Metacognition and Artificial Intelligence

An Introductory Literature and Resource Review

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July 11, 2025

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Continuing Education
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Table of Contents

Outline

“In our rapidly evolving world, educational institutions face the challenge of imparting every technical skill required for the future” Dahri et al. [14]

Defining Metacognition

Flavell's 1979 Definition:

- "Understanding of an individual's cognitive processes"
- This involves planning, monitoring, and evaluating the learning under ones individual control [59, 18, 58, 21, 1]
- Metacognition is tied to a person's internal mental representation of reality. These consist of four parts: [21, 18]
  - Description of a Problem's Initial State
  - Description of the Problem's Goal State
  - Operators to Transform the Initial State into the Goal State
  - Constraints which limit the potential solution paths

Components of Metacognition

There is less of a general consensus in the literature which defines metacognition. There is general consensus about the following components: [21, 1, 18, 3]

- Knowledge of One's Knowledge [9, 60, 24, 16, 56]
- Cognitive and Affective States [9, 46]
- Ability to Monitor and Regulate one's Knowledge and Affective States

Defining Metacognition

Components of Metacognition for Learning

Thinking About Thinking

- **Metacognitive Knowledge:** What a learner understands about their learning process, and one's internal stored world knowledge [14, 18, 21, 9, 24]
- **Metacognitive Skills:** The capacity to manage activities related to a task, problem, or situation [18, 24]. This may also be known as cognitive regulation [9].
- **Metacognitive Goals:** The desired outcomes or objectives of a cognitive pursuit [16].
- **Verbalization:** A report the student makes either before, during, or after the learning process about the task at hand [21]. This may present itself as a student either literally verbalizing or developing a form of an information representation [1, 58, 18].

Integrating Metacognition

What is the benefit of Metacognition in the classroom?

Students are able to identify their knowledge gaps [59], adjust their learning strategies, develop learner autonomy[59], and increase their academic performance [9, 5, 1]. **Especially,** in online learning environments[1, 5, 21].

Are students aware that the skills they are using are metacognitive strategies? [31]:

- Students who are First-Generation or from Underrepresented Groups are **less** likely to utilize metacognitive strategies [31].
- Modeling these skills for students in the classroom will support a students metacognitive process and the development of their metacognitive skills [9].

Utilizing constructive strategies will support students in finding value in their learning [31]. Examples of these strategies a **student** can use are:

- Self-testing, retrieval practices, and monitoring of learned knowledge [31, 16, 46]
- Developing Study Plans (with adequate time to space out material!) to evaluate use of metacognitive skills [11, 16]

Incorporating Metacognition

To incorporate metacognition the learning activity should include [3]:

- Metacognitive instruction into the content matter
- Learners should be aware of the metacognitive activities
- Metacognitive activities are used to support the task

Incorporating Metacognition | Constructive Strategies

Utilizing constructive strategies will support students in finding value in their learning [31]. Instructor may nudge students to enter the Zone of Proximal Development to maintain learning growth[31]. Examples of these strategies an **instructor** can use are:

- Utility Value Interventions [31]
- Building Time For Metacognitive Work into the Course [9, 46]
- Providing Voluntary (but originally for credit) Metacognitive Activities in Coursework [46]
- Providing Sample Study Sets and Self-Quizzing Opportunities [31]

Examples of these strategies an **instructor** can use are:

- Opening Strategies: Demonstrations, Summaries of Prior Coursework, Reactivating Prior Knowledge [60, 46]
- Exit Strategies: Providing Space for Students to Ask Questions, Create Concept Maps, or Reflect on Steps for Assignment Completion [60, 11, 46]
- Providing Feedback to Students recognizing the task is challenging and providing strategies[9, 31]
- Prompting Reflection During Assignments on student confidence, confusion, or value [11, 46, 9, 31]

Incorporating Metacognition | Constructive Strategies

Examples of assignments (and links!) that support constructive metacognitive strategies [60, 46]:

- Collaborative Notetaking
- One Minute Papers
- Think-Pair-Share
- Concept Mapping
- Role Playing Scenarios
- Self-Assessments
- Student Generated Test Questions
- Assignment Peer Review

Artificial Intelligence and Higher Education

Defining Artificial Intelligence

What is Generative AI?

