. In the control group, consisting of 36 prospective teachers, 22 were female and 14 were male. Among them, 27 participants had previously engaged in cooperative learning activities during their academic careers, whereas nine had not.

Instruments

Cooperativeness scale. The scale, originally developed by El-Deghaidi and Nouby[47], was adapted into Turkish by Kiper[48]. This scale is designed to measure students' attitudes toward cooperativeness. It is a single-dimensional, five-point Likert-type scale ranging from "strongly disagree" to "strongly agree," and it consists of 20 items (e.g., "An important part of education is learning to get on with others"). Among these, nine items are negatively worded. The internal consistency reliability of the scale, as measured by Cronbach's alpha, was found to be 0.80, indicating strong reliability.

Co-regulated learning questionnaire. The questionnaire, originally developed by DiDonato[49], was adapted into Turkish by Pan and Tanrıseven[50]. This instrument aims to assess student behaviors related to the cooperative regulation of the learning process. The scale is single-dimensional and consists of 19 items (e.g., "In our group, we looked over each other's work to see if we understood what each member was doing"), two of which are negatively worded. The questionnaire employs a four-point Likert scale ranging from "never" to "always." The internal consistency coefficient for this scale was estimated at 0.89, reflecting high reliability.

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Achievement test. The achievement test used in this study served as both the pretest and posttest and consisted of 15 multiple-choice questions. It was prepared by the researcher to cover the topic of "theoretical foundations of curriculum development" within the curriculum development in education course. To ensure content validity, the test was reviewed by two subject-matter experts. The reliability of the test was determined using the Kuder-Richardson 20 internal consistency coefficient, which was estimated as 0.70.

Moreover, the difficulty indices of the test items ranged from 0.12 to 0.93, with an average difficulty level of 0.57. This value aligns closely with the ideal average difficulty level of 0.50 for educational assessments[51].

Semi structured interview form. A semi-structured interview form was developed to gather qualitative data regarding the general opinions of prospective teachers in the experimental group about the cooperative learning technique implemented in the study. The form included four open-ended questions designed to elicit participants' perspectives on the following aspects: (1) What are your thoughts on teaching the curriculum development course using the cooperative learning technique known as Curriculum Concept Constellation?, (2) In your opinion, what are the positive aspects of CCCT?, (3) In your opinion, what are the limitations of CCCT?, (4) What are your suggestions for making the CCCT more effective? These questions aimed to provide a comprehensive understanding of participants' experiences with the technique, including their perceptions of its strengths, challenges, and potential improvements.

Study phases and data collection

The study was conducted in three distinct phases: (1) the development of a new and original cooperative learning technique tailored to the course content and the characteristics of the participating prospective teachers, (2) the implementation of the experimental application, including the administration of pre- and post-measurements, and (3) the conduction of semi-structured interviews with the prospective teachers in the experimental group to gather qualitative insights.

Phase I

In the first phase, efforts were directed toward developing a novel and original cooperative learning technique that aligns with the content of the theoretical foundations of curriculum development in the "Curriculum Development in Education" course and the unique characteristics of the participating prospective teachers. To achieve this, two key documents were prepared and presented to five different artificial intelligence (AI) chatbots (ChatGPT, Copilot, DeepSeek, Gemini, and Qwen). The first document contained detailed information about the course content, including the historical, social, psychological, and philosophical foundations of curriculum development (Supplementary Material 1). The second document provided an overview of cooperative learning, including its definition, features, types of learning groups, key elements that distinguish cooperative learning from other group-based learning methods, and descriptions of widely recognized cooperative learning techniques such as Student Teams Achievement Divisions, Teams-Games-Tournament, Group Investigation, Team-Assisted Individualization, Jigsaw I, Jigsaw II, Think-Pair-Share, and Numbered Heads Together (Supplementary Material 2).

Subsequently, the AI chatbots were informed about the need to develop a new, original, and effective cooperative learning technique. It was emphasized that this technique should make positive contributions to students' academic success, co-regulation situations, and attitudes toward cooperativeness. Additionally, it was

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noted that the newly developed technique would be applied during two-week sessions of the curriculum development course, which is a theoretical course without a practical component. The participants in this course were second-year teacher candidates from the Faculty of Education. Therefore, the AI chatbots were tasked to propose a completely new, original, and effective cooperative learning technique that incorporates the essential elements of cooperative learning and offers a unique approach by examining the information provided in the attached files and considering other cooperative learning techniques in the literature.

Following the generation of proposals from five AI chatbots (Supplementary Material 3), a systematic evaluation was conducted to select the most appropriate technique for experimental implementation. To ensure scientific rigor and transparency in the selection process, the researcher developed an evaluation rubric (Supplementary Material 4) based on four predetermined criteria derived from the study's objectives, the essential elements of cooperative learning, and the specific context of the "Curriculum Development in Education" course:

1. Novelty/distinctiveness: The extent to which the proposed technique differed from existing cooperative learning methods documented in the literature.
2. Alignment with cooperative learning principles: The degree to which the technique incorporated the five essential elements of cooperative learning.
3. Alignment with course context: The suitability of the technique for the theoretical "Curriculum Development in Education" course, including its feasibility within the two-session timeframe and its appropriateness for sophomore-level teacher candidates. Given that this course focuses on abstract foundational concepts (historical, social, psychological, and philosophical foundations of curriculum development) without a practical component, techniques that promoted deep conceptual understanding were prioritized over those emphasizing product creation or practical application.
4. Clarity and practicality: The clarity of the proposed implementation steps and the feasibility of executing the technique within the constraints of the course (e.g., materials, time, class size).

Each proposal was evaluated against these criteria through comparative analysis. The analysis revealed that while all five chatbots generated pedagogically sound proposals incorporating core cooperative learning elements, the techniques proposed by ChatGPT, Copilot, DeepSeek, and Gemini were primarily syntheses or adaptations of existing cooperative learning methods. For instance, DeepSeek's "Curriculum Design Collaborative" combined elements of Group Investigation, Jigsaw, and Think-Pair-Share; Copilot's "Interactive Curriculum Design" similarly integrated familiar structures; Gemini's "Curriculum Design Challenge" was structured around case study analysis with debate components; and ChatGPT's "Curriculum Quest" offered engaging gamification elements and followed a Jigsaw-inspired format with creative presentation techniques. Also, DeepSeek's "Curriculum Design Collaborative" and Copilot's "Interactive Curriculum Design" demonstrated high clarity, but their focus on curriculum design and product creation was less suited to the theoretical nature of the course. Both techniques emphasized practical application over conceptual exploration, making them more appropriate for a curriculum design course than a theoretical foundations course. Gemini's "Curriculum Design Challenge" showed strong alignment with course context through its case study approach, which required students to identify philosophical and theoretical foundations embedded in real-world scenarios. The inclusion of a class debate added unique elements and promoted critical thinking. However, the

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technique required substantial case study preparation and leaned toward application-oriented analysis.

