Metacognition and Artificial Intelligence

An Introductory Literature and Resource Review
Speaker Notes and Hyperlink Sheet
July 2025 — Natalie Castro

Note 1. *This document is the speaker notes, which complement the presentation linked here. Any of the shaded boxes are directly from the slideshow, and the text outside of them exist as the words spoken in the presentation. In addition, there are many links in both the slidedeck and this notesheet as well! I hope this is useful and serves as a starting resource for these concepts.*

Table of Contents

Metacognition and Artificial Intelligence: An Introductory Literature and Resource Review

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I'm interested in discussing metacognition and artificial intelligence at length because the aspects presented consider the possibilities of fostering skill sets for students in the future and developing an innovative learning environment in response to Generative AI. As this is prepared, articles are beginning to develop which consider this important overlap - yet there is still a relatively large gap in current understanding and theory.

1 Table of Contents

I will present four different sections. First, I will define metacognition through Flavell's lens, then consider AI in higher education more broadly, next, the connection between metacognition and AI - so what this overlap looks like in current literature. Finally I will provide an extensive list of resources and bibliography for this presentation.

In our rapidly evolving world, educational institutions face the challenge of imparting every technical skill required for the future [14]

First, I would like to preface with a quote from Dahri and colleagues: "In our rapidly evolving world, educational institutions face the challenge of imparting every technical skill required for the future". This notion is not new, however the development of artificial intelligence introduces new ways of interacting with technology, information, and its open access.

2 Defining Metacognition

But first, let's define metacognition.

2.1 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

According to Flavell 1979, it's an "understanding of one's individual cognitive processes". Some refer to this as 'thinking about thinking', but this involves planning, monitoring, and evaluating the learning under one's individual control. So it's much larger than just reflecting on ones own thinking, its tied to one's own internal mental representation of reality, which consists of four parts: the problem's initial state, the problem's goal state, how they will go about from reaching the initial to goal state, and the constraints on the solution.

Metacognition considers how students engage and work through different problems. In addition, it considers study material, study habits, latter engagement with the course material, and so on.

2.2 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

While Flavell defined some original understandings about metacognition, there is less of a general consensus in the literature about its components. However, the following elements are included in the majority of definitions. First is, knowledge of one's knowledge - what does one know, what does one not know and are they able to recognize the gaps in their knowledge through cognitive and affective states? A cognitive state is the state of mind an individual is in while completing a particular activity, while an affective state is the emotional influences while completing the task. Finally, the third component is the ability to monitor and regulate one's knowledge and affective states.

So without the ability to know what they don't know, or to recognize how to transform the problem state to the goal state, metacognition isn't occurring during the learning process.

2.2.1 Components of Metacognition in Learning — Thinking About Thinking

Now, let's consider how these components of metacognition specifically apply to learning.

- **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].

I would like to first start with a few definitions.

Metacognitive knowledge is what a learner understands about their learning process, and one's internal stored world knowledge. This is informed by media, cultural experiences, current events, and things of the like.

Metacogntive skills is the capacity to manage activities related to a task, problem, or situation. This is also known as cognitive regulation. This is what I was describing before, when a student may be recognizing how to get from point A to point B and what capacities of their own they have to do so.

Point B, so to say, may be understood as metacognitive goals, or the desired outcomes or objectives of a cognitive pursuit. For each student this will appear differently dependent on their goals of the class, what knowledge they already possess, and their value perception of the material.

Verbalization, I introduce here because I believe it is crucial to the overlap of metacognition and AI - so we will get more into that later. For now, the definition of verbalization is the report that a student makes at any point from getting to their metacognitive goals. This may present itself as a student either literally verbalizing or developing a form of an information representation.

For example, if a student is reviewing a concept, and their metacognitive goal is to study module A, they will use their metacognitive knowledge and skills to select a study habit. Let's say the student decided to create a concept map - they are illustrating their metacognitive knowledge through a visualization. Even though this process isn't directly spoken, they are still engaging with the knowledge to achieve their goals through a form of verbalization.

2.2.2 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].

So, what is the benefit of metacognition in classroom? Students are able to identify their knowledge gaps, adjust their learning strategies, develop learner autonomy, and increase their academic performance. This is especially true in online learning environments

2.2.3 Incorporating Metacognition — Equity Concerns

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].

