Human-AI Collaborative Interfaces that Enable Efficient Authoring of Tutoring Systems

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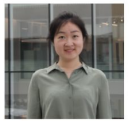
About myself

I’m an Assistant Professor in CSE working on educational technologies + HCI, and I direct the lifelong learning lab. https://web.eecs.umich.edu/~xwanghci/

People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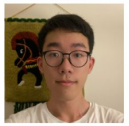
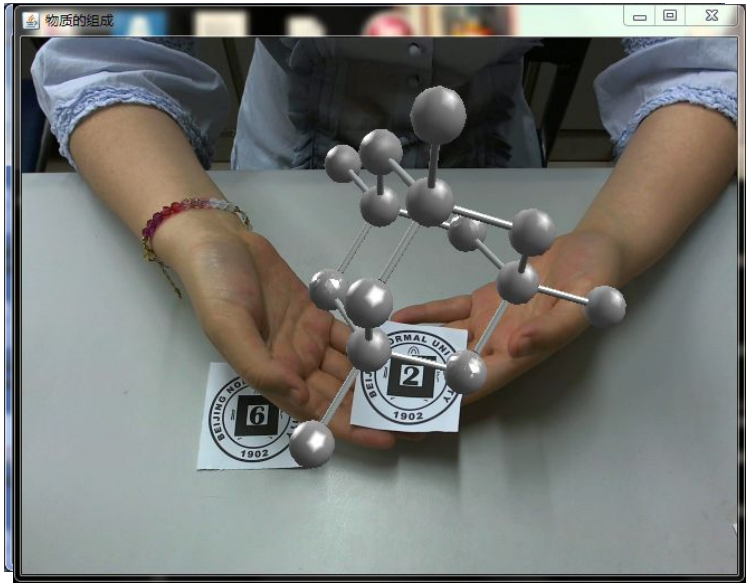

Muche Wu
Undergraduate Student

Agenda

- **Overview of Research on Educational Technologies**
  - How might we optimize human learning?
- **Human-AI Collaborative Interfaces that Enable Efficient Authoring of Tutoring Systems**
  - ReadingQuizMaker: A Human-NLP Collaborative System that Supports Instructors to Design High-Quality Reading Quiz Questions. (CHI'23) Xinyi Lu, Simin Fan, Jessica Houghton, Lu Wang, Xu Wang
  - Exemplify: Understanding How Instructors Use AI to Create InteractiveWorked Examples as Scaffolding Exercises. (under submission) Xinyi Lu, Mitchell Dudley, Raelin Musuraca, Lu Wang, Xu Wang

How I started working on educational technologies?



(a) Grouping and starting the applications

(b) Learning with AR

(c) Cooperating in groups

(d) Answering the quiz test

What is the science behind learning?

How might “Optimizing Learning” be done?

- **Is your learning as good as it could be?**
  - When has the instruction or training you’ve been provided worked particularly well?

How might “Optimizing Learning” be done?

- **Is your learning as good as it could be?**
  - When has the instruction or training you’ve been provided worked particularly well?
- Several examples:
  - Deliberate practice
  - Mastery learning
  - Intelligent tutoring systems
  - Active learning

How might “Optimizing Learning” be done? -Deliberate Practice

- **To become an expert takes time! Estimates: 10 years & 10,000 hours**
  - To become a chess grand master or a great composer like Mozart
  - Even Bill Gates & the Beatles put in many hours over many years before success
- **Similarly for academic expertise, like reading, writing, math**
  - Lots of hours of practice with feedback

Ericsson, K. A., Krampe, R. T., & Tesch-Römer, C. (1993). The role of deliberate practice in the acquisition of expert performance. Psychological review, 100(3), 363.

