EDUC 545: Intelligent Tutoring Systems
Fall 2020
Professor Ryan Baker

SYLLABUS

Instructor Info
Email: rybaker@upenn.edu
Office hours: Wednesdays, 815am-9am
Course time: Friday, 715pm-815pm
Office hours and course location: https://bluejeans.com/rybaker/
Class discussion forum: piazza.com/upenn/fall2020/educ545

Required Texts:
- None

Information on how to obtain course readings will be provided on the course discussion forum.

Course Goals: More and more education takes place asynchronously and online (especially this semester), but relatively little asynchronous instruction takes advantage of the technological advancements that have taken place in recent decades, replicating traditional models for instruction online.

In this class, you will learn about the pedagogy and technology of intelligent tutoring systems (often referred to as adaptive learning systems), individualized and personalized technology that helps students construct understanding and develop skill.

We will read and reflect on both classic and recent papers on this technology, and study many of the successful examples of intelligent tutoring systems, both systems that have scaled and systems that have failed to scale. We will investigate key methods this type of learning leverages, and key pedagogies it affords.

This class will use a connectivist pedagogy, where you will teach and learn from your classmates, with heavy involvement from the professor as a participant in discussions.

Course Pre-requisites: None.

Assignments:

This course will be graded on the basis of three assignments:
1. Topical Review
2. System Review
3. Participation

For the topical review, every student will select a course topic and prepare a presentation of this topic, using an asynchronous learning or communication technology of your choice. For example, this assignment could be completed by creating slides with video and/or audio, a webpage, an intelligent tutoring system, or a game. This presentation should represent a comprehensive discussion of the topic, its history of research in the field, key findings, and key open questions or challenges. This assignment will be due according to the course syllabus – each topic will be due exactly five days before it is covered in synchronous class (i.e. exactly 120 hours before class starts). This assignment may be individual or

conducted in a group, depending on class size. After you post this presentation, your classmates (and I) will comment on your presentation and ask questions, and you will lead a discussion of the topic in the discussion forum.

For the system review, every student will select a notable intelligent tutoring system (from a list recommended by the professor, or your own choice approved by the professor). You will write a brief (5-8 page) paper describing the system, how it works, what pedagogies it supports, and how well it has worked with real learners. This assignment is due November 15.

Participation in asynchronous activities will also be part of the course grade. Students are expected to provide at least two substantive comments several lines long on at least 10 (out of 13) topical reviews, and to provide at least two substantive comments several lines long on at least six other students' system reviews. In both cases, your comments should be targeted towards the content of the review (and the topic/system it describes) rather than on the presentation. To count towards your grade, your posts for topical reviews must be submitted within five days of the resource being posted, and your posts for system reviews must be submitted within 14 days of the resource being posted. Participation in the synchronous class will not be part of the course grade but is still encouraged.

Given the state of the world in 2020, extensions will be given on the system review as needed. However, please be reasonable. Turning in the topical review late will impact your classmates' learning experiences, so any delay will result in a 20% penalty on the assignment, which will increase as the assignment gets later. *You are strongly recommended to complete your topical review early* so that disruptions in the world (which we can all expect) do not impact your classmates. *This is not the sort of assignment that you should start two days before the due date.*

No examinations will be given in this class.

Grading

- Topical Review 33.33%
- System Review 33.33%
- Participation 33.33%

Course Schedule

Intelligent Tutoring Systems
Professor Ryan S. Baker

Fri, Sep. 4
Introduction and Do These Things Work?

Readings

- https://en.wikipedia.org/wiki/Intelligent_tutoring_system
- https://en.wikipedia.org/wiki/Adaptive_learning
- VanLehn, K. (2011). The relative effectiveness of human tutoring, intelligent tutoring systems, and other tutoring systems. *Educational Psychologist*, *46*(4), 197-221.
- Kerr, P. (2016). Adaptive learning. *ELT Journal*, *70*(1), 88-93.

Fri, Sep. 11
Knowledge Communication, Knowledge Construction, or Procedural Skill Development: What's the Point?

Readings

- Anderson, J. R., Corbett, A. T., Koedinger, K. R., & Pelletier, R. (1995). Cognitive tutors: Lessons learned. *The journal of the learning sciences*, *4*(2), 167-207.
- Graesser, A. C., VanLehn, K., Rosé, C. P., Jordan, P. W., & Harter, D. (2001). Intelligent tutoring systems with conversational dialogue. *AI magazine*, *22*(4), 39-39.
- Wenger, E. (2014). *Artificial intelligence and tutoring systems: computational and cognitive approaches to the communication of knowledge*. Morgan Kaufmann. Chapter 1: Knowledge Communication

Fri, Sep. 18
Knowledge Tracing and Mastery Learning

Core Readings

- Corbett, A. (2001). Cognitive computer tutors: Solving the two-sigma problem. In *International Conference on User Modeling* (pp. 137-147). Springer, Berlin, Heidelberg.
- Ritter, S., Yudelson, M., Fancsali, S. E., & Berman, S. R. (2016). How mastery learning works at scale. In *Proceedings of the Third (2016) ACM Conference on Learning@ Scale* (pp. 71-79).