Knowing these benefits and core definitions, what are the potential equity concerns of metacognition in the learning environment? First, students may not be aware that they are using metacognitive strategies. Students who are first-generation or from underrepresented groups are less likely to utilize metacognitive strategies - thus at a disadvantage in being able to capitalize on these skills. This is why it is important to model these skills in the classroom to support students in both recognizing and developing their metacognitive skills in the context of higher education.

2.3 Incorporating Metacognition — Constructive Strategies

Students in the age of AI need to learn how to learn, especially when the tangible product of learning may be craftily stitched together using a variety of online tools without using deep critical thinking or metacognitive skills. Next, I will be presenting some strategies for how to incorporate metacognition from the student side and the instructor side to support effective learning and competency building in the classroom.

2.3.1 Incorporating Metacognition — Constructive Strategies: Students

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]

Using constructive strategies like this will support students in finding value in their learning, potentially increasing a form of motivation to deeply engage with the material versus creating a digital facade of competency.

Examples of cognitive strategies a student can use are self-testing, retrieval practices, and monitoring of learned knowledge. Flashcards may be useful, however rote memorization is not a constructive strategy as it doesn't foster opportunites for deep engagement with the material. To create these opportunities, a student may want to create a study plan, and with adequate time to space out the material and their potential for using metacognitive skills to do so.

2.3.2 Incorporating Metacognition — Constructive Strategies: Instructors

2.3.3 Incorporating Metacognition — Core Elements

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

Before introducing different instructor centered strategies, I would like to preface with three tenants of learning activities that will foster metacognition. First, metacognitive instruction should be introduced with the content matter. Second, the learner should be aware if any course material is a particular metacognitive strategy. Third, the learning activity should utilize a combination of activities that draw on the learner's metacognitive skills to complete the task.

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]

Instructors may utilize constructive strategies to nudge students into the Zone of Proximal Development to maintain learning growth. Examples of constructive strategies instructors may use are utility value interventions, building time for metacognitive work into the course, providing voluntary but originally for credit metacognitive activities in coursework, providing sample study sets, and self-quizzing opportunities.

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]

Some additional strategies are a combination of opening and exit strategies. For example, an exit strategy may collect points of student confusion at the end of the lecture, and then at the start of the next lecture time may be dedicated to answering student generated questions, provide summaries of the coursework, or the reactivate prior course concepts.

Additional exit strategies pull on the concept of verbalization through developing concept maps, a quick think-pair-share, or space to reflect on steps to complete an upcoming assignment.

Instructors may also provide feedback to students and recognizing the challenging nature of tasks and potential heuristics to completing the assignment. As mentioned earlier, first generation students and underrepresented groups are less likely to engage in these metacognitive strategies and may not have a mentor to introduce such scaffolding. In addition, the instructor may prompt the student to reflect during assignments about their confidence on a particular question, any points of confusion, or how their disciplinary knowledge may add value to their current coursework.

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

Some specific assignments to utilize these constructive strategies in the classroom are: collaborative notetaking, one minute papers, think-pair-share, concept mapping, role playing scenarios, self-assessments, student generated test questions, or assignment peer review.

3 Artificial Intelligence and Higher Education

Now that we have a brief overview about what metacognition is and ways to incorporate it into the classroom, let's consider how AI is shifting the educational and labor landscapes.

3.1 Defining Artificial Intelligence

What is Generative AI?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]

Let's start by defining generative artificial intelligence so we share an understanding. AI is a mix of computational and natural language processing techniques to generate meaningful content from training data. It is a tool to produce written, illustrated, or vocal responses to input prompts. These are built on a long history of natural language processing and concepts from cognitive sciences.

3.2 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]

AI has impacted student's ability to complete assignments and learn. It has put into questions ways learning and ability are assessed. Some of the core concerns of this discussion are: 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? How should AI be regulated and supported in the classroom?

These questions are important to address because of the uncertain AI futures. Its rapid development, early regulated state, and open access nudges technology policies and learning consideration

into an AI oriented state. In a study published in *Labour Economics*, Alekseeva and colleagues found an increase in job postings with 'AI' in the job description, and a wage premium on these jobs as well.

3.3 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]

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.

As I noted earlier, this isn't the first rapid change in education as a result of technology. What's different about this is that AI provides a facade of human cognition, unlike prior tools.

