What do we know about AI's relationship to learning?

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AI is (nearly) unavoidable

- Late 2022:
  - ChatGPT
- Early 2025:
  - Dozens of LLMs available online
  - Microsoft Office 365 Copilot integration
  - Google Gemini and search summaries
  - Grammarly AI writing assistant
  - Adobe Reader AI summaries

Student use and perceptions of AI

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Student use and perceptions of AI

Some data and a case study

Cognitive Theory 101

AI and learning

- "How Are Students Really Using AI?" *Chronicle of Higher Education*
  - Somewhere from 1/3 to nearly all students use it. Use increasing over time and with age.
  - Main uses: find info, generate ideas, writing support. Main reasons for using it are saving time, improving work. Many prefer AI to talking to a professor. 25-35% admit using it for full answers, almost none get caught.
  - Student views divided: half concerned about learning impact, hallucinations. 15-25% think AI should not be used in education at all. 9 of 10 don't trust it to grade.
  - Class policies vary widely: Over half required or expected to use it in a class, 72% had at least one professor ban it.

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- A sampling of empirical research on AI use
  - Negative effects on memory retention, critical thinking, creativity.
  - Positive effects on . . . the same things (though in different ways, such as "gist memory" versus detailed memory).
- Hua Hsu, "What Happens After A.I. Destroys College Writing?" *The New Yorker*
  - "Almost all the students I interviewed in the past few months described the same trajectory: from using A.I. to assist with organizing their thoughts to off-loading their thinking altogether."
  - "In 2023, researchers at Harvard introduced a self-paced A.I. tutor in a popular physics course. Students who used the A.I. tutor reported higher levels of engagement and motivation and did better on a test than those who were learning from a professor. [One student] told me that she often has ChatGPT produce extra practice questions when she's studying for a test."

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- Lorena Barba, "Experience Embracing GenAI in an Engineering Computations Course: What Went Wrong and What's Next," *IEEE Computer*
  - Students "began using the autograder and generative AI iteratively to "solve" the exercises in a trial-and-error fashion, avoiding the mental effort that is supposed to take place while working on the assignments."
  - "I talked to them in class about proper uses and asked them not to copy and paste assignment questions. They did not heed my advice and seemed unaware that they were harming their learning."
  - "In retrospect, they needed much more guidance on how to use AI in a way that is conducive to learning—I thought with some live demos and plenty of spoken advice they would get it. It didn't work."

Cognitive Theory 101

- Cognitive load and schemas (Sweller 1988)
  - Cognitive load: Amount of mental effort a task takes.
  - Schemas: Cognitive structures linking a given problem to a problem type (and thus a solution procedure). Experts solve problems via schemas, novices do not.
  - Working memory: Part of cognition that actively works on a problem. Limited capacity.
  - Long-term memory: Stored information and schemas that can be called on by working memory. Far less limited.
- Types of load (Sweller 1994, Orru and Longo 2019)
  - Intrinsic: Proper to the task itself. (E.g., arithmetic and counting skills when solving an addition problem.)
  - Extraneous: Not proper to the task. (E.g., interpreting vocabulary or context in an addition word problem.)
  - Germane: Effort involved constructing schemas. (E.g., building a mental model of arithmetic while solving an addition problem.)

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AI and learning

- General conclusions:
  - Learning centers on constructing schemas, which help us solve novel problems, support knowledge transfer, and are long-lasting.
  - Schemas are conceptual in nature—they grasp problems as belonging to a type. They reduce effort by focusing our attention to what matters in a problem.
  - Meaningful learning involves developing a conceptual grasp of a problem, then incorporating it into long-term memory so that working memory can call on it.

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- How to learn, as it intersects with cognitive theory:
  - "It is virtually impossible to become proficient at a mental task without **extended practice**" (Willingham, 2008, p. 81).
  - "Knowledge representations are built up through many opportunities for observing similarities and differences across diverse events" (National Research Council, 2001, p. 65). ***Schema-building requires many cases and contexts***.
  - Teachers "must design lessons that will ensure that students are thinking about the meaning of the material" (Willingham, 2008, p. 49). ***Practice should involve deep processing and building meaning****, not rote memorization*.
  - "The best learners are those who can take control of their metacognitive processes and direct them toward a goal" (Svinicki, 2004, pp. 128-129). *Effective learning requires* ***awareness of one's own learning process****.*
- Learning requires work. Lots of meaning-oriented, self-reflective work across varied cases and contexts.

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- Back to Lorena Barba’s class:
  - They were “copying assignment questions directly into the AI tool, and with a one-shot prompt, they expected to get *the answer*, to then copy *the answer* into their assignment Jupyter notebook.” (author’s emphasis)
  - Students were “using the autograder and generative AI iteratively to “solve” the exercises in a trial-and-error fashion, avoiding the mental effort that is supposed to take place.”
  - “The exam results were also dreadful, despite the fact that students had access to AI and the full open Internet, their notes, and my course materials while completing it. What they could not do was trial and error via one-shot prompts.”

AI and learning

- Ways AI endangers learning:
  - Defaults to providing "the right answer", rather than working toward understanding.
  - Allows brute trial-and-error approach to solutions.
  - Reduce or eliminates the work of learning.
- From the lens of cognitive theory:
  - Intrinsic load is circumvented by AI presenting solutions to problems, so no skill practice occurs.
  - Germane load is eliminated—there is no engagement with the problem, no interpretation of meaning, and no metacognition, so no schema formation happens. If the answer is right, the student doesn't learn why. If the LLM literally says why, the student learns that as a fact and not a part of cognitive architecture.

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- Conventional LLMs (ChatGPT, Claude, Gemini, etc.), other things being equal, don't support learning well.
  - Conventional LLMs are generally designed to be engaging and helpful (less positively, "sycophantic").
  - Conventional LLMs, structurally, are designed to always answer (produce a token for) a prompt, making it far harder for a learner to be pushed to do the work. (It also means "hallucinations" are an unsolvable, though reducible, problem.)
  - Conventional LLMs can adjust responses based on the person, but must trust the user as to who they are and their needs, and are easily manipulated ("jailbroken") to get around restrictions and guardrails, even the most recent models.

AI and learning

- What would a good LLM for learning look like?
  - Purpose-built: Focused on discipline-specific content.
  - Adaptive: Adjusts to the student's level and needs.
  - Practice-oriented: Provide opportunities for varied, meaning-oriented, iterative practice and metacognition.
- Barba's LLM prompt specifically asked for these. What else is needed at the level of LLM design?
  - Designed around subject area or task (i.e., not generic LLM—more like a "small language model").
  - Not built around engagement.
  - Focuses on reasoning, not answers. May not always give answers, requires user to show their work.
- How to communicate with students?
  - Students are not experts in your subject or metacognition--don't assume they know how to use AI well or spot issues
  - Emphasize effort, reasoning, process
  - Be specific about how an LLM can/cannot be used—identify which things students must practice