Качество обучения в высших учебных заведениях в условиях распространения гибридных систем «человек — искусственный интеллект»: подход с позиции эпистемической регуляции

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АННОТАЦИЯ

Введение. Стремительное внедрение генеративного искусственного интеллекта (ИИ) в высшее образование сделало проблему сохранения качества обучения в условиях технологической опосредованности образовательного процесса более актуальной. Системы ИИ расширяют доступ студентов к информации и поддерживают конструирование знаний, однако их использование сопровождается рисками снижения когнитивной вовлечённости, чрезмерной опоры на автоматизированные ответы и смещения акцента с понимания на выполнение заданий. *Целью исследования* является разработка концептуальной модели, объясняющей роль эпистемической регуляции в поддержании качества обучения в гибридных системах человек-ИИ.

Материалы и методы. Исследование выполнено на основе интегративного анализа литературы и последующего теоретического синтеза. Анализ охватывал исследования генеративного ИИ в образовании, саморегулируемого обучения, метакогниции, распределённого познания, гибридного интеллекта и взаимодействия человека с ИИ. На этом этапе были сопоставлены подходы к пониманию влияния генеративного ИИ на качество обучения, гибридизацию учебной деятельности и распределение когнитивных функций между студентом и ИИ. На втором этапе был проведён теоретический синтез, позволивший выделить эпистемическую регуляцию как механизм поддержания качества обучения.

Результаты. Интегративный анализ показал, что генеративный ИИ трансформирует обучение не только как средство доступа к информации, но и как участник создания, переформулирования и структурирования учебного содержания. В этих условиях образовательная деятельность приобретает признаки гибридной и распределённой, а классические модели саморегулируемого обучения и метакогниции оказываются недостаточными для описания контроля над знанием, возникающим во взаимодействии с ИИ. Предложена концептуальная модель, в которой генеративный ИИ создаёт образовательные возможности и эпистемические риски, а эпистемическая регуляция обеспечивает контроль над статусом знания. Её функции включают оценку, верификацию, сравнение, калибровку доверия, структурирование взаимодействия и ответственность за итоговую позицию. Модель разграничивает эпистемическую и метакогнитивную регуляцию и описывает шесть уровней её развития.

Заключение. Качество обучения в гибридных образовательных системах человек-ИИ зависит не от самого факта использования генеративного ИИ, а от способности студентов сохранять эпистемический контроль над распределённым конструированием знания. Предложенная модель создаёт основу для проектирования учебных заданий, поддерживающих верификацию, критическую оценку, рефлексию и ответственное авторство в ИИ-опосредованном обучении.

КЛЮЧЕВЫЕ СЛОВА

качество обучения, эпистемическая регуляция, генеративный искусственный интеллект, гибридные образовательные системы человек-ИИ, саморегулируемое обучение, метакогниции, высшее образование

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Learning Quality in Higher Education within Hybrid Human-AI Systems: An Epistemic Regulation Approach

A. N. VORONIN, V. V. PALENOVA

ABSTRACT

Introduction. The rapid implementation of generative artificial intelligence (AI) in higher education has intensified the problem of maintaining learning quality under conditions of technological mediation of the educational process. AI systems expand students' access to information and support knowledge construction; however, their use is accompanied by risks of reduced cognitive engagement, overreliance on automated responses, and a shift from understanding to task completion. The aim of the study was to develop a conceptual model explaining the role of epistemic regulation in maintaining learning quality in hybrid human-AI systems.

Materials and Methods. The study was based on an integrative analysis of literature and theoretical synthesis. The analysis covered research on generative AI in education, self-regulated learning, metacognition, distributed cognition, hybrid intelligence, and human-AI interaction. At the first stage, approaches to understanding the influence of generative AI on learning quality, the hybridization of learning activity, and the distribution of cognitive functions between the student and AI were compared. At the second stage, theoretical synthesis was conducted, which made it possible to identify epistemic regulation as a mechanism for maintaining learning quality.