3.3.1 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]

There are multiple impacts of AI on a student's metacognition, but I would like to first present two considerations:

First, AI, with proper prompts may be able to scaffold a students metacongition and develop their skills in an anytime-anywhere sort of fashion. This may be particularly useful for students who work a lot during the school year or may not be physically near campus or in the same time zone to join office hours. However, the digital divide also must be of concern here - a student needs reliable internet access to engage with AI in this fashion.

Second, Students who possess metacognitive skills prior to their AI use may have a greater motivation to 'resist distractions for effective engagement'. In this case, it is especially important to consider which types of students who may already possess

Figure 1: Human Computer Symbiosis (Chat-GPT AI Image Generation)

3.4 The Human Computer Symbiosis

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."

Reference Figure 1

To consider how AI may additionally impact student metacognition, I would like to go back to a concept introduced in 1960 by J. C. Licklider: the human computer symbiosis. Posited by Licklider, he posited that computers may allievate the cognitively menial or routine tasks which 'fill the intervals between decisions' to support human efficiency. This concept was subsequently built on in human-centered-computing literature and earned the name 'distributed cognition'. At the point of this work, Licklider noted that "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." However - as we now know, AI can preform more than just elementary operations.

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]

So how does the understanding on the human computer symbiosis change with artificial intelligence? AI may now complete tasks beyond just the clerical but develop robust coding strategies, author compositions, and interact like a human. The role of technology as shifted - it can now engage in processes at the core of decision making and creation itself.

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]

So, what does this new human computer symbiosis look like?

Reference the quote above from Jinhee Kim and colleagues! This is in context with SSRL, or socially shared regulation of learning.

3.5 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]

To consider how to integrate AI, knowing that it is beyond just a clerical tool, students need conversations and guidance about how to recognize the constructive use cases for utilizing AI. As Shelly Jarenski says "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."

Conversations that create environments of care may ask questions of the students about how they perceive AI, what emotions it may evoke, how they currently use it, operationalizing acceptable use case, and identifying potential ethical issues.

By engaging with conversations with students a more transparent learning environment is developed. In addition, having these conversations is holding space for students to verbalize how they feel - a core tenant of metacognition.

3.5.1 Student Centered Methods for AI Discussions

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

Ohio State University provided a framework to build conversations of care. They recommend and instructor to integrate transparency and collaboration, root the conversation in knowledge of AI technologies. Through this the instructor is able to model critical thinking about new technologies and thus developing one's metacognitive knowledge about it.

3.5.2 Syllabus Statements

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 and AI Use Class Policy [54]

I've collected some tools that may help you develop an AI syllabus statement for your course, I certainly will be bookmarking these for later!

The first is Chris Heard's Interactive AI syllabus tool where you are prompted through questions and it formats your answers into a statement. Next is the CU Boulder Center for Teaching and Learning's sample syllabus statements - these are informed by the AI assessment scale and the objectives for the particular course. CU Boulder's CTL also provides scaffolding for co-creating an AI use policy and how to moderate these conversations with students.

The AI Assessment Scale: Perkins, Roe & McVaugh 2024 Reference Figure 2

This is the AI Assessment scale I mentioned in the last slide. It is written by Perkins, Furze, Roe and MacVaugh - their website is linked here in the speaker notes. This provides scaffolding for learning objectives and assignments to give language to what type of AI use is appropriate, and what the expectations are for completing a particular task.

The five scales are: (1) NO AI - students cannot use AI at all, (2) AI PLANNING - students may use AI to brainstorm but have completed the majority of the tangible product themselves, (3) AI COLLABORATION - students may use the AI to help complete specific tasks, but the student must take onus for the content submitted, (4) FULL AI - the student may use AI at their discretion or per the ask of the assignment, the goal of full AI is to utilize it to achieve their goal state, and finally (5) AI EXPLORATION - students are expected to use AI creatively to solve the task and be transparent with the instructor as they do so.

This transparency at all five levels on the scale is important as it scopes the student when selecting potential metacognitive skills to achieve their goal state. AI use may vary by discipline, and this scale provides students with the ability to select particular aspects of their knowledge to complete the task at hand.

3.6 Technical Affordances

Now, let's consider the technical affordances of AI. This encompasses both literally and implied use cases perceived by the student at any given time.