In contrast, Qwen's "Curriculum Concept Constellation Technique (CCCT)" demonstrated substantially greater novelty in several respects. Unlike Jigsaw, which focuses on dividing content among group members, CCCT requires groups to synthesize and connect multiple concepts into a cohesive whole. Unlike Think-Pair-Share, which is discussion-based, CCCT involves a hands-on, visual, and metaphorical task. Unlike STAD or TGT, which emphasize competition and quizzes, CCCT focuses on collaborative creativity and peer exploration. Unlike Group Investigation, which involves extensive research and reporting, CCCT prioritizes conceptual mapping and metaphorical thinking. Moreover, its metaphorical and visual approach – conceptualizing curriculum concepts as "stars" forming "constellations" – represented a fundamental departure from existing cooperative learning paradigms, which typically emphasize research, presentation, problem-solving, or discussion-based formats. Besides, CCCT's focus on conceptual mapping and metaphorical thinking offered a unique mechanism for engaging students with abstract theoretical content, directly addressing the challenge of teaching theoretical courses without practical components. Furthermore, the role structure (Star Finder, Constellation Designer, Metaphor Maker, Visual Artist, Navigator) was specifically designed to foster both individual accountability and creative collaboration in ways that extended beyond traditional role assignments in existing techniques. The two-session structure was clear and practical, requiring only simple materials (canvas, markers, sticky notes). Lastly, the incorporation of a gallery walk for peer feedback, while not entirely novel in itself, was seamlessly integrated with the constellation metaphor to create a cohesive and engaging learning experience. Based on this systematic evaluation, Qwen's CCCT was selected for experimental implementation. A detailed comparative summary of all five proposals is provided in Supplementary Material 3.

It is important to clarify the nature of human-AI interaction in this study. The process was not iterative in the sense of multiple back-and-forth exchanges refining the output. Rather, the AI chatbots were prompted once with comprehensive information about the course context, learning objectives, and cooperative learning principles and techniques. The generated proposals were then systematically evaluated by the researcher using predetermined criteria. Thus, the AI's role is more accurately characterized as "AI-generated" or "AI-assisted generation" rather than "co-design," which implies continuous collaborative refinement. This distinction acknowledges the AI's contribution as a creative generator while recognizing that the selection, adaptation, and implementation decisions remained with the human researcher.

The CCCT is an innovative cooperative learning technique designed to engage students in exploring the theoretical foundations of curriculum development through creativity, visualization, and metaphorical thinking. Below are the general characteristics of the CCCT:

Metaphorical and visual approach. The CCCT uses the metaphor of stars forming constellations in the night sky to represent key concepts in curriculum development. Each concept is treated as a "star," and students work cooperatively to connect these stars into meaningful patterns or "constellations." This visual and metaphorical approach helps students grasp abstract ideas by transforming them into tangible, relatable forms.

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Focus on conceptual mapping. Unlike traditional cooperative learning techniques that emphasize research, presentations, or problem-solving, CCCT prioritizes conceptual mapping. Students identify and connect key concepts (e.g., historical events, philosophical ideas, psychological theories) to explore how they interact and influence one another. The activity encourages students to think critically about relationships between concepts rather than focusing solely on content delivery.

Cooperative and role-based structure. Students work in small, heterogeneous groups of 4-5 members, with each member assigned a specific role to ensure individual accountability and positive interdependence:

Star Finder: Identifies key concepts to include in the constellation.

Constellation Designer: Connects the concepts into coherent patterns.

Metaphor Maker: Creates metaphors to explain relationships between concepts.

Visual Artist: Designs the visual representation of the constellation.

Navigator: Keeps the group on track and resolves conflicts.

This structure ensures that all group members contribute meaningfully to the task.

Creative and playful learning. The technique fosters creative thinking by encouraging students to use metaphors and visual representations to describe relationships between concepts. For example, a concept might be described as the "North Star" guiding other ideas or as a "gravitational force" pulling others toward measurable outcomes. This playful yet intellectually rigorous approach makes learning engaging and enjoyable.

Two-week format. The CCCT is implemented over two weeks:

Week 1: Introduction to the technique, group formation, role assignment, and initial exploration of concepts.

Week 2: Completion of the constellation creation, followed by a gallery walk where students explore and provide feedback on other groups' work. The gallery walk promotes peer interaction and critical reflection on different interpretations of the task.

Reflection and group processing. After completing the constellations, students engage in a reflection activity to discuss what they learned about the relationships between theoretical foundations, how their understanding evolved, and any challenges they faced.

Alignment with cooperative learning principles. The CCCT aligns with key principles of cooperative learning, including:

Positive Interdependence: Groups work together to create a cohesive constellation.

Individual Accountability: Each member has a specific role and responsibility.

Face-to-Face Interaction: Students collaborate closely to refine their ideas.

Development of Social Skills: Roles and group discussions foster organizational and leadership skills.

Distinct from traditional techniques. CCCT stands out from existing cooperative learning methods:

Unlike Jigsaw, which divides content among group members, CCCT requires synthesizing multiple concepts into a cohesive whole.

Unlike Think-Pair-Share, which is discussion-based, CCCT involves hands-on, visual, and metaphorical tasks.

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Unlike Student Teams Achievement Divisions or Teams-Games-Tournament, which emphasize competition and quizzes, CCCT focuses on cooperative creativity and peer exploration.

Unlike Group Investigation, which involves extensive research and reporting, CCCT emphasizes conceptual mapping and metaphorical thinking.

Expected outcomes. Students develop a deeper understanding of the relationships between theoretical foundations of curriculum development. They improve their ability to work effectively in teams and develop positive attitudes toward cooperative learning and the course content. The creative constellations produced by students reflect their unique understanding of the material, showcasing both intellectual rigor and creativity.

Phase II

In the second phase of the study, participants were formally introduced to the research objectives and procedures, and informed consent forms were obtained. During the first week of the implementation, all participants completed a series of pre-measurements, which included the cooperativeness scale, co-regulated learning questionnaire, and an achievement test. Upon analyzing the pre-test and pre-survey results, it was determined that there were no statistically significant differences between the average scores of the two classes (as shown in Table 2). This indicated that the groups were equivalent in terms of initial performance and characteristics, providing a solid foundation for random assignment. Subsequently, the Guidance and Psychological Counseling class was designated as the experimental group, while the Primary School Mathematics Teaching class was assigned as the control group through random selection. To ensure heterogeneity and balance within the cooperative learning groups, the prospective teachers in the experimental group were organized into six heterogeneous teams based on their pre-test and pre-survey results, as well as demographic characteristics such as gender, grade point average (GPA), and prior experience with cooperative learning. This approach aimed to create diverse groups that would foster cooperation and equitable participation. As a result, the experimental group was divided into six cooperative learning teams, with one group consisting of six members and the remaining five groups comprising five members each.