Results. The integrative analysis showed that generative AI transforms learning not only as a means of access to information, but also as a participant in the production, reformulation, and structuring of educational content. Under these conditions, educational activity acquires hybrid and distributed characteristics, while classical models of self-regulated learning and metacognition prove insufficient for describing control over knowledge emerging in interaction with AI. A conceptual model is proposed in which generative AI creates both educational opportunities and epistemic risks, while epistemic regulation ensures control over the status of knowledge. Its functions include evaluation, verification, comparison, trust calibration, interaction structuring, and responsibility for the final position. The model distinguishes epistemic regulation from metacognitive regulation and describes six levels of its development.

Conclusion. Learning quality in hybrid human-AI educational systems depends not on the mere use of generative AI, but on students' ability to preserve epistemic control over distributed knowledge construction. The proposed model provides a basis for designing learning tasks that support verification, critical evaluation, reflection, and responsible authorship in AI-mediated learning.

KEYWORDS

learning quality, epistemic regulation, generative artificial intelligence, hybrid human-AI educational systems, self-regulated learning, metacognition, higher education

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INTRODUCTION

The rapid development of artificial intelligence (AI), especially generative AI, has become a major issue in international educational policy. The European Commission's ethical guidelines emphasize that the use of AI and data in teaching and learning should be grounded in transparency, human oversight, fairness, and pedagogical responsibility [1]. UNESCO's policy guidance on AI and education similarly frames AI not merely as a technological innovation, but as a challenge for educational governance, inclusion, equity, and the preservation of human-centered learning [2]. More specifically, UNESCO's guidance on generative AI in education and research highlights the need to preserve human agency, ensure responsible pedagogical use, and regulate AI applications in educational settings [3]. In higher education, these international policy orientations raise fundamental questions concerning meaningful learning, students' intellectual autonomy, and the quality of knowledge construction under conditions of increasing technological mediation.

Recent research shows that generative AI is transforming learning practices in higher education. Crompton and Burke's review of the field demonstrates that AI is increasingly used across higher education for teaching support, learning assistance, feedback, assessment, and personalization [4]. Dwivedi et al. discuss ChatGPT and related conversational AI systems as technologies that can support writing, idea generation, explanation, and knowledge work, while also raising practical and ethical challenges for education and research [5]. Earlier work by Holmes, Bialik, and Fadel similarly emphasized the pedagogical potential of AI for adaptive learning, scaffolding, and individualized support, while warning that these opportunities require careful educational design [6]. At the same time, the educational effects of generative AI remain ambivalent. Kizilcec argues that advancing AI use in education requires closer attention to how educators and learners actually understand and appropriate AI systems, rather than assuming that technological availability automatically improves learning [7]. Tlili et al., using ChatGPT as a case study, show that chatbots may support learning but may also produce unreliable responses, encourage dependency, and create new challenges for assessment and academic integrity [8]. Yusuf, Pervin, and Román-González further demonstrate that generative AI in higher education is associated with both reformative potential and threats related to academic integrity, overreliance, and the transformation of student learning practices [9]. Thus, the key issue is not whether AI is used in higher education, but how students interact with it and whether this interaction supports or weakens learning

Generative AI also changes the structure of students' productive and creative activity. Unlike traditional digital tools that mainly provide access to information, learning materials, or predefined feedback, generative AI participates in the production and transformation of educational content itself. It generates ideas, proposes alternative framings, reformulates questions, structures arguments, and offers possible solutions. As a result, learning acquires features of hybrid and distributed creativity, in which cognitive and productive functions are distributed between the student and the AI system.

This transformation makes classical approaches to learning regulation both relevant and insufficient. In the theory of self-regulated learning, students are understood as active subjects who set learning goals, select strategies, monitor their actions, control their progress, and evaluate learning outcomes [10]. These processes remain essential, but interaction with generative AI introduces an additional regulatory layer. Students must control not only their own learning strategies and understanding, but also the epistemic status of knowledge produced in interaction with an external generative system: its accuracy, relevance, justification, applicability, and consistency with disciplinary standards.

This reveals a theoretical gap in the analysis of learning quality in AI-mediated higher education. Existing research has described the opportunities and risks of generative AI in education and emphasized the importance of self-regulated and metacognitive learning. However, less attention has been paid to the mechanisms through which students evaluate, verify, compare, refine, and take responsibility for knowledge generated in hybrid human-AI interaction. Therefore, the question of how learning quality is maintained under conditions of distributed knowledge production remains conceptually underdeveloped.