3.6.1 Defining A Technical Affordance

Norman 1988: [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

Reference Figure3

Note 2. The original book published by Norman was title 'The Psychology of Everyday Things', or POET, but later editions were titled 'The Design of Everyday Things'. It is rumored that the title did not afford a very clear location in the bookstores...

I'd like to define an affordance relying on another HCC oriented definition published by Don Norman in 1988. This operationalizes an affordance as: (1) Perceived properties that may or may

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

Figure 2: The AI Assessment Scale

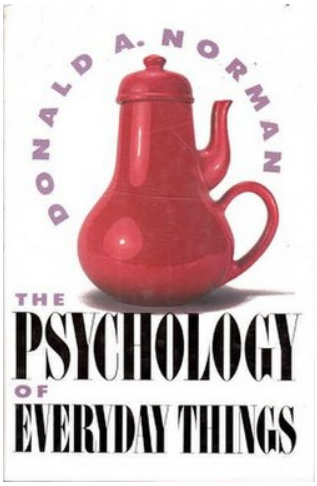

Figure 3: The Design of Everyday Things

not actually exist, (2) Suggestions or clues as to how to use the properties, (3) Can be dependent on the experience, knowledge, or culture of the actor, and (4) Can either make the action easier or more difficult.

I'll provide a short example here outside of digital technology - think about the cheesy red and blue glasses you may have gotten for a 3-D movie. When you look at them you will perceive that their are different colors suggesting they have a particular use, however, unless you know the use case is seeing something appear to be in 3-D you may be confused. The physical build that they are glasses will suggest to the use that they can be worn around your face - but in the same sense this design may be challenging to fit if someone is already wearing glasses. They don't fit, it's blurry, it's a mess!

Essentially an affordance is through the perceived and suggested qualities of a design will indicate particular use cases and frictions for a user of that technology. However, these traits do not always have to be positive - consider the affordances of hostile architecture for an example.

3.6.2 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.

So with respect to AI, affordances are more complex than what 3-D glasses may suggest. Educators must encourage students to think about their thinking, placing the onus of learning back on the

student to become more autonomous learners. In addition, online learning does not afford immediate communication with the student which may cause later confusions or barriers to a student learning subsequent content material. However, AI affords a way for students to engage with the material and *verbalize* their thinking at every step in the assignment completion. The interaction of AI and other digital technologies create an online learning environment that places great autonomy on the student if they would like to deeply engage with the content.

- 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]

Now, I will provide a short list from the literature about speculated affordances of AI on the literature. The first is decreased perception of task difficulty - the student is walked through a particular assignment making something which otherwise would have generated a lot of questions and a trip to office hours. Next, many citations suggest AI use may increase academic performance - their rationale is that the increased efficiency, personalized feedback, and immediate responses may support a student in an online learning environment greatly. This interaction inherently prompts students to verbalize, nudging students to reflect on what they know, how they can get there, and in what ways their resources may be able to support them. Processes like this will encourage students to self-reflect on the work that has been created.

Others suggest that AI may be able to foster personal motivation through this kind of increased access to learning opportunities and multiple forms of instructional representations. This combination provides autonomy to learners, and more so in online environments, however these processes may easily develop a facade the student has learned, when in reality they have relied too heavily on AI generated content.

3.6.3 Harms of AI

AI also may afford harms to certain groups of students through narrative, representaiton, or misinformaiton. I will go over two general types of harms here: socio-cultural harms and harms specific

to learning.

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

The socio-cultural harms which may be induced as a result of AI usage are broad - these consist of misinformation, privacy risks, bias, unable to understand the language, and potential for social isolation. Because AI is generating text, and not directly 'reading websites' and subsequently citing their sources its misinformation is presented confidently. For subject matter experts this may be obvious, however students who are not versed in the literature or nuances of a particular discipline may not know the extent of AI misinformation. A second concern is privacy risks, this covers both FERPA data, but student data more broadly - AI tools develop a persona of someone and in their training data may already be laden with personal information. The bias risks related to AI are extensively documented. It is known to align more with Western ways of speaking, even within this there are nuance in the language AI uses suggesting power-subordinate languages. The list could extend greatly. In addition, AI is unable to interpret socio-emotional cues, suggesting that students may struggle to engage meaningfully with the AI. AI also introduces potential for social isolation - this may in some cases be exacerbated in online classes. Finally, the environmental harm of AI is detrimental and disproportionately impacts those who are already marginalized.