- A mix of computational and natural language processing techniques to generate meaningful content from training data [6, 48].
- A tool to produce written, illustrated, or vocal responses to input prompts [48]

Uncertain AI Futures

AI has impacted students' ability to complete assignments and learn. It has put into question ways learning and ability are assessed [57].

- What type of skills do students need today?
- What type of skills will students need in the future?
- How will learning objective shift in the future with AI?
- How does the design of assessments change? [45]
- How should AI be regulated and supported in the classroom? [45]

Metacognition and Artificial Intelligence

> *Advances in the cognitive sciences, computational sciences, robotics, and artificial intelligence (AI) provide excellent tools and techniques for detecting, measuring, and modeling how metacognition and cognition complexly interact with one another.*

- Roger Azevedo [3]

Impacts of AI on Metacognition

- AI may support students' metacognitive scaffolding tendencies [58, 18, 14]
- Students who posses metacognitive skills prior to their AI use may have a greater motivation to "resist distractions for effective engagement in these settings" [14, 59]

The Human Computer Symbiosis

Human Computer Symbiosis
Chat-GPT AI Image Generation

Licklider 1960: [30]

- Conceived originally as a use for distributed cognition and efficient work
- The integration of technology was developed to support the completion of menial tasks that 'fill the intervals between decisions'
- "Relative to men, computing machines are very fast and very accurate, but they are constrained to perform only one or a few elementary operations at a time."

How Does This Understanding Change With Artificial Intelligence?

The tasks which can be completed by the computer are no longer just clerical operations - but the core of decision making and creation itself. [45]

The Human Computer Symbiosis

> *AI can influence our perspectives and what we know about the world, which, in turn, grants them a certain level of agency to modify our environment through these interactions. Then, attempting to frame AI use as a simple duality, such as machine versus tool or tool versus object, becomes ineffective when considering how to leverage AI for SSRL*

- Jinhee Kim et al. [25]

Conversations As Care

"Having these conversations with students while we are still learning about what gen AI will be and do can help ease our students' and our own anxieties and help make us all a part of this future rather than observers of it."- Shelly Jarenski [23]

- How do you perceive AI?
- What emotions does it evoke in you?
- How are you using AI for your work now?
- What uses do you think are acceptable? What about for cheating?
- What ethical concerns do you see with this technology?

CU Boulder: AI Dialogue with Students [52]

Framework provided by Ohio State University: AI Teaching Strategies, Having Conversations with Students [43]

- Transparency
- Rooted in Knowledge of AI Technologies
- Collaborative Conversations
- Modeling Critical thinking

Tools for Developing AI Syllabus Statements:

- Chris Heard's (Director of Pepperdine's Center for Teaching Excellence) Generative AI Syllabus Statement Tool [22]
- CU Boulder Center For Teaching and Learning: AI Syllabus Statements Guidance - This is scaffolded with the AI Assessment Scale [53]
  - Course objectives impact the level of AI usage for a student [57]
- CU Boulder Center for Teaching and Learning: Co-Creating an AI Use Class Policy [54]

The AI Assessment Scale

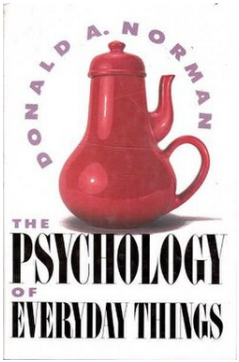
1	**NO AI**	The assessment is completed entirely without AI assistance in a controlled environment, ensuring that students rely solely on their existing knowledge, understanding, and skills **You must not use AI at any point during the assessment. You must demonstrate your core skills and knowledge.**
2	**AI PLANNING**	AI may be used for pre-task activities such as brainstorming, outlining and initial research. This level focuses on the effective use of AI for planning, synthesis, and ideation, but assessments should emphasise the ability to develop and refine these ideas independently. **You may use AI for planning, idea development, and research. Your final submission should show how you have developed and refined these ideas.**
3	**AI COLLABORATION**	AI may be used to help complete the task, including idea generation, drafting, feedback, and refinement. Students should critically evaluate and modify the AI suggested outputs, demonstrating their understanding. **You may use AI to assist with specific tasks such as drafting text, refining and evaluating your work. You must critically evaluate and modify any AI-generated content you use.**
4	**FULL AI**	AI may be used to complete any elements of the task, with students directing AI to achieve the assessment goals. Assessments at this level may also require engagement with AI to achieve goals and solve problems. **You may use AI extensively throughout your work either as you wish, or as specifically directed in your assessment. Focus on directing AI to achieve your goals while demonstrating your critical thinking.**
5	**AI EXPLORATION**	AI is used creatively to enhance problem-solving, generate novel insights, or develop innovative solutions to solve problems. Students and educators co-design assessments to explore unique AI applications within the field of study. **You should use AI creatively to solve the task, potentially co-designing new approaches with your instructor.**