Secondary Readings

- Pelánek, R., & Řihák, J. (2018). Analysis and design of mastery learning criteria. *New Review of Hypermedia and Multimedia*, *24*(3), 133-159.
- Emery, A., Sanders, M., Anderman, L. H., & Yu, S. L. (2018). When mastery goals meet mastery learning: Administrator, teacher, and student perceptions. *The Journal of Experimental Education*, *86*(3), 419-441.
- Lee, J. I., & Brunskill, E. (2012). The Impact on Individualizing Student Models on Necessary Practice Opportunities. *Proceedings of the International Conference on Educational Data Mining Society*.

- Guskey, T. R., & Gates, S. L. (1986). Synthesis of research on the effects of mastery learning in elementary and secondary classrooms. *Educational leadership*, *43*(8), 73.
- Sales, A. C., & Pane, J. F. (2019). The role of mastery learning in an intelligent tutoring system: Principal stratification on a latent variable. *The Annals of Applied Statistics*, *13*(1), 420-443.

Fri, Sep. 25
Knowledge Graphs and Prerequisite Tracing

Core Readings

- Essa, A. (2016). A possible future for next generation adaptive learning systems. *Smart Learning Environments*, *3*(1), 16.
- Zou, X., Ma, W., Ma, Z., Baker, R. (2019) Towards Helping Teachers Select Optimal Content for Students. *Proceedings of the 20th International Conference on Artificial Intelligence in Education*, 413-417.

Secondary Readings

- Desmarais, M. C., Meshkinfam, P., & Gagnon, M. (2006). Learned student models with item to item knowledge structures. *User Modeling and User-Adapted Interaction*, *16*(5), 403-434.
- Chen, P., Lu, Y., Zheng, V. W., Chen, X., & Yang, B. (2018). KnowEdu: a system to construct knowledge graph for education. *IEEE Access*, *6*, 31553-31563.
- Krauss, C., Salzmann, A., & Merceron, A. (2018). Branched Learning Paths for the Recommendation of Personalized Sequences of Course Items. In *DeLFI Workshops*.
- Brunskill, E. (2011). Estimating Prerequisite Structure From Noisy Data. *Proceedings of the International Conference on Educational Data Mining* (pp. 217-222).
- Chen, Y., González-Brenes, J. P., & Tian, J. (2016). Joint Discovery of Skill Prerequisite Graphs and Student Models. *Proceedings of the International Conference on Educational Data Mining*

Fri, Oct. 2
Memory Optimization and Spiraling Review

Core Readings

- Wang, Y., & Heffernan, N. T. (2014). The effect of automatic reassessment and relearning on assessing student long-term knowledge in mathematics. In *International Conference on Intelligent Tutoring Systems* (pp. 490-495). Springer, Cham.
- Seibert Hanson, A. E., & Brown, C. M. (2020). Enhancing L2 learning through a mobile assisted spaced-repetition tool: an effective but bitter pill?. *Computer Assisted Language Learning*, *33*(1-2), 133-155.

Secondary Readings

- Pavlik, P., Bolster, T., Wu, S. M., Koedinger, K., & Macwhinney, B. (2008). Using optimally selected drill practice to train basic facts. In *International conference on intelligent tutoring systems* (pp. 593-602). Springer, Berlin, Heidelberg.
- Settles, B., & Meeder, B. (2016). A trainable spaced repetition model for language learning. In *Proceedings of the 54th annual meeting of the association for computational linguistics (volume 1: long papers)* (pp. 1848-1858).
- Khajah, M. M., Lindsey, R. V., & Mozer, M. C. (2014). Maximizing students' retention via spaced review: Practical guidance from computational models of memory. *Topics in cognitive science*, *6*(1), 157-169.

Fri, Oct. 9
Hints and Feedback

Core Readings

- Hattie, J., & Timperley, H. (2007). The power of feedback. *Review of educational research*, *77*(1), 81-112.
- Aleven, V., Mclaren, B., Roll, I., & Koedinger, K. (2006). Toward meta-cognitive tutoring: A model of help seeking with a Cognitive Tutor. *International Journal of Artificial Intelligence in Education*, *16*(2), 101-128.