To address this gap, the article pursues two interrelated objectives. The first objective is to conduct an integrative analysis of literature on generative AI in higher education, hybrid human-AI learning activity, distributed creativity, self-regulated learning, metacognition, and regulatory

challenges. This analysis clarifies why AI-mediated learning cannot be adequately understood either as simple tool use or only through classical models of individual learning regulation.
The second objective is to develop a theoretical synthesis in the form of a conceptual model of epistemic regulation. This model explains how generative AI contributes to hybrid and distributed creativity, how this creates epistemic risks, and how epistemic regulation supports learning quality by enabling students to evaluate, verify, compare, refine, and take responsibility for knowledge produced in interaction with AI.

Within this framework, epistemic regulation is understood as a mechanism that enables students to maintain control over the epistemic status of knowledge emerging in interaction with AI: its reliability, justification, relevance, applicability, and consistency with disciplinary standards. The article therefore conceptualizes AI-mediated learning not simply as the use of a digital tool, but as a regulated educational process in which students preserve epistemic agency and responsibility for knowledge construction.

MATERIALS AND METHODS

The article is designed as a conceptual study based on an integrative analysis of literature and theoretical synthesis. This design was chosen because the research problem concerns not the measurement of a single empirical effect, but the conceptual clarification of how learning quality can be maintained in higher education under conditions of generative AI use and distributed human-AI knowledge production.

The material for analysis included publications from several interrelated research fields: generative AI in higher education, self-regulated learning and metacognition, distributed cognition, hybrid intelligence, human-AI interaction, epistemic cognition, and creativity in AI-mediated environments. Special attention was paid to studies addressing learning processes, learner agency, cognitive engagement, trust, verification, regulation, authorship, and the risks of overreliance on AI-generated outputs.

The study did not follow the logic of an exhaustive systematic review. Instead, it used an integrative conceptual strategy aimed at identifying, comparing, and synthesizing theoretical constructs relevant to AI-mediated learning quality. This approach is appropriate when heterogeneous theoretical and empirical findings need to be organized into a new explanatory framework [11; 12].

The analytical procedure included two main stages. At the first stage, an integrative analysis of literature was conducted in order to clarify the relationship between generative AI, hybrid human-AI learning activity, distributed creativity, epistemic risks, and the limits of classical regulatory models. The results of this stage are presented in Section 3.1. At the second stage, theoretical synthesis was used to distinguish epistemic regulation as a construct that extends self-regulated learning and metacognitive regulation under conditions of distributed knowledge production. This synthesis provided the basis for the conceptual model presented in Section 3.2.

RESULTS

1. Generative AI, Hybrid Learning Activity, and Regulatory Challenges

Generative artificial intelligence can be regarded as one of the key factors transforming higher education because it changes not only access to information, but also the production, transformation, and evaluation of learning content. In contrast to earlier digital tools that mainly provided access to prepared information, learning materials, communication, assessment, or predefined feedback, generative AI systems produce textual, conceptual, and argumentative responses to learners' prompts. Crompton and Burke show that AI is increasingly used in higher education for learning support, feedback, assessment, and personalization, while Dwivedi et al. emphasize the role of ChatGPT and related systems in writing, explanation, idea generation, and academic knowledge work [4; 5]. Holmes et al. similarly describe AI as a means of scaffolding and individualized support, provided that its use is embedded in appropriate pedagogical design [6]. Thus, AI use shifts from information support toward participation in explanation, argumentation, drafting, and iterative refinement of academic work. The educational potential of generative AI is therefore connected

with idea generation, scaffolding, personalization, exploratory learning, clarification of concepts, comparison of perspectives, and the structuring of arguments [8; 13]. At the same time, these opportunities require responsible pedagogical integration, preservation of human agency, and attention to the quality, integrity, and safety of learning processes, as emphasized in UNESCO's guidance on generative AI in education and research [3].