Note 3. For more information on types of biases and harms caused by AI more broadly reference:

- Dev et al: On Measures of Biases and Harms in NLP
- Bender et al: On the Dangers of Stochastic Parrots
- Weidinger et al: Taxonomy of Risks posed by Language Models
- MIT: Explained - Generative AI's environmental impact

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]

Next, let's consider some of the harms that are directly related to learning. The first, and most common is the lack of critical thinking. If a student becomes overly reliant is a lack of information engagement, so collating sources or working through debugging code, or have a decreased learner motivation because their work is superficially recreated when using AI. This may be in part be because AI may serve as a distraction to students - other cases may result in increased plagiarism or skipping the learning. The earlier part of this presentation has considered how a potential use for AI in education is for metacognitive scaffolding - however these harms are often not as immediately known to students, and may increase over time.

3.7 Affordances of AI on Metacognition

3.7.1 Metacognition and AI Awareness

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].

Knowing the affordances, harms and definitions of 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. Students with this support are also more likely to use AI in a way that is constructive and serve as complementary to their knowledge. I argue here that the use of metacognition for students will create a more productive human-computer symbiosis. As Licklider illustrated, distributed cognition in the form of AI may support students learning, but without the appropriate scaffolds, this may ultimately harm their learning trajectories.

3.7.2 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]

To appropriately scaffold the student's learning experience sources from Utah State, Ohio State, and Times Higher Education recommend four levels: awareness, planning, monitioring, and evaluation. First is awareness, the student needs to know how their cognitive skills impact their particular use of AI. The next is planning, the student should use self-awareness to delegate tasks between themselves and AI. Throughout this, the student will have to monitor the progress of their work to a particular metacognitve goal. After task completion, the student will reflect on what went well and what did not.

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?

To support this scaffolding the student may ask themselves, or be prompted in an assignment at

each of the following stages. Answering these questions is a form of verbalizaiton that supports metacognition overall.

3.7.3 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]

Mollick and Mollick outline four roles AI may assume. These are tutor, learner, team coach, and simulation. These roles support students in different learning activities and ways of scaffolded verbalization. The authors provide an extensive outline of prompts that utilize the affordances of AI rather well. I won't go into much detail here, however, I do recommend reviewing the citations, I found them particularly useful.

4 Metacognition and AI in Current Literature

4.1 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.

4.2 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.

5 Resources

5.1 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

These are a few assignment resources to foster metacognition and AI. These are Kate Mondloch's "Turning Point Assignment" which prompts students to reflect they way they learned the content. This is relevant to AI, however asks the student to reflect on a broad range of resources and their metacognitive skills while completing the assignment.

From the WAC Publishing House, they provide a general goal for how students may use ChatGPT on an undergraduate course project. These are aligned with the S.M.A.R.T. goals, which closely align with metacognition.

Note 4. S.M.A.R.T. stands for specific, measurable, achievable, relevant, time-bound.

5.2 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.

Some more general guides are the 'Professors at Play AI Playbook', ideas for writing assignments, teaching frameworks for metacognition, and how to use metacognition for AI. The final two links on this slide are collected student and AI use cases - these resources are very detailed and would be a good starting point to assume the student view. These are developed from the University of Sydney and utilizes Canvas modules to present the material.

At the end of the speaker notes are resources for developing authentic assessments. A few of the sources mentioned these as a core strategy for incorporating metacognition and AI, however, it is not discussed at length in the presentation.

5.3 Centers for Teaching and Learning + Academic Oriented Blogs

These final slides are the linked resources used in this presentation. The CTL pages will be provided both in a less structured format here, but are also included in the bibliography. I am going to now flip through these, so you can get an overview of the sources and the article titles.

- 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]
- Stanton et al: Instructor Checklist [50]

- 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]

- 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]

Figure 4: This photo was generated with Chat-GPT

- Quality Matters: Beyond a Checklist: Authentic Learner Activity and Assessment in the Age of AI[45]

5.4 Bibliography

There are multiple slides here dedicated to the bibliography that is utilized throughout the slide deck. They are printed at length at the end of this document.