 Perkins, Furze, Roe & MacVaugh (2024). The AI Assessment Scale

Artificial Intelligence and Higher Education

Technical Affordances

Defining a Technical Affordance



The Design of Everyday Things

Norman 1998: [42]

- Perceived properties that may or may not actually exist
- Suggestions or clues as to how to use the properties
- Can be dependent on the experience, knowledge, or culture of the actor
- Can either make the action easier or more difficult

Affordances of Technology on Learning

"Educators must encourage students to think about their thinking, placing the onus of learning back on the student to become more autonomous learners" - Huanhui Chen and Clinton Chidiebere Anyanwu [5]

- Online learning lacks immediate communication with the student, potentially exacerbating or clouding the students personal gaps in knowledge [59]. AI may allow students to engage with the material and *verbalize* their thinking along the way.

Affordances of Technology on Learning

- Decreased Perception of Task Difficulty: [59]
- Increased Academic Performance: [59, 39, 58, 13, 1, 5]
- Personalized Feedback: [18, 25, 1, 14, 39, 59, 45, 39]
- Increased Efficiency: [18]
- Automated Learning Tasks: [59]
- Fostered Personal Motivation: [18]
- Increased Access to Learning Opportunities: [18]
- Immediate Responses and Prompted Self-Reflection: [59, 25, 18, 39]
- Multiple Forms of Instructional Representations: [39, 25, 58, 1]

Artificial Intelligence and Higher Education

Harms of AI

Socio-Cultural Harms of Artificial Intelligence

- AI Misinformation: [1, 39]
- Privacy Risks: [39, 25]
- Bias Risks: [39, 25]
- AI is Unable to Interpret Socio-Emotional Cues: [25, 13, 1]
- Potential for Social Isolation: [13]
- Environmental Harms

Learning Harms of Artificial Intelligence

- Lack of Critical Thinking: [39, 58, 59, 1, 25]
- Lack of Information Engagement: [59]
- Technology as a Distraction: [14, 25]
- Lack of Pedagogical Backing: [29, 25]
- Decreased Learner Motivation: [1]
- Increased Plagarism: [13, 1]

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Affordances of AI on Metacognition

Does Metacognition Change the Way Students Interact With AI?

Yes! Metacognitive support will promote critical thinking skills, reducing a potential direct reliance on AI and questioning of the outputs[59, 18, 1]. Students with this support are also more likely to use AI in a way that is constructive and serve as complementary to their knowledge[25].

Four Scaffolds for AI and Metacognition

1. **Awareness**: Knowing how one's cognitive skills impact the way they communicate with and respond to AI output [57, 47]
2. **Planning**: Leveraging self-awareness to delegate tasks between the self and AI [47]
3. **Monitoring**: The Progress of the student's work (including the AI) to reach a metacognitive goal [47]
4. **Evaluation**: After completing the Task, the student reflects on what went well and what did not [47, 43, 57]

Four Scaffolds for AI and Metacognition

1. **Awareness**: “What is it that I am trying to achieve on this task?” [47]
2. **Planning**: “What types of errors do I need to look out for when using this AI tool on this type of task?” [47]
3. **Monitoring**: “Am I making progress towards my objectives? What biases may be influencing my judgment?” [47]
4. **Evaluation**: “Could I have made better use of the AI on the task? What should I do differently next time?” [47, 43]
    - What AI tool did you use?
    - What prompt was used to generate the outcomes? Was it successful?
    - What revisions to the prompt were needed to achieve your outcome?
    - Did the output have any bias or misinofrmation?
    - How did you monitor your progress?
    - Would you use this AI tool again for a similar task?