The use of generative AI also requires distinguishing ordinary digital tools from hybrid human-AI educational systems. Traditional educational technologies may organize access to content or support communication and assessment, but they do not substantially participate in the production, transformation, or reframing of educational content. Large language models change this relation: they do not merely deliver information, but generate responses, propose interpretations, reformulate questions, structure reasoning, and offer alternative approaches to a task. Educational activity becomes hybrid when cognitive and epistemic functions are distributed between the student and the AI system: the student initiates, evaluates, selects, and takes responsibility, while AI generates, reformulates, expands, and structures possible content. This interpretation corresponds to theories of distributed cognition, according to which cognitive processes may be distributed across individuals, artifacts, representational systems, and technological environments [14; 15]. It is also close to the concept of hybrid intelligence, which emphasizes complementary interaction between human and artificial intelligence rather than the replacement of human cognition by machine performance [16]. From this perspective, the defining feature of a hybrid educational system is not the presence of AI itself, but the organization of interaction between human and artificial components.

In higher education, this distinction is especially important because many learning tasks are open-ended, knowledge-intensive, and productive in nature. Students are expected not only to reproduce information, but also to formulate questions, compare explanations, construct arguments, justify positions, and produce academic texts. When generative AI participates in these processes, the boundary between the student's own cognitive activity and the system's contribution becomes less clear. For this reason, learning with generative AI may acquire features of hybrid and distributed creativity. Glăveanu conceptualizes distributed creativity as a process that is not confined to the individual mind, but emerges through interaction among people, artifacts, symbolic resources, and environments [17]. In the context of AI, Grilli and Pedota emphasize that creativity should be analyzed at multiple levels, including human-AI interaction, while Vinchon et al. argue for a collaborative view of artificial intelligence and creativity [18; 20]. Empirical work on student-AI collaborative creative problem-solving further shows that human agency remains central when AI participates in creative tasks [19]. Accordingly, hybrid creativity should be understood not only as the joint production of outputs, but also as the distribution of generative, evaluative, and problem-framing functions between the learner and the AI system.

This distribution also affects problem genesis: the educational problem, question, or task framing may be progressively clarified and reformulated through interaction with AI, rather than being fully defined before the interaction begins. Dorst and Cross describe creative work as a co-evolution of problem and solution spaces, where understanding of the problem changes as possible solutions are explored [21]. Getzels and Csikszentmihalyi emphasize problem finding as a central component of creative activity, showing that the way a problem is discovered and formulated influences subsequent creative outcomes [22]. Reiter-Palmon and Robinson define problem identification and construction as key processes that shape later problem-solving and creative performance [23]. Reiter-Palmon et al. further show that problem construction depends on ability, cue interpretation, and active processing, which makes the framing of the task itself a meaningful part of creative work [24]. In this sense, problem identification and construction become part of AI-mediated learning, since the quality of later solutions depends on how students recognize, frame, and reformulate the problem before accepting or developing AI-generated responses.

In educational contexts, however, hybrid and distributed creativity should not be reduced to the production of original outputs. Its pedagogical value lies in expanding possible interpretations, comparing alternative framings, reorganizing understanding, and supporting the development of grounded academic positions. Generative AI may stimulate divergent thinking and offer multiple variants of explanation or argumentation, but the educational value of these outputs depends on the student's ability to evaluate, select, transform, and justify them. Without such regulation, hybrid creativity may become a mechanical accumulation of AI-generated variants rather than a meaningful learning process. This is especially important because academic learning requires epistemically

responsible creativity: ideas, interpretations, and arguments should be not only original or fluent, but also grounded, coherent, relevant, and justified. Grilli and Pedota show that AI-related creativity should be analyzed at multiple levels, including the interaction between human and artificial agents, while Vinchon et al. argue that AI creativity should be understood through collaboration rather than simple replacement of human creativity [18; 20]. At the same time, Runco warns that AI-generated novelty should not be equated with human creativity, since it raises specific questions about authorship, originality, evaluation, and the human role in creative activity [25].

The ambivalence of generative AI is therefore directly related to learning quality. Students may accept AI-generated outputs as ready-made answers, rely on plausible but inaccurate responses, reduce their own cognitive effort, or shift from understanding to task completion [7; 9]. In such cases, AI may improve the production of learning outputs while weakening conceptual understanding, argumentation, critical evaluation, and responsibility for knowledge claims. Consequently, learning quality depends not on the mere availability of AI, but on whether students can regulate their interaction with it in ways that preserve understanding, agency, and epistemic responsibility.