How might “Optimizing Learning” be done? -Deliberate Practice

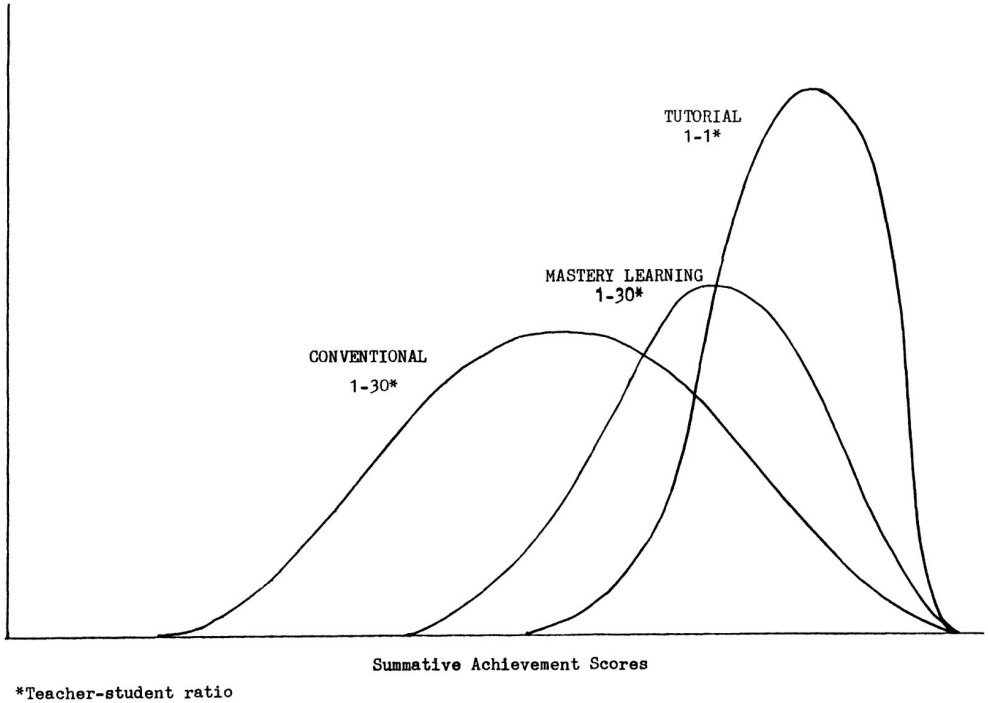
Deliberate Practice Elements

- Effortful exertion to improve performance
- Intrinsic motivation to engage in task
- Carefully tailored practice tasks that focus on areas of weakness
- Feedback
- Continued repetition over a number of years

Ericsson, K. A., Krampe, R. T., & Tesch-Römer, C. (1993). The role of deliberate practice in the acquisition of expert performance. Psychological review, 100(3), 363.

How might “Optimizing Learning” be done? -Mastery Learning

FIGURE 1. *Achievement distribution for students under conventional, mastery learning, and tutorial instruction.*



Bloom’s 2 Sigma Challenge

Bloom, B. S. (1984). The 2 sigma problem: The search for methods of group instruction as effective as one-to-one tutoring. *Educational researcher*, *13*(6), 4-16.

How might “Optimizing Learning” be done? -Mastery Learning

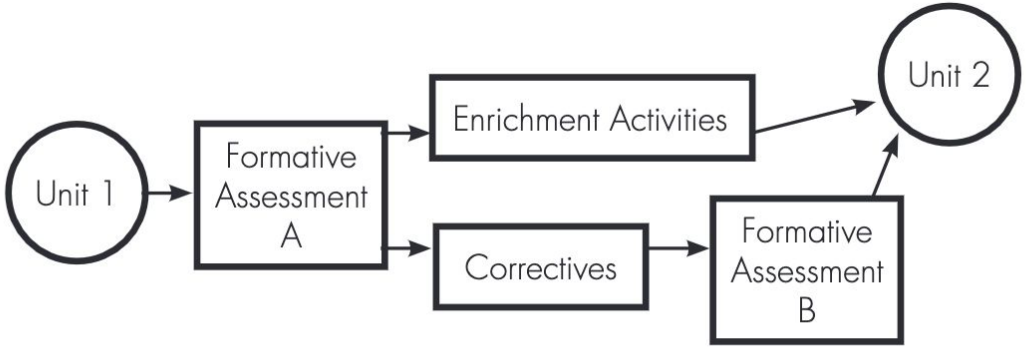


Figure 2. The mastery learning instructional process.