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Variable	**Groups**	***N***	***X***	***SD***	***t***	***p***
Achievement	EG	31	43.39	13.99	0.254	0.800
	CG	36	42.64	10.03		
Co-regulation situations	EG	31	61.32	9.97	0.724	0.472
	CG	36	59.75	7.79		
Attitudes towards cooperativeness	EG	31	68.03	10.63	-1.213	0.229
	CG	36	70.75	7.64		

Table 2. Pre-test results.

In the second week of the study, the experimental group participated in a structured session designed to introduce them to both the course content and the cooperative learning technique to be implemented. The session began with a 20-minute presentation that provided an overview of the course material, focusing on the theoretical foundations of curriculum development. Following this, a brief 20-

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minute briefing was conducted to explain the innovative cooperative learning technique. The metaphor underlying the CCCT was introduced by drawing an analogy between stars forming constellations in the sky and concepts in curriculum development forming interconnected patterns that shape educational practices. Students were informed that their task would involve working collaboratively in groups to create their own "curriculum constellations." Specifically, they were instructed to identify key concepts (referred to as "stars") related to the theoretical foundations of curriculum development and connect these concepts into meaningful patterns (or "constellations"). It was emphasized that the activity was not about presenting findings but rather about cooperatively constructing a visual representation of their collective understanding.

To facilitate this process, the roles (star finder, constellation designer, metaphor maker, visual artist, navigator) that group members could assume were explained in detail. After the roles were clarified, each group distributed the roles among its members. This role allocation process took approximately 20 minutes to complete, ensuring that all group members understood their responsibilities and were prepared to contribute effectively. In the final 40 minutes of the second week's implementation, the task was formally introduced, and initial exploration began. Each group was provided with materials to create their constellation, including a large blank canvas, color markers, sticky notes, scissors, and tape. The task was explained as follows: At least 5-7 key concepts ("stars") related to the theoretical foundations of curriculum development – such as John Dewey's philosophy, behaviorism, societal needs, and developmental psychology – were to be identified. These concepts were to be connected into patterns ("constellations") that represented how they related to one another. Additionally, metaphors were to be used to describe these relationships, such as "Behaviorism is the gravitational force pulling all other ideas toward measurable outcomes." Groups were then allowed to brainstorm initial ideas and divide tasks among members.

In the first 50 minutes of the third week of implementation, the experimental group reconvened to finalize their curriculum constellations. Each group member contributed to the task based on their assigned role, ensuring a collaborative and structured process. The star finder verified that all key concepts were included, while the constellation designer organized these concepts into coherent patterns, emphasizing their interconnections. The metaphor maker enriched the constellation by crafting creative descriptions to explain the relationships between concepts, and the visual artist brought the constellation to life through visually appealing designs. Meanwhile, the navigator ensured that the group stayed on schedule and mediated any challenges that arose during the process. Throughout this session, face-to-face promotive interaction was actively encouraged, as groups engaged in discussions to refine their ideas and ensure the accuracy and creativity of their constellations.

The next 30 minutes were dedicated to a gallery walk and peer feedback activity. All completed constellations were displayed around the classroom, creating an interactive learning environment. During the gallery walk, students moved from one constellation to another, exploring how other groups had interpreted and represented the task. As they examined each other's work, students left sticky notes with questions or comments. For instance, some participants wrote, "The metaphors are very nice, thank you for your effort," while others remarked, "This is the work I enjoyed looking at the most." This activity encouraged students to critically evaluate the relationships and metaphors presented in other groups' constellations, fostering deeper engagement with the course content and promoting peer learning.

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The final 20 minutes of the session were devoted to reflection and group processing. Students were asked to discuss within their groups what they had learned about the relationships between different theoretical foundations of curriculum development. They reflected on how their understanding of the subject had evolved through the activity and considered the broader implications of these connections for educational practices. Additionally, students discussed the challenges they encountered during the process and how they worked collaboratively to overcome them. This reflective discussion not only reinforced their learning but also provided valuable insights into the dynamics of cooperative learning.

In contrast, the control group received instruction through a traditional lecture-based approach. Over the course of two weeks, each consisting of two 50-minute sessions, teaching focused on the theoretical foundations of curriculum development. A presentation was used for each lecture, covering topics such as the historical, social, psychological, and philosophical foundations of curriculum development. Frequent question-and-answer activities were incorporated to encourage prospective teachers to express their opinions and clarify their understanding of the material. These activities also facilitated in-class discussions, allowing students to engage with the content and share their perspectives. To further support learning, supplementary readings on the subject were assigned as homework. Throughout the entire process, both groups were instructed by the same instructor – the researcher conducting the study. This ensured consistency in teaching style and delivery, minimizing potential confounding variables related to instructor differences.

In the fourth week of the study, both the experimental and control groups completed the achievement test as a post-test to measure their understanding of the theoretical foundations of curriculum development. However, due to the nature of the instructional methods employed, the cooperativeness scale and the co-regulated learning questionnaire were administered only to the participants in the experimental group. Since the control group did not engage in any cooperative learning activities during the study, these instruments were not applicable to them.

Phase III

In the third phase of the study, a semi-structured interview protocol was developed to gather in-depth qualitative data from participants regarding their experiences with the CCCT. The interviews were conducted during the fifth week of the research, following the completion of the CCCT intervention. A semi-structured interview form, designed by the researcher, was used to collect detailed feedback on the implementation of the technique. This form aimed to explore four key areas: (1) Participants' overall opinions about the use of CCCT in the curriculum development course, (2) The perceived positive aspects and limitations of the technique, and (3) Suggestions for enhancing the effectiveness of CCCT in future applications.

Seventeen prospective teachers from the experimental group volunteered to participate in the interviews, providing their insights into the cooperative learning experience. These participants were selected based on their willingness to share their perspectives, ensuring that the data collected was both authentic and comprehensive. The interviews lasted approximately 40 minutes and were conducted in a conversational yet structured manner, allowing participants to express their thoughts openly while addressing the specific questions outlined in the interview form. At the conclusion of the interview, participants were asked to submit

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their responses in writing, ensuring that their feedback was accurately documented for analysis.

Data analysis

To determine the appropriate data analysis method for the quantitative data, a normality analysis was initially conducted. The skewness and kurtosis coefficients for each variable were estimated, yielding values ranging from -0.800 to 0.421. Since these coefficients fell within the acceptable range of -1 to +1, it was concluded that the data exhibited a normal distribution[52]. Based on this assumption, parametric tests were deemed suitable for analyzing the quantitative data. For the statistical analysis, an independent samples t-test was employed to compare the mean scores of the experimental and control groups, while a paired samples t-test was used to assess changes between the pre- and post-tests within the experimental group. To evaluate the magnitude of the observed differences, effect sizes were estimated using Hedges' g coefficient[53]. The interpretation of effect sizes was guided by the classification proposed by Cohen et al.[54].