This creates a regulatory challenge that cannot be fully described by classical models of self-regulated learning and metacognition. In self-regulated learning, students are viewed as active participants who set goals, choose strategies, monitor progress, control their actions, and evaluate learning outcomes [10; 26]. Metacognitive models similarly emphasize monitoring and control: learners monitor their knowledge, comprehension, and confidence and use this information to regulate cognitive activity [27]. These processes remain indispensable for AI-mediated learning, but they are not sufficient. Interaction with generative AI requires students to regulate not only their own goals, strategies, comprehension, and progress, but also the epistemic status of AI-generated outputs. Students must ask not only "Do I understand this?" or "Have I completed the task?", but also "Can this information be trusted?", "What are its grounds?", "What assumptions does it contain?", "Does it correspond to disciplinary knowledge?", and "What part of the final answer is my own justified position?"

Thus, the integration of generative AI into higher education requires a shift from regulating individual learning activity to regulating knowledge construction in hybrid human-AI systems. Metacognitive regulation concerns the learner's control over their own learning processes, whereas epistemic regulation concerns control over the status of knowledge emerging in interaction with AI. It includes evaluating the accuracy and relevance of AI-generated content, verifying claims, comparing alternative formulations, calibrating trust, identifying assumptions, and taking responsibility for the final interpretation or solution. This shift forms the basis for the conceptual model proposed in the following section: generative AI contributes to hybrid and distributed creativity, this creates epistemic risks, and epistemic regulation becomes a condition for maintaining learning quality in higher education.

2. Conceptual Model of Epistemic Regulation

The proposed model explains learning quality in higher education as the result of regulated interaction within hybrid human-AI educational systems. Its logic can be summarized as follows: generative AI in learning → hybrid and distributed creativity → epistemic risks → epistemic regulation → learning quality. Generative AI expands students' productive activity by generating ideas, explanations, arguments, alternative formulations, and draft texts. This makes learning more hybrid and distributed, but also creates risks of overreliance, superficial acceptance, reduced autonomy, and blurred responsibility. Epistemic regulation is introduced as the mechanism that allows students to maintain control over knowledge produced in interaction with AI. The overall structure of the proposed model is presented in Figure 1.

Generative AI expands students' productive activity and contributes to hybrid and distributed creativity, but also creates epistemic risks. Epistemic regulation functions as the key mechanism through which students evaluate, verify, compare, and refine AI-generated knowledge, thereby maintaining learning quality.

Building on the preceding analysis, the model defines a hybrid human-AI educational system as a configuration in which cognitive and epistemic functions are distributed between the student and the AI system. The student initiates, evaluates, selects, and takes responsibility, while AI generates, reformulates, expands, and structures possible content. The main differences between traditional digital tools and hybrid human-AI educational systems are summarized in Table 1.