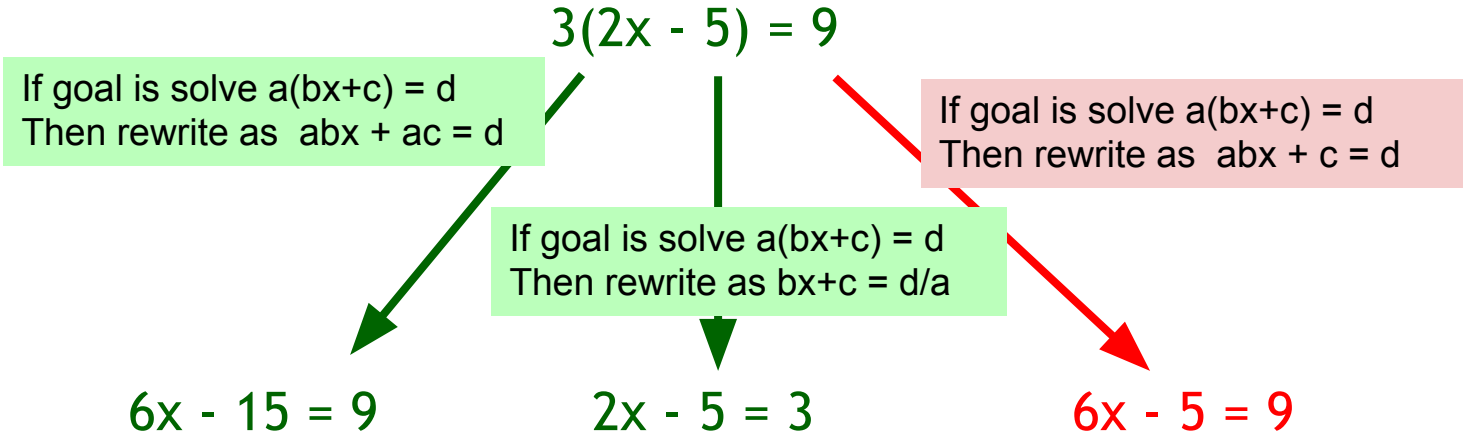
Mastery Learning:
Feedback-corrective procedure

Feedback on learning tasks, activities for correcting learning difficulties

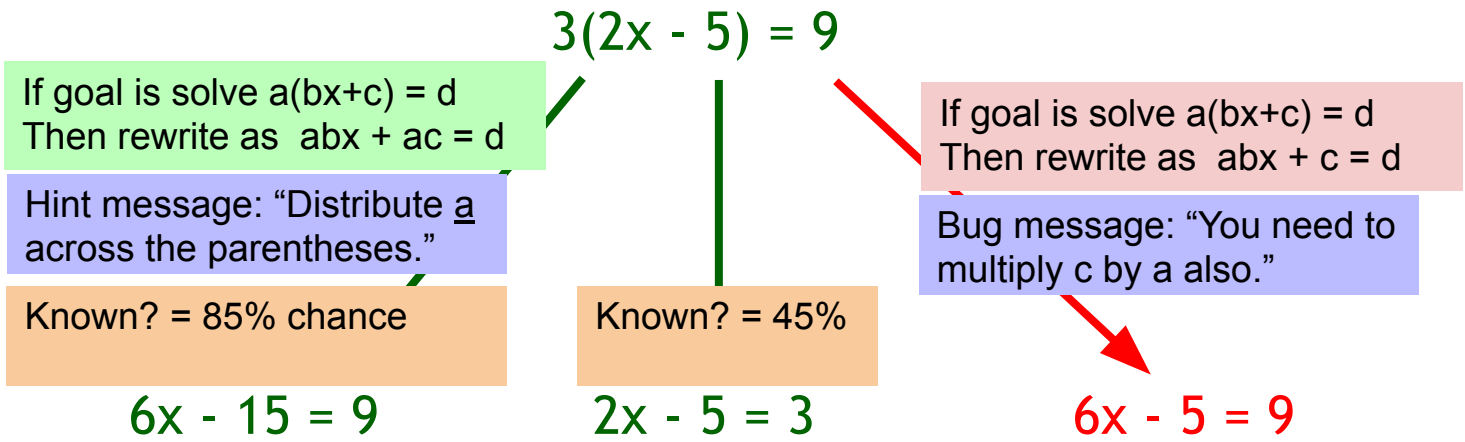
Cognitive tutors: Using a Cognitive Model to adapt instruction to individual student needs