On the other hand, the qualitative data obtained from the semi-structured interviews were analyzed using thematic analysis, a method particularly suited for identifying patterns or themes within qualitative datasets[55]. This approach allowed for flexibility and adaptability to the specific context of the study. The coding process was conducted independently by two coders, one of whom was the researcher. Each question in the interview form was treated as a distinct theme, serving as the initial framework for analysis. The coders read the qualitative data multiple times to ensure familiarity and then assigned codes to segments of the text. Subsequently, peer debriefing meetings were held to refine the coding process and consolidate codes into broader categories. Throughout the analysis, thick and rich descriptions, supported by direct participant quotes, were utilized to substantiate the identified themes.

Ethics approval

Ethics approval (2025/38) was obtained from Hakkari University Scientific Research and Publication Ethics Board. Informed consent was obtained from all participants involved in the study. All research was performed in accordance with relevant guidelines and regulations.

Results

Academic achievement

Table 3 presents the results of paired samples t-tests conducted to compare the mean scores of both the experimental and control groups in the pre-test (X = 43.39, SD = 13.99; X = 42.64, SD = 10.03, respectively) and post-test (X = 51.45, SD = 6.08; X = 43.89, SD = 10.76, respectively) for academic achievement. The results indicate that while both groups demonstrated an increase in mean scores from the pre-test to the post-test, the improvement was statistically significant only for the experimental group (p = 0.005). Furthermore, the effect size analysis revealed a moderate effect size (g = 0.738) for the improvement observed in the experimental group, suggesting a meaningful impact of the intervention on academic achievement. In contrast, the control group exhibited only a weak effect size (g = 0.119), indicating minimal practical significance in their score improvement.

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Group	Academic achievement	*N*	*X*	*SD*	*t*	*p*	*g*
EG	Pre	31	43.39	13.99	-3.008	0.005	0.738
	Post	31	51.45	6.08			
CG	Pre	36	42.64	10.03	-0.510	0.613	0.119
	Post	36	43.89	10.76			

Table 3. Results of the paired samples t-tests for academic achievement.

The comparison of the post-test mean scores between the experimental and control groups revealed that the experimental group (X = 51.45, SD = 6.08) outperformed the control group (X = 43.89, SD = 10.76). This difference was not only evident in the higher mean scores of the experimental group but was also found to be statistically significant (p = 0.001). Moreover, the analysis indicated a moderate effect size (g = 0.839), suggesting that the observed difference between the groups had practical significance (Table 4).

Group	*N*	*X*	*SD*	*t*	*p*	*g*
EG	31	51.45	6.08	3.601	0.001	0.839
CG	36	43.89	10.76			

Table 4. Results of the independent samples t-tests for academic achievement.

Co-regulation status

To assess the change in student behaviors related to the cooperative regulation of the learning process, the mean scores of the prospective teachers in the experimental group on the co-regulated learning questionnaire were compared before and after the implementation of the CCCT (Table 5). The results revealed a statistically significant difference (p = 0.043) between the post-survey mean scores (X = 65.45, SD = 5.21) and the pre-survey mean scores (X = 61.32, SD = 9.97). Additionally, the effect size for this improvement in co-regulation behaviors was found to be moderate (g = 0.512), indicating a meaningful and practically significant shift in the participants' cooperative regulation of the learning process. These findings suggest that the CCCT intervention effectively fostered positive changes in how students collaboratively managed and regulated their learning activities, further underscoring the technique's potential to enhance cooperative learning dynamics.

Co-regulation situations	*N*	*X*	*SD*	*t*	*p*	*g*
Pre	31	61.32	9.97	-2.118	0.043	0.512
Post	31	65.45	5.21			

Table 5. Results of the paired samples t-tests for co-regulation situations.

Attitudes towards cooperativeness

As part of the research, the impact of implementing the CCCT on the attitudes of prospective teachers towards cooperativeness within the experimental group was also investigated. The results, presented in Table 6, reveal a notable increase between the participants' pre-survey mean scores (X = 68.03, SD = 10.63) and post-survey mean scores (X = 75.19, SD = 8.02). This observed increase was found

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to be statistically significant ($p = 0.007$), indicating that the CCCT implementation had a meaningful influence on enhancing participants' attitudes towards cooperativeness. Furthermore, the estimated effect size for this change was moderate ($g = 0.751$), suggesting a substantive practical significance in the positive shift of attitudes among the prospective teachers in the experimental group.

Attitudes towards cooperativeness	***N***	***X***	***SD***	***t***	***p***	***g***
Pre	31	68.03	10.63	-2.908	0.007	0.751
Post	31	75.19	8.02			

Table 6. Results of the paired samples t-tests for attitudes towards cooperativeness.

Qualitative results

A qualitative phase was subsequently undertaken to explore the effects of the implementation of the CCCT in greater depth. Following semi-structured interviews with 17 participants, thematic analysis was conducted to identify patterns and themes that emerged from the data. Five overarching analytical themes were identified: (1) Fostering Student Agency and Accountability, (2) Social Cohesion and Interpersonal Growth, (3) Cognitive and Pedagogical Engagement, (4) Collaborative Learning Dynamics, and (5) Structural and Logistical Challenges. Each theme, along with its constituent codes and illustrative quotes, is presented in Table 7.

A considerable theme that emerged from participants' reflections was the role of CCCT in fostering student agency and accountability. Prospective teachers frequently highlighted how the technique encouraged active participation and instilled a sense of shared responsibility among group members. The structured role assignment within CCCT appeared to be a key mechanism underlying this outcome. As one participant (P7) explained, "I think it provides more active participation than traditional methods because it is a team effort." Another participant (P3) shared this thought, stating, "In my opinion, the positive aspect of this technique is that it encourages shared responsibility." Beyond responsibility, participants also emphasized that CCCT promoted active engagement with the learning process. Unlike traditional lecture-based instruction, where students often assume passive roles, CCCT required each group member to contribute meaningfully to the constellation-building activity. A participant (P1) noted, "Everyone should be assigned an equal share of tasks," highlighting the importance of equitable participation – a suggestion that also pointed to the value participants placed on fair task distribution. Collectively, these reflections suggest that CCCT empowered students to take ownership of their learning while remaining accountable to their peers, thereby fostering both individual and collective agency.

Another remarkable theme centered on the social and relational outcomes of CCCT. Participants consistently reported that the technique brought them closer to classmates with whom they had previously little or no interaction. This theme reflects CCCT's power to break down social divides and foster interpersonal connections within the classroom. One participant (P9) remarked, "This technique brought people together for a purpose and created unity, even if they did not get along." Similarly, another participant (P16) shared, "It strengthened my ability to communicate with individuals I had never interacted with before." The theme of social cohesion also encompassed broader outcomes such as team spirit, trust, and

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classroom integration. A particularly striking reflection came from a participant (P4) who stated, “My perception of classmates, whom I had been with for about two years but had never spoken to – and even held prejudice against – changed positively. This way, I felt the team spirit.” This transformation in interpersonal perceptions underscores the potential of CCCT to foster inclusive learning environments where students feel connected and valued. Additionally, participants appreciated the heterogeneous grouping strategy, with one (P17) noting, “The heterogeneous formation of groups increased both interaction and diversity of activity.” These findings suggest that CCCT not only facilitated academic collaboration but also fostered social connections and mutual understanding among students.