5.5 Thank You!

Thank You!

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- July 7th, 2025

Note 5. Natalie Castro is a current graduate research assistant fulfilling the role of Data Analysis, Evaluation, And Assessment Specialist at the Division of Continuing Education and Online Credit at CU Boulder. She is an incoming Ph.D. student in Computer Science at Northeastern University as of Fall 2025! Her prior education is in information science, education, sociology, data science, and digital humanities.

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6 Authentic Assessments in the Classroom

While this is not explicitly mentioned in the presentation, the idea of authentic assessments is a constructive strategy. It is outside of just rote memorization and requires students to draw on their knowledge to develop a tangible product [6, 41]. Below is an annotated list of specific examples for authentic assessments in the context of higher education.

1. The Case for Authentic Assessment: Grant Wiggins
    - Presented by Grant in 1990, a short ERIC publication became the seminal source for authentic assessments.
2. The Authentic Assessment Toolbox: Jon Mueller
    - This webpage has sections detailing what an authentic assessment is, why use one, and how to develop an authentic assessment.
    - This page is very comprehensive and draws comparisons between traditional assessments and an authentic assessment.
    - Linked at this text (authentic task examples) is a list of different authentic assessment types for each discipline. **This list is very comprehensive and would be a good starting point.**
3. Assess Student Learning Using Authentic Assessments
    - This source provides a short list of authentic assessment tools for different types of disciplines. In addition, the author provides an explanation of using AI to benefit learners in the classroom and potential considerations when developing authentic assessments.
4. The Power of Authentic Assessment in the Age of AI
    - Authored by Drs Siham Al Amoush and Amal Farhat, assessment strategies in the age of AI are presented. Specific examples are empirical research, student demonstrations, and developing presentations for peers.
    - The authors also present multiple components that should be included in authentic assessments.
5. Authentic Assessment Online - the Benefits, Challenges and Examples
    - Authored by Jo Bowden, a definition of authentic assessment is illustrated. They also provide a criteria for what is in an authentic assessments. Examples of this criteria are realistic real-world scenarios, opportunities for practice, and drawing on a wide range of students skills.
    - Bowden provides a specific example to contextualize authentic assessments specifically in online environments as well.
6. Authentic Assessment
    - This page is written by the Indiana University Bloomington Center for Innovative Teaching and Learning.

- This page provides a table that compares 'typical tests', to 'authentic tasks', and what 'indicators of authenticity' may be present. A short list of example assignments is provided.

7. Building Authentic Assessments

   - Authored by the Center for Instructional Technology and Training at the University of Florida, this webpage provides resources for developing authentic assessments, what scaffolding is needed, and what an authentic rubric may look like.

8. Creating Authentic Assessments

   - Rachel Niemer, from the University of Michigan authored this article for the Universities Online Teaching Website. This article provides information about how to define the term authentic assessment, what the value is, and a space to brainstorm ideas for authentic assessments in online courses.

9. Alternative Authentic Assessment Methods

   - A long summary of authentic assessments are provided with their potential strengths and limitations for each method. In addition, there are strategies for how to combine a traditional and authentic assessment.

10. Elements of Course Design: Authentic Assessments

    - This page provides specific examples for how to develop an authentic assessment in the online classroom and a linked manuscript describing authentic activities in online learning.

11. Teaching Guides: Authentic Assessments

    - This page describes the what and the why of authentic assessments, and types of authentic assessments for different teaching goals (inquiry-based learning, problem-based learning...).
    - **This source is very comprehensive and provides rationale for each step of the instructional design.**

12. Alternative Assessment Strategy for a Physics Final

    - This six minute video from Dr. Peter Selkin at the University of Washington describes developing a portfolio and other grading strategies for their students.

13. Authentic Assessment

    - From the University of Liverpool, this guide provides multiple case studies for using authentic assessments across disciplines.

14. Assessing Authentically

    - This page provides an overview of authentic assesment, what this strategy looks like digitally, how to design an assessment, and how to grade authentic assessments.
    - This source also provides information about the specific dimensions and characteristics needed to develop an authentic assessment.

- At the end of the webpage, the authors describe multiple authentic assessment examples that are general, but may cater across disciplines.

15. Authentic Assessment Matters

    - This resource provides eight core questions to consider when developing an authentic assessment.