- Cognitive Model: A computer simulation that solves problems in the various ways students can

Cognitive tutors: Using a Cognitive Model to adapt instruction to individual student needs



- Two algorithms use the *cognitive model* to approximate personalized tutoring
- Model Tracing: Follows student through their individual approach to a problem => context-sensitive instruction

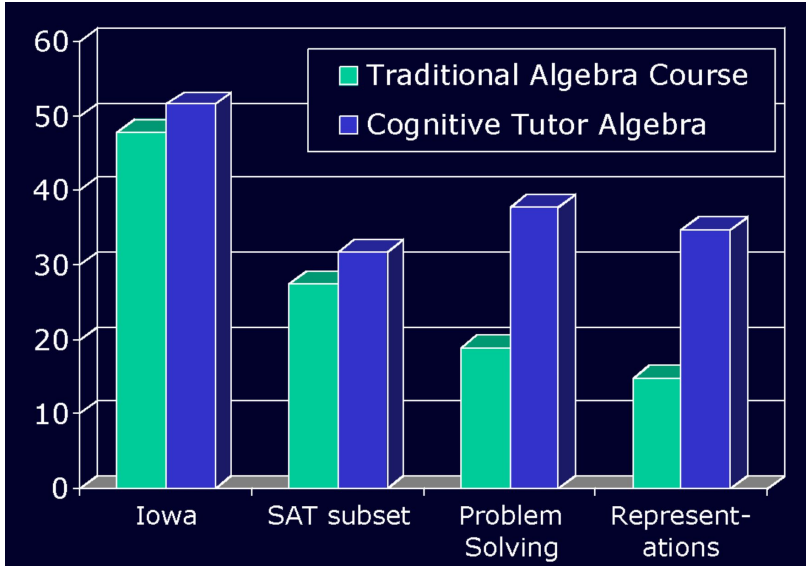


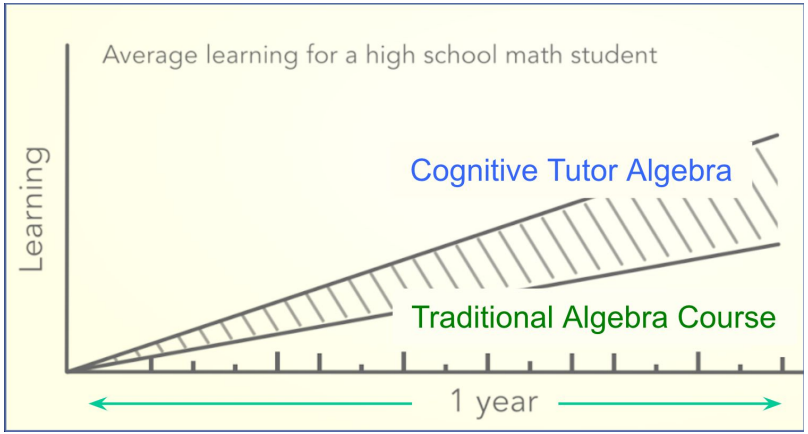
- Two algorithms use the *cognitive model* to approximate personalized tutoring:
- Model Tracing: Follows student through their individual approach to a problem => context-sensitive instruction
- Knowledge Tracing: Assesses student's knowledge growth => individualized activity selection and pacing

Koedinger et al. (2013). New potentials for data-driven intelligent tutoring system development and optimization. *AI Magazine.*