Theme	**Codes**	***f***	**Illustrative Quotes**
Fostering student agency and accountability	· Shared responsibility	6	‘In my opinion, the positive aspect of this technique is that it encourages shared responsibility.’ (P3)
	· Active participation	5	· ‘I think it provides more active participation than traditional methods because it is a team effort.’ (P7)
	· Equal task distribution	4	· ‘Everyone should be assigned an equal share of tasks.’ (P1)
	· Task ownership	3	· ‘Because of the diversity of skills among the individuals in the group, group work has been very successful in uniting as a body and producing a product.’ (P8)
Social cohesion and interpersonal growth	· Bringing people together	8	· ‘This technique brought people together for a purpose and created unity, even if they did not get along.’ (P9)
	· Strengthening communication	6	· ‘The technique had the most positive aspects regarding communication. It strengthened my ability to communicate with individuals I had never interacted with before.’ (P16)
	· Team spirit	5	· ‘My perception of my classmates, whom I had been with for about two years but had never spoken to, and even held prejudice against, changed positively. This way, I felt the team spirit.’ (P4)
	· Integration in the classroom	3	· ‘This learning technique enabled group members to communicate with each other and create an environment of integration.’ (P3)
	· Heterogeneous grouping	2	· ‘The heterogeneous formation of groups increased both interaction and diversity of activity.’ (P17)
	· Trust	1	· ‘It helped me trust others.’ (P6)
Cognitive and pedagogical engagement	· Made the lesson more fun, easy, understandable and productive	5	· ‘When the lesson was conducted with this technique, I actually got more efficiency and it was more fun.’ (P13)
	· Active learning	3	· ‘Active learning took place to understand the subject because it included both interaction and visual elements.’ (P10)
	· Permanent learning	1	· ‘It increased the retention of learning.’ (P6)
	· Holistic learning	1	· ‘It enabled the best use of holistic learning.’ (P8)
	· Showing relationships between concepts	1	· ‘Thanks to the technique, we have analyzed the connection between the concepts.’ (P13)
Collaborative learning dynamics	· Sharing ideas	6	· ‘Allowed everyone to express their own opinions.’ (P1)
	· Unequal contribution	5	· ‘In some cases, only one or two members actively participate, while the rest withdraw, assuming others will handle the task.’ (P10)
	· Intra-group disagreements	4	· ‘When disagreements were not resolved, the group could be negatively affected.’ (P14)
	· Cooperation	3	· ‘We have a better understanding of cooperation and sharing ideas.’ (P15)
	· Motivation	1	· ‘Provided intrinsic motivation.’ (P12)
Structural and logistical challenges	· Implementing more frequently	5	· ‘For the technique to be more effective, it needs to be implemented more frequently.’ (P9)
	· Participants choose own group members	4	· ‘It would have been more effective if we had chosen our own group members.’ (P15)

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	· Spreading over longer period	2	· 'My suggestion is to spread the work over a longer period of time.' (P7)
	· Requires excessive time	1	· 'The fact that it requires too much time could be considered a limitation.' (P6)
	· Not completing tasks on time	1	· 'Some group members failed to complete their tasks on time.' (P5)
	· Reducing group size	1	· 'To reduce the number of members of the group.' (P10)
	· Reminding of responsibilities	1	· 'Members in the groups should be reminded to know their responsibilities and to take ownership of them.' (P13)

Table 7. Themes, codes and illustrative quotes.

Participants also spoke extensively about how CCCT enhanced their cognitive engagement with the course content. The constellation metaphor – treating curriculum concepts as 'stars' that form interconnected patterns – appeared to make abstract theoretical concepts more accessible and memorable through visual representation. One participant (P13) reflected, "When the lesson was conducted with this technique, I actually got more efficiency and it was more fun." Another participant (P10) elaborated on the pedagogical value of the approach, stating, "Active learning took place to understand the subject because it included both interaction and visual elements." Beyond enjoyment and active learning, participants noted that CCCT promoted deeper cognitive processing. The task of identifying key concepts, forming connections, and creating metaphors required students to move beyond superficial understanding and engage in higher-order thinking. A participant (P6) observed, "It increased the retention of learning," while another (P8) emphasized, "It enabled the best use of holistic learning." The constellation metaphor itself served as a cognitive scaffold, helping students visualize and internalize relationships between curriculum theories. As one participant (P13) explained, "Thanks to the technique, we have analyzed the connection between the concepts." These reflections indicate that CCCT successfully combined affective engagement with cognitive rigor, making learning both meaningful and enjoyable.

The fourth theme reflects the multifaceted nature of collaboration within CCCT, encompassing both its strengths and challenges. On the positive side, participants frequently highlighted the technique's capacity to facilitate idea sharing, motivation, and cooperation. A participant (P1) noted, "Allowed everyone to express their own opinions." One participant (P12) reflected, "Provided intrinsic motivation," while another (P15) remarked, "We have a better understanding of cooperation and sharing ideas." These comments reflect the inclusive and participatory approach that CCCT developed within groups. However, participants also openly discussed the challenges inherent in collaborative work. Unequal contribution emerged as a recurring concern, with some group members failing to participate actively. One participant (P10) described this dynamic: "In some cases, only one or two members actively participate, while the rest withdraw, assuming others will handle the task." Intra-group disagreements were also noted as potential obstacles. A participant (P14) explained, "When disagreements were not resolved, the group could be negatively affected."

The final theme encompasses participants' reflections on the structural and logistical aspects of CCCT, including its limitations and suggestions for improvement. Time emerged as a notable constraint, with some participants expressing that more time was needed. One participant (P6) stated, "The fact that it requires too much time could be considered a limitation." Another participant (P5) pointed to issues

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with task completion, noting, “Some group members failed to complete their tasks on time.” Despite these challenges, participants offered several constructive suggestions for enhancing the effectiveness of CCCT. The most frequent recommendation was to implement the technique more frequently throughout the semester. A participant (P9) advised, “For the technique to be more effective, it needs to be implemented more frequently.” Others suggested extending the duration of the activity to allow for deeper exploration and reflection. One participant (P7) recommended, “My suggestion is to spread the work over a longer period of time.” Additional suggestions included allowing students to choose their own group members, reducing group size, and reminding members of their responsibilities. These insights provide valuable guidance for improving future versions of CCCT and highlight participants' views on optimizing the technique to provide the greatest benefit.