AI and Its Supporting Roles

These roles are developed by Mollick and Mollick (linked here), affiliated with the Wharton School [39]

- AI as Personal Tutor [37]
- AI as Leaner [36]
- AI as Team Coach [38]
- AI as Simulation [33]

Metacognition and AI in Current Literature

Journal: Metacognition and Learning

Website:Metacognition and Learning Homepage

As of 6/3/2025, the Metacognition and Learning Journal has 16 articles that discuss artificial intelligence.

- The earliest published article is from 2014, but the majority of which are published after 2022.
- Many articles demonstrate a future of AI, but do not deeply explore or motivate their beliefs in the article. Only three of the articles explore artificial intelligence at length.
- These brief articles discuss that AI can increase personalization and 'learned' traits of a learner to do so.

Journal of Artificial Intelligence in Education

Journal of Artificial Intelligence in Education Website

As of 6/3/2025, the Journal of Artificial Intelligence in Education has 12 articles that discuss both metacognition and higher education.

- Many of the articles do elaborate on the use of metacognitive strategies in combination with AI, more so than that of Metacognition and Learning
- The articles that do not elaborate as much about metacognition note that AI can support (I would say 'datafication') a better understanding of students metacognitive processes through trace data.

Resources

Resources

Assignments

Assignments to Foster Metacognition and AI

- Gen AI Teaching Idea: Kate Mondloch's "Turning Point" Assignment
  - Students write a personal essay every two weeks to reflect on how they learned the content during the module
- Promoting Ethical Artificial Intelligence Literacy with Generative AI Tools Like ChatGPT on an Undergraduate Course Project
  - Students set S.M.A.R.T goals (aligned closely with the four phases of metacognitive assignment creation) to evaluate ethical AI uses

Resources for Educators

- Professors at Play AI Playbook (Free Digital Access)
- Ideas for Writing Assignments - Instructional Responses to Generative AI
- Teaching Frameworks and Associated Assignment Samples
- The Right Tool for the Job: Metacognitive Processes and AI
- Collected Student AI Use Cases
  - A detailed collection of how students use AI and for what purposes AI may be useful for learning.
- Collected Educator Guide on AI
  - A detailed collection (also from the University of Sydney) about how AI may be considered with assessment.

Resources

Centers for Teaching and Learning + Blogs

University Links | Metacognition

- TurnItIn: Metacognitive Strategies to Grow Students Independent Thinking [16]
- Stanford: Promoting Student Metacognition [46]
- University of Minnesota: Center for Educational Innovation: Metacognitive Strategies Improve Learning [56]
- Yale CTL: Encouraging Metacognition in the Classroom [60]
- Columbia CTL: Metacognition [10]
- Medium: How to Use AI to Enhance Student Learning and Self-Reflection [24]
- Cornell Center for Teaching Innovation: Metacognitive Strategies [11]
- MIT Teaching and Learning: Supporting Student Learning Through Metacognitive and Motivational Strategies [31]
- Evidence-Based Teaching Guides: Student Metacognition [49]

University Links | Artificial Intelligence

- Columbia CTL: Considerations for AI Tools in the Classroom [10]
- University of North Texas: Using AI in the Higher Education Classroom [48]
- Harvard Business Impact: Student Use Cases for AI [33]
  - AI as Feedback Generator [35]
  - AI as Personal Tutor [37]
  - AI as Team Coach [38]
  - AI as Learner [36]
- Times Higher Education: In the AI era, how do we battle cognitive laziness in students? [32]
- Edutopia: 5 Ways to Use AI Tools to Meet Students' Needs [41]
- Chris Heard (Pepperdine): Generative AI Syllabus Statement Tool [22]

University Links | Applications of Metacognition and AI

- CU Boulder CTL: Technology and AI [55]
- Shelly Jarenski (University of Michigan) Conversation as Care: Why Talking to Students About AI is Our Most Essential Task Right Now [23]
- Ohio State University: AI Teaching Strategies: Having Conversations with Students [43]
- Times Higher Education: How to strengthen your metacognitive skills to collaborate effectively with AI [47]
- Utah State University: AI in Teaching: Focus and Adapt Teaching for AI [57]
- Quality Matters: Beyond a Checklist: Authentic Learner Activity and Assessment in the Age of AI[45]

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Thank You!

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