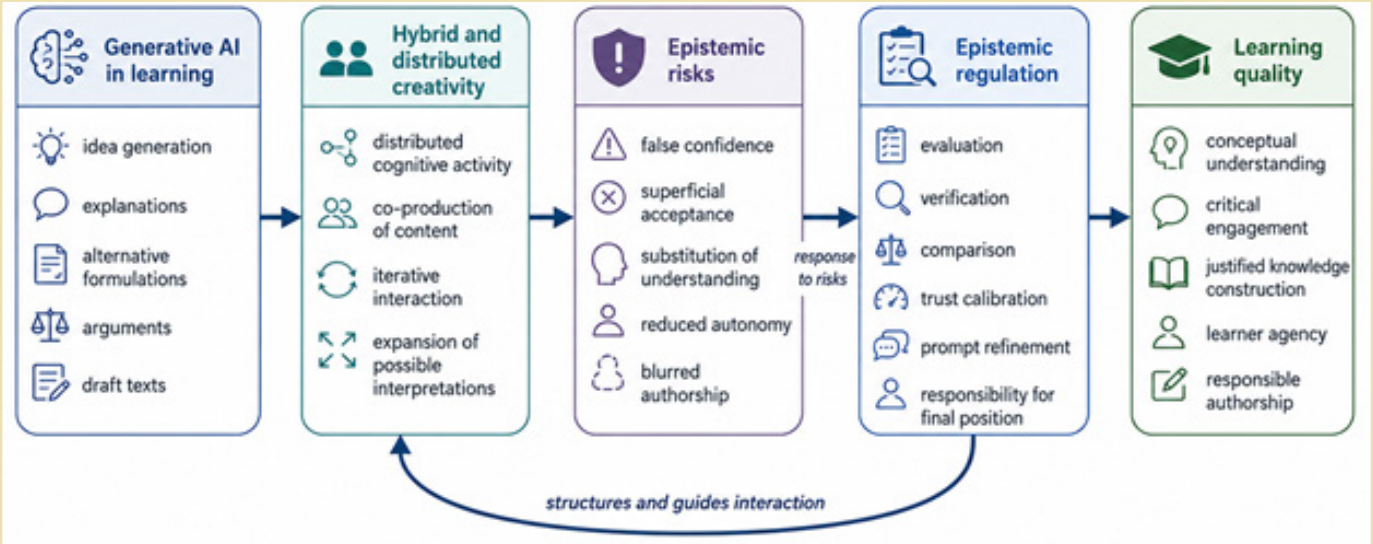


Figure 1 Conceptual model of epistemic regulation of learning quality in hybrid human-AI educational systems.

Table 1 Traditional Digital Tools and Hybrid Human-AI Educational Systems

Criterion	Traditional digital tools	Hybrid human-AI educational systems
Main function	Access to information, materials, communication, assessment	Generation, reformulation, structuring, and transformation of content
Type of response	Predefined or externally prepared	Dynamic and prompt-dependent
Role of student	User of a tool	Co-participant in distributed knowledge construction
Role of AI	Resource or support system	Generative component of learning activity
Main pedagogical issue	Effective use of the tool	Regulation of knowledge produced in interaction
Central risk	Inefficient use	Loss of epistemic control and responsibility

Thus, the key question is not whether AI is used, but how knowledge is produced, evaluated, transformed, and authorized within the human-AI system.

Building on the analysis of hybrid and distributed creativity, the model specifies the epistemic risks that arise when AI-generated ideas, explanations, arguments, and formulations enter the learning process as seemingly coherent knowledge products before they have been evaluated, verified, or appropriated by the student. Three risks are especially important. First, AI-generated responses may appear coherent and authoritative while remaining inaccurate, biased, or insufficiently grounded [28; 29]. Second, students may accept such outputs as ready-made answers, reducing their own cognitive effort and weakening conceptual understanding [7; 9]. Third, the boundary between student contribution and AI contribution may become unclear: collaborative approaches to AI and creativity require explicit clarification of the human role, while AI-generated novelty cannot be automatically equated with human authorship and responsibility [20; 25]. In the proposed model, these risks explain why epistemic regulation becomes a necessary condition for learning quality.In this article, epistemic regulation is defined as a system of actions through which students control the epistemic status of knowledge produced in interaction with AI. It includes evaluating the accuracy and relevance of AI-generated content, verifying claims, comparing alternative formulations, identifying assumptions, calibrating trust, refining prompts, and taking responsibility for the final interpretation or solution. The construct builds on research on epistemic cognition, which emphasizes how learners evaluate knowledge, evidence, justification, and sources [30; 31]. In hybrid human-AI systems, however, this regulation becomes especially important because knowledge is not only found or interpreted, but also generated by an external system. The main functions of epistemic regulation in human-AI learning are summarized in Table 2.

Table 2 Functions of Epistemic Regulation in Human-AI Learning

Function	Meaning in human-AI learning
Evaluation	Assessing accuracy, relevance, coherence, and disciplinary adequacy
Verification	Checking claims against sources, prior knowledge, or task criteria
Comparison	Contrasting alternative answers, explanations, or framings
Trust calibration	Adjusting reliance on AI according to task, evidence, and uncertainty
Interaction structuring	Refining prompts, specifying constraints, and guiding dialogue
Responsibility	Formulating the final position as the student's justified conclusion

Through these functions, AI-mediated learning can move from passive consumption of generated outputs to active knowledge construction.