Discussion

The present study aimed to investigate the effectiveness of the CCCT, a novel cooperative learning technique developed with the support of artificial intelligence, in enhancing academic achievement, co-regulation situations, and attitudes towards cooperativeness among prospective teachers in a curriculum development course. The findings revealed significant positive outcomes in all three quantitative measures for the experimental group compared to the control group. The qualitative data, organized around five analytical themes – Fostering Student Agency and Accountability, Social Cohesion and Interpersonal Growth, Cognitive and Pedagogical Engagement, Collaborative Learning Dynamics, and Structural and Logistical Challenges – provide explanatory depth, illuminating the processes underlying these quantitative improvements. This discussion synthesizes the quantitative and qualitative findings within the broader context of cooperative learning research and explores practical recommendations for future applications.

One of the most striking findings of this study was the statistically and practically significant improvement in academic achievement observed in the experimental group compared to the control group. The moderate effect size (g = 0.839) underscores the meaningful impact of CCCT on students’ understanding of the theoretical foundations of curriculum development. This finding align with prior research emphasizing the efficacy of cooperative learning techniques in promoting academic success[56-58]. It also aligns with meta-analytic evidence showing that properly structured cooperative learning enhances academic performance more effectively than competitive or individualistic learning[7,59-62].

The qualitative theme of Cognitive and Pedagogical Engagement provides rich explanatory insight into this quantitative outcome. Participants consistently described how CCCT made abstract theoretical content more accessible and memorable. As one participant (P13) reflected, “When the lesson was conducted with this technique, I actually got more efficiency and it was more fun.” Another participant (P10) elaborated, “Active learning took place to understand the subject because it included both interaction and visual elements.” These accounts suggest that the metaphorical and visual approach of CCCT –transforming abstract curriculum concepts into tangible “constellations” – facilitated cognitive processing and conceptual integration, as suggested by constructivist theories of learning[63].

The cognitive benefits described by participants – such as enhanced retention, holistic understanding, and conceptual analysis – align with cognitive elaboration theory, which posits that learners achieve deeper understanding when they explain

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ideas to others and reorganize content in meaningful ways[29]. In CCCT, the requirement to create metaphors and visual representations likely prompted such elaboration. One participant (P13) explicitly noted, “Thanks to the technique, we have analyzed the connection between the concepts,” while another (P6) observed, “It increased the retention of learning.” These reflections indicate that CCCT successfully combined affective engagement with cognitive rigor.

Furthermore, the visual and creative nature of the activity aligns with dual coding theory, which suggests that information processed both verbally and visually is more easily remembered and integrated[64]. The constellation metaphor may have activated verbal and visual dual coding processes, which are argued to significantly enhance memory and comprehension. As one participant (P8) noted, “It enabled the best use of holistic learning,” suggesting that CCCT promoted meaningful learning by encouraging students to see the interconnectedness of concepts rather than treating them as isolated facts. The creative mapping of curriculum concepts into constellations likely promoted meaningful learning, as described by Novak and Cañas, who emphasize the power of concept mapping in organizing and integrating knowledge[65].

The collaborative and role-based structure of CCCT also appears to have increased cognitive engagement – a critical factor in learning[66]. Participants in this study were not passive recipients of information but rather active constructors of knowledge, echoing the constructivist principles of Vygotsky[36] and Piaget[67]. These findings reinforce calls by scholars such as Gillies for the continued development of cooperative strategies that stimulate interaction, critical thinking, and student responsibility[68].

Another key finding pertains to the statistically significant improvement in co-regulated learning behaviors among participants in the experimental group. Co-regulated learning refers to the shared regulation of cognition, behavior, and motivation among learners in group contexts[69]. With a moderate effect size (g = 0.512), CCCT appears to be particularly effective in fostering collaborative regulation of learning processes.

The qualitative theme of Fostering Student Agency and Accountability provides compelling explanatory evidence for this quantitative finding. Participants’ reflections on shared responsibility and active participation resonate with DiDonato’s framework, which posits that structured roles and clear expectations promote co-regulation in group contexts[49]. In CCCT, the assignment of specific roles (e.g., Star Finder, Constellation Designer, and Navigator), appears to have functioned as a structural scaffold that distributed leadership and accountability across group members. As one participant (P7) explained, “I think it provides more active participation than traditional methods because it is a team effort.” Another participant (P3) echoed this sentiment, stating, “The positive aspect of this technique is that it encourages shared responsibility.”

The theme of Collaborative Learning Dynamics further enriches this interpretation. Participants’ positive reflections on idea sharing and cooperation align with the cooperative learning literature’s emphasis on promotive interaction – the face-to-face exchanges through which students encourage and facilitate each other’s efforts[14,15]. One participant (P1) noted, “Allowed everyone to express their own opinions,” while another (P15) remarked, “We have a better understanding of cooperation and sharing ideas.” These comments reflect the inclusive and participatory ethos that CCCT cultivated within groups. These findings are also consistent with those reported by Panadero and Järvelä, who emphasize that

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structured roles enhance group regulatory processes[70]. Furthermore, this result resonates with Hadwin et al., who highlight the critical role of co-regulation in group learning environments, particularly when tasks demand shared cognitive responsibility[71]. The structured roles within CCCT likely contributed to this outcome by promoting distributed leadership and accountability, both of which are known to enhance group regulation[72].

The gallery walk and peer feedback components of CCCT may have further supported co-regulation by encouraging metacognitive reflection and social negotiation – key elements in the development of self- and co-regulatory skills[70]. These findings also align with Moreno et al., who argue that interpersonal regulation is essential in collaborative learning environments[73]. The observed increase in co-regulatory behaviors suggests that the CCCT approach fostered a socially safe environment where learners could negotiate meaning, seek feedback, and collaboratively problem-solve.

However, participants also candidly discussed challenges inherent in collaborative work. Unequal contribution emerged as a recurring concern, with some group members failing to participate actively. One participant (P10) described this dynamic: “In some cases, only one or two members actively participate, while the rest withdraw, assuming others will handle the task.” Intra-group disagreements were also noted as potential obstacles. A participant (P14) explained, “When disagreements were not resolved, the group could be negatively affected.” These findings resonate with Baloche and Brody’s observation that merely placing students in groups does not guarantee effective cooperation[6]. Without ongoing facilitation and attention to group dynamics, even well-structured techniques can be undermined by social loafing or interpersonal conflict.

Although CCCT has implemented different role assignments to prevent this situation, and specifically assigned a ‘navigator’ in each group to keep the group on track and resolve conflicts, the recurrence of concerns about unequal contribution suggests that role assignments are not fully adhered to in some groups and that navigators are not fully fulfilling their duties. This underscores the need for mechanisms of individual accountability that go beyond role assignment, such as peer review or individual reflection components.