Cognitive Tutor Experiments

- Early quasi-experiment
  - 2x better learning
- Wide adoption
  - ~500k students per year
  - ~80 minutes per week
- Huge random assignment experiment
  - 120 schools
  - 2x better learning



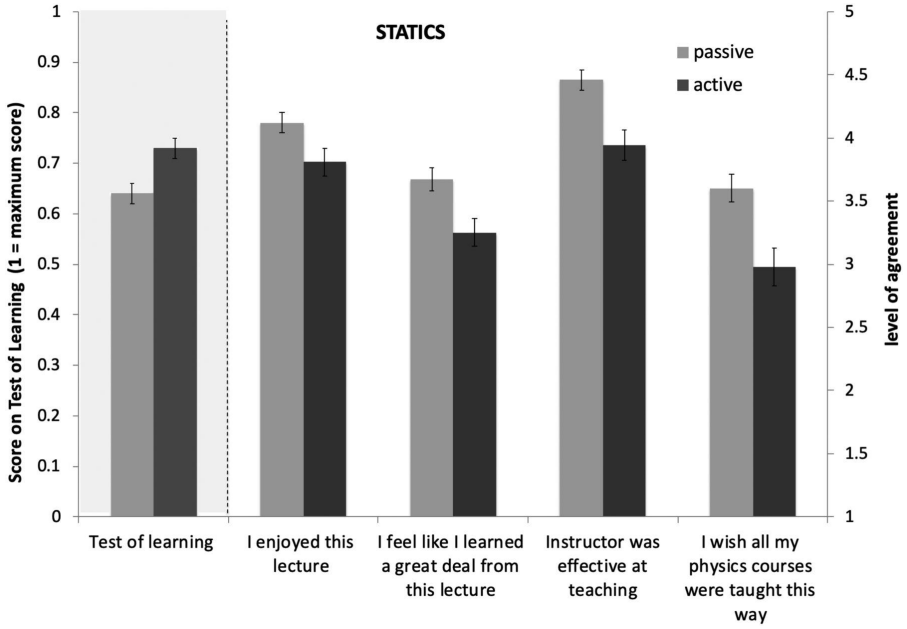


Koedinger et al. (1997). Intelligent Tutoring Goes to School in the Big City. *Artificial Intelligence in Education*.

Pane et al. (2013). Effectiveness of Cognitive Tutor Algebra I at Scale. Santa Monica, CA: RAND Corp.

How might “Optimizing Learning” be done? - Active Learning

Active problem solving results in more learning than lecturing.



Deslauriers, L., McCarty, L. S., Miller, K., Callaghan, K., & Kestin, G. (2019). Measuring actual learning versus feeling of learning in response to being actively engaged in the classroom. Proceedings of the National Academy of Sciences, 116(39), 19251-19257.

How might optimizing learning be done?

- Commonalities:
  - Feedback
  - Active engagement
  - Personalized
  - Learning by doing -> problem solving
  - ....
- Experts are required in creating learning environments that provide the above properties. **Very Hard!!!**

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  Example: lecture (passive) is prominent in STEM teaching. (Stains et al., 2018, Science)

Stains, M., Harshman, J., Barker, M. K., Chasteen, S. V., Cole, R., DeChenne-Peters, S. E., ... & Young, A. M. (2018). Anatomy of STEM teaching in North American universities. Science, 359(6383), 1468-1470.

Create high quality learning opportunities

- Human-alone:
- AI-alone:
  - **NLP-powered Automatic QG systems do not meet educational needs**
  - **The way algorithms work is very different from how human experts construct questions**
- **Human-AI: our focus today**
  - **Instructional design is knowledge intensive, experts input are required**
  - **How to design human-AI collaborative interfaces to enable the efficient authoring of tutoring opportunities?**

Survey 1

https://forms.gle/4CxXMGTxzAAiDJof7

https://www.yellkey.com/leg

Which of the following are ways that "Optimizing Learning" can be done according to the lecture? *

- [ ] Deliberate practice
- [ ] Mastery leanring with feedback-corrective procedure
- [ ] Intelligent tutoring systems
- [ ] Listening to a lecture