The distinction between metacognitive and epistemic regulation identified in the preceding analysis is specified here as part of the conceptual model. In this model, metacognitive regulation refers primarily to the learner's control over their own cognition and learning activity, whereas epistemic regulation refers to control over the status of knowledge produced in interaction with AI. The main differences between these two forms of regulation are summarized in Table 3.

Table 3 Metacognitive and Epistemic Regulation

Criterion	Metacognitive regulation	Epistemic regulation in human-AI systems
Main object	Student's own cognition and learning activity	Knowledge produced in interaction with AI
Central question	"Do I understand?" / "Is my strategy effective?"	"Can this knowledge be trusted and justified?"
Main operations	Goal setting, monitoring, control, reflection	Evaluation, verification, comparison, trust calibration
Main risk	Ineffective learning strategy	Acceptance of plausible but unreliable AI output
Unit of analysis	Individual learner	Hybrid human-AI system
Expected result	Better control of learning activity	Better control of knowledge construction

Thus, epistemic regulation does not replace metacognitive regulation. It extends it under conditions of distributed knowledge production.

The proposed model distinguishes six levels of epistemic regulation, from passive delegation to reflective epistemic control. These levels are presented in Table 4.

Table 4 Levels of Epistemic Regulation in Human-AI Learning

Level	Name	Typical student behavior
0	Delegating use	Accepts AI output as a ready-made answer
1	Surface evaluation	Judges output by fluency, clarity, or plausibility
2	Verification	Checks facts, sources, and task relevance
3	Critical interpretation	Identifies assumptions, limitations, contradictions, and alternatives
4	Constructive regulation	Uses AI to refine ideas, arguments, prompts, and problem formulations
5	Reflective epistemic control	Distinguishes student and AI contributions and takes responsibility for the final knowledge claim

These levels describe not a fixed developmental sequence, but increasing complexity of regulatory activity. Higher levels indicate that students use AI not as a substitute for understanding, but as a resource for critically controlled knowledge construction.

Epistemic regulation does not emerge automatically from access to AI. It requires pedagogical conditions that make verification, comparison, reflection, and responsibility part of the learning task. Such conditions are especially important because effective AI-supported learning depends on students' active engagement with AI outputs and their ability to use AI applications in support of self-regulated learning, rather than as a substitute for it [32; 34]. Research on student prompts also shows that the quality of interaction with ChatGPT depends on how learners formulate, refine, and structure their prompts [33]. The main pedagogical conditions for developing epistemic regulation are summarized in Table 5.

Table 5 Pedagogical Conditions for Developing Epistemic Regulation

Condition	Pedagogical form	Target regulatory function
Verification requirement	Students must check AI-generated claims against sources	Verification
Comparison of alternatives	Students compare AI outputs, course materials, and their own arguments	Evaluation and comparison
Error-detection tasks	Students identify inaccuracies, omissions, or hidden assumptions	Critical interpretation
Prompt refinement	Students revise prompts and justify changes	Interaction structuring
Reflection logs	Students describe how their understanding changed during AI interaction	Metacognitive and epistemic reflection
Human final authorship	Students formulate the final conclusion in their own justified position	Responsibility

Accordingly, the quality of learning in hybrid human-AI educational systems depends not on the presence of AI itself, but on whether educational design supports students' movement from delegation to reflective epistemic control. The conceptual model proposed in this article therefore treats epistemic regulation as a condition for preserving learning quality in higher education.

DISCUSSION

The theoretical contribution of the proposed model is that it shifts the analysis of AI-mediated learning from the individual regulation of learning activity to the regulation of distributed knowledge construction. Classical models of self-regulated learning remain important for understanding how students set goals, select strategies, monitor progress, control their actions, and evaluate learning outcomes [10; 26]. Metacognitive theory also emphasizes monitoring and control as key processes through which learners regulate their knowledge, comprehension, and confidence [27]. However, in hybrid human-AI systems, the central regulatory problem also concerns the reliability, justification, relevance, and ownership of knowledge produced through interaction with a generative system. Epistemic regulation therefore specifies the form of regulation that becomes necessary when knowledge construction is partially distributed between the student and AI.