The third major finding relates to the statistically significant improvement in participants’ attitudes towards cooperativeness, as evidenced by a moderate effect size ($g = 0.751$). The observed shift aligns with the broader literature suggesting that effective cooperative learning environments not only enhance cognitive outcomes but also foster positive social and affective dispositions[74,75]. The metaphorical and creative nature of CCCT may have contributed to these attitudinal shifts by reducing performance anxiety and encouraging inclusive participation. This echoes findings by Gillies, who noted that cooperative learning environments that emphasize creativity and peer support tend to cultivate more positive attitudes toward collaboration[76]. These findings are particularly noteworthy given the increasing emphasis on socio-emotional learning (SEL) in educational policy and practice. According to Durlak et al., SEL interventions that promote empathy, collaboration, and conflict resolution yield long-term benefits for students’ personal and academic development[77]. By fostering an inclusive environment where every voice is valued, CCCT exemplifies how cooperative learning techniques can contribute to SEL goals.

The qualitative theme of Social Cohesion and Interpersonal Growth provides powerful explanatory depth for this attitudinal shift. Participants repeatedly

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described how CCCT transformed their relationships with classmates, bridging social divides and fostering communication among students who had previously little interaction. One participant (P9) remarked, “This technique brought people together for a purpose and created unity, even if they did not get along.” Similarly, another participant (P16) shared, “It strengthened my ability to communicate with individuals I had never interacted with before.” A particularly powerful reflection came from a participant (P4) who stated, “My perception of classmates, whom I had been with for nearly two years but had never spoken to – and even held prejudice against – changed positively. This way, I felt the team spirit.” These reflections align closely with the foundational principles of social interdependence theory, which posits that positive interdependence among group members fosters interpersonal attraction and motivates individuals to support one another[78,79]. The participants’ experiences highlights how CCCT facilitated a shift in perceptions and attitudes, cultivating a sense of unity and shared purpose among group members.

Furthermore, participants’ qualitative feedback emphasized the role of CCCT in building trust, promoting shared responsibility, and enhancing interpersonal harmony – outcomes that are central to the social cohesion theory of cooperative learning[29]. These findings suggest that CCCT not only supports cognitive and regulatory processes but also strengthens the socio-emotional dynamics within collaborative groups. By fostering an environment where learners feel connected and accountable to one another, CCCT appears to address both the academic and relational dimensions of cooperative learning. Such insights underscore the importance of designing instructional approaches that integrate structured collaboration with opportunities for meaningful interpersonal interaction, thereby enhancing both individual and collective learning outcomes.

The qualitative theme of Structural and Logistical Challenges offers valuable practical insights for refining CCCT and similar cooperative learning techniques. Participants’ concerns about time constraints reflect a broader tension in educational practice between the depth of engagement that active learning requires and the coverage demands of packed curricula. One participant (P6) stated, “The fact that it requires too much time could be considered a limitation.” Another participant (P5) pointed to issues with task completion, noting, “Some group members failed to complete their tasks on time.” This challenge is not unique to CCCT; as Hattie’s synthesis of educational research indicates, many effective instructional strategies require substantial time investments to yield meaningful learning gains[34].

Participants’ suggestions for improvement offer constructive guidance for future implementations. The most frequent recommendation was to implement the technique more frequently throughout the semester. A participant (P9) advised, “For the technique to be more effective, it needs to be implemented more frequently.” Others suggested extending the duration of the activity to allow for deeper exploration and reflection. One participant (P7) recommended, “My suggestion is to spread the work over a longer period of time.” These recommendations align with research on the importance of repeated practice in developing cooperative skills. Johnson and Johnson argue that cooperative learning is not a one-time activity but rather a sustained approach that requires ongoing implementation and refinement[17]. By recommending that CCCT be integrated more fully throughout the semester, participants intuitively recognized that the full benefits of cooperative learning emerge over time as students develop trust, refine their collaboration skills, and internalize shared norms.

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This study represents one of the first empirical investigations into the use of artificial intelligence as a generative tool in the development of cooperative learning techniques, marking a significant departure from prior research that has predominantly focused on AI's role in implementing established methods, such as intelligent tutoring systems[80]. By employing a single-prompt generation approach followed by systematic human evaluation, this study offers novel insights into how AI-generated instructional designs can be effectively integrated into educational practice.

A distinguishing contribution of this research lies in its use of AI not merely as a support tool but as an active partner in instructional design. While previous studies have demonstrated AI's potential to facilitate communication and collaboration within learning environments[42,43], the present study advances this discourse by employing AI in the ideation and construction of an original cooperative learning methodology. This approach aligns with Sheoran and Kaur's assertion that AI can extend beyond personalization to support the generation of pedagogically sound and contextually responsive innovations[40].

The CCCT exemplifies the creative potential of AI in education through its integration of cooperative learning principles with metaphorical visualization, as reflected in the constellation metaphor conceived through AI support. This design reflects AI's ability to synthesize educational theory with imaginative instructional approaches. By involving conversational AI tools in the design process, the study also echoes Martens' suggestion that such technologies can serve as catalysts for pedagogical creativity and innovation[41]. In contrast to traditional models, CCCT introduces a novel modality of cooperative learning based on conceptual interconnection and metaphorical representation. This advancement supports the view of Baloche and Brody, who argue that the continued evolution of cooperative learning must respond to changing educational demands and technological advancements[6].

Moreover, the integration of multiple AI models to iteratively generate and refine the technique illustrates a productive synergy between human educators and intelligent systems – a direction endorsed by Holmes et al.[38] and Sheoran and Kaur[40]. The ability of AI to customize the technique according to specific course content and learner profiles further demonstrates its alignment with the principles of personalized and adaptive learning. As such, the methodology adopted in this study may serve as a model for future innovations in instructional design, where AI not only supports but actively shapes educational practices in collaboration with educators.

The choice of a lecture-based control group warrants further elaboration. Some readers may question why this study did not compare CCCT to an existing cooperative learning technique, given the extensive evidence base supporting cooperative learning's efficacy. This decision was guided in line with the study's objective: to investigate whether artificial intelligence can create a novel, pedagogically sound cooperative learning technique from scratch. Before subjecting an AI-generated technique to the "gold standard" comparison with established methods, it was necessary to establish that the technique produces meaningful learning gains relative to the instructional status quo (i.e., lecture-based teaching) within the specific course context. The moderate effect sizes observed (g = 0.512–0.839) provide encouraging evidence that AI-generated techniques can be effective, warranting further investigation. The next logical step is to conduct comparative studies pitting CCCT against well-established cooperative learning methods. Such

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research would clarify whether the metaphorical and visual elements of CCCT offer unique cognitive or motivational advantages, or whether its effectiveness is attributable to the general principles of cooperative learning that it shares with other techniques.

Implications

The findings of this study yield important implications for both educational practice and theory. Practically, the CCCT offers a viable and replicable model for implementing cooperative learning in higher education, particularly within teacher education programs. With its structured roles, visual outputs, and reflective components, CCCT provides a comprehensive scaffold that fosters meaningful collaboration and deep learning. Furthermore, the technique demonstrates particular promise in theoretical, non-practical courses where fostering student engagement can be especially challenging.