The conceptual contribution of the model is also connected with moving beyond an instrumental understanding of generative AI. Instead of treating AI only as a resource for information access, task completion, or productivity, the proposed framework conceptualizes it as a generative component of a hybrid learning configuration. In such a configuration, AI participates in producing and transforming educational content, while the student remains responsible for evaluation, verification, selection, and final authorization of knowledge claims. This shift is consistent with distributed cognition, which treats cognitive processes as distributed across people, artifacts, and technological environments [14; 15]. It is also aligned with the hybrid intelligence perspective, according to which the value of human-AI systems depends on the coordination of human agency and artificial contributions rather than on technology alone [16]. Therefore, learning quality should be analyzed not as a direct effect of AI use, but as the result of how human agency, AI-generated content, and epistemic responsibility are coordinated in the learning process.

The concept of epistemic regulation is especially important for understanding hybrid and distributed creativity in learning. Generative AI can expand students' access to ideas, interpretations, arguments, and alternative formulations, but this expansion becomes educationally valuable only when students critically evaluate and transform AI-generated outputs. Otherwise, distributed creativity may lead to superficial accumulation of generated variants, reduced autonomy, blurred authorship, and weak responsibility for knowledge claims. This supports the view that AI can expand creative possibilities, but only within interactional arrangements in which the human role in evaluation, selection, and transformation remains explicit [18; 20]. At the same time, AI-generated novelty should not be automatically equated with human creativity, since questions of authorship, originality, and responsibility remain conceptually unresolved [25].

For pedagogical design, the main implication is that AI-supported learning should not be organized around access to AI alone. Educational tasks should require students to verify AI-generated claims, compare alternative answers, identify errors and assumptions, refine prompts, reflect on the interaction process, and formulate their own final position. This is consistent with studies showing that AI-supported learning is more effective when students actively regulate their engagement with AI tools and use them to support self-regulated learning processes [32; 34]. Research on student prompts further demonstrates that the quality of interaction with ChatGPT depends on how learners formulate, refine, and structure their prompts [33]. Therefore, assessment should include not only the final product, but also the quality of students' epistemic work with AI-generated knowledge.

The proposed model links learning quality with the level of epistemic regulation. When students delegate cognitive and epistemic functions to AI, learning may become faster but less meaningful. When students verify, compare, refine, and justify AI-generated content, interaction with AI can support conceptual understanding, critical engagement, learner agency, and responsible authorship. Thus, learning quality in hybrid human-AI educational systems depends not on the presence of generative AI itself, but on whether students preserve epistemic control over distributed knowledge construction.

The study has several limitations. First, the proposed model is conceptual and requires empirical validation in real educational contexts. Second, the levels of epistemic regulation should be operationalized through observable indicators of student behavior, such as prompt revision, source verification, error detection, comparison of alternatives, and reflective explanation of final decisions. Third, future research should examine how epistemic regulation varies across disciplines, task types, levels of student expertise, and modes of AI integration. These directions would make it possible to transform the proposed framework into diagnostic tools and pedagogical interventions for supporting learning quality in AI-mediated higher education.

CONCLUSION

This article proposed a conceptual model of epistemic regulation in hybrid human-AI educational systems. The model shows that learning quality in higher education depends not on the mere presence of generative AI, but on students' ability to control the epistemic status of knowledge produced in interaction with AI.

Epistemic regulation was defined as a system of actions through which students evaluate, verify, compare, refine, and justify AI-generated content while maintaining responsibility for the final interpretation or solution. In this sense, epistemic regulation extends classical models of self-regulated learning and metacognition by addressing the specific challenges of distributed knowledge production.

The proposed framework also clarifies the pedagogical meaning of hybrid and distributed creativity in AI-mediated learning. Generative AI can expand students' access to ideas, arguments, explanations, and alternative formulations, but these opportunities become educationally productive only when supported by verification, critical evaluation, reflection, and responsible authorship.

Thus, supporting epistemic regulation should be considered a key condition for maintaining learning quality in higher education. The framework can be operationalized through indicators such as prompt revision, source verification, error detection, comparison of alternatives, and reflective justification of final decisions, and can serve as a basis for designing pedagogical interventions that foster students' epistemic control in real educational settings.

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