The positive outcomes associated with CCCT also underscore its value as a pedagogical model for prospective teachers. By participating in cooperative learning as students, teacher candidates are better prepared to implement similar strategies in their future classrooms, thereby promoting a cycle of collaborative teaching and learning.

The study further highlights the transformative potential of artificial intelligence in the field of educational innovation. Artificial intelligence can function as a generative tool in developing pedagogical tools that are not only theoretically sound but also contextually relevant. When provided with comprehensive contextual information and clear pedagogical parameters, AI can generate novel instructional designs that human educators can then evaluate, adapt, and implement. This human-AI collaborative model – where AI handles creative generation and humans provide pedagogical expertise and contextual judgment – offers an efficient and scalable approach to instructional innovation.

From a theoretical perspective, this research contributes to the growing body of literature at the intersection of artificial intelligence and education. It provides empirical support for established theories of cooperative learning, self-regulation, and constructivist pedagogy, while simultaneously opening new avenues for research in AI-assisted instructional design. Future studies should investigate the effectiveness and scalability of AI-generated techniques like CCCT across diverse educational levels, disciplines, and student populations, further advancing understanding in this emerging field.

Limitations and future directions

Despite the promising findings, several limitations should be acknowledged. First, the study was conducted with a relatively small sample drawn from two departments within a single university, which may limit the generalizability of the results. Expanding future research to include more diverse and larger samples across multiple institutions would enhance the external validity of the findings.

Second, the study utilized two pre-existing intact classes from different academic disciplines – Guidance and Psychological Counseling and Primary School Mathematics Teaching. While statistical equivalence on pre-test measures supports the comparability of the groups in terms of baseline knowledge and dispositions, unmeasured disciplinary differences may have influenced the outcomes. Counseling students, by virtue of their training, may possess greater natural inclination toward metaphorical thinking, interpersonal communication, and reflective practices – all of which align closely with the CCCT's emphasis on metaphor creation, social

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cohesion, and collaborative meaning-making. In contrast, mathematics education students may be more accustomed to logical, sequential, and individual problem-solving approaches. Consequently, the observed effectiveness of CCCT may be partially attributable to the congruence between the technique's metaphorical-social orientation and the experimental group's disciplinary predispositions, rather than solely to the technique's universal pedagogical value. Future research should replicate this study with more comparable groups (e.g., two sections of the same department) or employ crossover designs to control for disciplinary effects.

Third, the study employed a traditional lecture-based instructional approach as the control condition rather than an established cooperative learning technique. As the extensive cooperative learning literature has already established the superiority of well-structured cooperative learning over traditional lecture-based instruction[7,59-62], this design choice limits the strength of the claims that can be made about CCCT's unique effectiveness. The finding that CCCT outperformed lectures is consistent with decades of prior research and does not, by itself, demonstrate that CCCT is superior to existing cooperative learning methods. However, the primary contribution of this study lies not in demonstrating that cooperation works, but in illustrating that artificial intelligence can successfully generate a pedagogically sound, novel cooperative learning technique that incorporates all five essential elements of cooperative learning[14,15] and produces meaningful learning gains. The lecture control served to establish baseline effectiveness within the specific context of this course and participant population, providing evidence that the AI-generated technique is at least as effective as conventional instruction – a necessary first step before undertaking more rigorous comparisons with established CL methods. Future research should directly compare CCCT to well-validated cooperative learning techniques to determine whether its metaphorical and visual approach offers additive benefits beyond existing methods.

Fourth, the brief duration of the intervention raises the possibility that the observed positive outcomes may be partially attributable to the novelty effect – the tendency for participants to respond positively to new or unfamiliar instructional approaches simply because they represent a break from routine[81]. While the moderate effect sizes and rich qualitative data suggest genuine learning gains, it is impossible to rule out the contribution of novelty, particularly given that many participants explicitly noted that CCCT made the lesson "more fun" and "more enjoyable" (P13). Longitudinal studies tracking students across multiple implementations of CCCT throughout a semester or academic year are needed to determine whether the observed gains are sustained and whether they translate into durable competency development.

Fifth, this study did not employ a formal systematic literature review (e.g., PRISMA guidelines) or bibliometric analysis to empirically establish a pedagogical gap justifying the development of a new cooperative learning technique. While the existing cooperative learning literature documents numerous well-validated techniques, and while the course's theoretical nature suggested a need for approaches emphasizing conceptual understanding, the decision to develop CCCT was guided primarily by the researcher's pedagogical judgment and the affordances of AI-generated ideation rather than by a comprehensive, data-driven analysis of gaps in the literature. Consequently, the claim that CCCT addresses a specific, previously unmet need in cooperative learning should be interpreted with caution. Future research should undertake systematic reviews to more rigorously map the landscape of cooperative learning techniques for theoretical courses in teacher

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education, thereby providing an empirical foundation for determining whether genuinely novel approaches are needed and what design features they should incorporate.

Another limitation concerns the reliance on self-reported qualitative data, which, while rich in insight, may be subject to social desirability bias. Future research could incorporate observational or performance-based measures to triangulate findings and provide a more comprehensive evaluation of CCCT's impact.

In terms of future directions, researchers could explore the applicability of CCCT across different educational contexts and disciplinary domains. Examining its influence on additional constructs such as creativity, critical thinking, and classroom climate would further clarify its pedagogical value. Moreover, investigating the implementation of CCCT in collectivist versus individualist educational cultures may yield valuable cross-cultural perspectives.

Conclusion

This study makes several important contributions to the field of educational research. First, it provides robust empirical evidence supporting the effectiveness of the CCCT, a novel cooperative learning method that integrates metaphorical thinking, visual mapping, and structured role-based collaboration. The findings demonstrate that such carefully designed cooperative strategies can facilitate the learning of abstract theoretical content, thereby addressing a longstanding pedagogical challenge noted in the literature[82].

Second, the study underscores the value of AI as an emerging tool in pedagogical innovation, extending the work of Holmes et al. by illustrating how artificial intelligence can be leveraged to design learning environments that are both engaging and effective[38]. While the role of AI is shown to be promising, the study also highlights the continued necessity of human oversight in guiding and contextualizing its use in education.

In sum, the CCCT represents a significant advancement in cooperative learning by combining AI-supported design with pedagogical principles aligned to future-oriented education. Its demonstrated effectiveness in improving academic performance, co-regulation, and attitudes toward cooperation positions it as a valuable tool for educators. By leveraging AI to address longstanding challenges in cooperative learning, CCCT exemplifies how technological advancements can enrich educational practices. Moving forward, researchers and practitioners must collaborate to refine and expand the application of AI-driven pedagogical innovations, ensuring that education remains inclusive, dynamic, and future-oriented.

Data availability

Data is available upon reasonable request made to the corresponding author.

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