Secondary Readings

- Wisniewski, B., Zierer, K., & Hattie, J. (2020). The power of feedback revisited: A meta-analysis of educational feedback research. *Frontiers in Psychology*, *10*, 3087.
- McKendree, J. (1990). Effective feedback content for tutoring complex skills. *Human-computer interaction*, *5*(4), 381-413.
- Keuning, H., Jeuring, J., & Heeren, B. (2018). A systematic literature review of automated feedback generation for programming exercises. *ACM Transactions on Computing Education (TOCE)*, *19*(1), 1-43.
- Heiner, C., Beck, J., & Mostow, J. (2004). Improving the help selection policy in a Reading Tutor that listens. In *InSTIL/ICALL Symposium 2004*.
- Hume, G., Michael, J., Rovick, A., & Evens, M. (1996). Hinting as a tactic in one-on-one tutoring. *The Journal of the Learning Sciences*, *5*(1), 23-47.
- Razzaq, L., & Heffernan, N. T. (2010, June). Hints: is it better to give or wait to be asked?. In *International Conference on Intelligent Tutoring Systems* (pp. 349-358). Springer, Berlin, Heidelberg.
- Almeda, V., Baker, R., Corbett, A. (2017) Help Avoidance: When Students Should Seek Help, and the Consequences of Failing to Do So. *Teachers College Record*, 117 (3).

Fri, Oct. 16
Model Tracing, Constraint-Based Tutoring, and Canned Answers

Core Readings

- Anderson, J. R., Boyle, C. F., Corbett, A. T., & Lewis, M. W. (1990). Cognitive modeling and intelligent tutoring. *Artificial intelligence*, *42*(1), 7-49.
- Mitrovic, A., Koedinger, K. R., & Martin, B. (2003). A comparative analysis of cognitive tutoring and constraint-based modeling. In *International Conference on User Modeling* (pp. 313-322). Springer, Berlin, Heidelberg.

Secondary Readings

- Roll, I., Aleven, V., & Koedinger, K. R. (2010). The invention lab: Using a hybrid of model tracing and constraint-based modeling to offer intelligent support in inquiry environments. In *International Conference on Intelligent Tutoring Systems* (pp. 115-124). Springer, Berlin, Heidelberg.
- Mitrovic, A. (2012). Fifteen years of constraint-based tutors: what we have achieved and where we are going. *User modeling and user-adapted interaction*, *22*(1-2), 39-72.
- Paquette, L., Lebeau, J. F., & Mayers, A. (2010). Authoring problem-solving tutors: A comparison between ASTUS and CTAT. In *Advances in intelligent tutoring systems* (pp. 377-405). Springer, Berlin, Heidelberg.

- Aleven, V., McLaren, B. M., Sewall, J., Van Velsen, M., Popescu, O., Demi, S., ... & Koedinger, K. R. (2016). Example-tracing tutors: Intelligent tutor development for non-programmers. *International Journal of Artificial Intelligence in Education*, *26*(1), 224-269.

Fri, Oct. 23
Assessing and Tutoring Complex Behavior

Core Readings

- Li, H., Gobert, J., Dickler, R., & Moussavi, R. (2018). The impact of multiple real-time scaffolding experiences on science inquiry practices. In *International Conference on Intelligent Tutoring Systems* (pp. 99-109). Springer, Cham.
- Stamper, J., Eagle, M., Barnes, T., & Croy, M. (2013). Experimental evaluation of automatic hint generation for a logic tutor. *International Journal of Artificial Intelligence in Education*, *22*(1-2), 3-17.

Secondary Readings

- Kim, Y. J., Almond, R. G., & Shute, V. J. (2016). Applying evidence-centered design for the development of game-based assessments in physics playground. *International Journal of Testing*, *16*(2), 142-163.
- Rowe, E., Asbell-Clarke, J., Baker, R.S., Eagle, M., Hicks, A.G., Barnes, T.M., Brown, R.A., Edwards, T. (2017) Assessing Implict Science Learning in Digital Games. *Computers in Human Behavior*, 76C, 617-630.
- Sao Pedro, M.A., Baker, R.S.J.d., Gobert, J., Montalvo, O. Nakama, A. (2013) Leveraging Machine-Learned Detectors of Systematic Inquiry Behavior to Estimate and Predict Transfer of Inquiry Skill. *User Modeling and User-Adapted Interaction, 23* (1), 1-39.
- Gobert, J. D., Moussavi, R., Li, H., Sao Pedro, M., & Dickler, R. (2018). Real-time scaffolding of students' online data interpretation during inquiry with Inq-ITS using educational data mining. In *Cyber-physical laboratories in engineering and science education* (pp. 191-217). Springer, Cham.

Fri, Oct. 30
Essay Writing and Automated Scoring

Core Readings

- Roscoe, R. D., & McNamara, D. S. (2013). Writing Pal: Feasibility of an intelligent writing strategy tutor in the high school classroom. *Journal of Educational Psychology*, *105*(4), 1010.
- Rus, V., Olney, A. M., Foltz, P. W., & Hu, X. (2017). Automated Assessment of Learner-Generated Natural Language Responses. *Design Recommendations for Intelligent Tutoring Systems: Assessment Methods*, *5*, 155-170.

Secondary Readings

- Crossley, S., Roscoe, R., & McNamara, D. (2013). Using automatic scoring models to detect changes in student writing in an intelligent tutoring system. In *The Twenty-Sixth International FLAIRS Conference*.
- Roscoe, R. D., Snow, E. L., & McNamara, D. S. (2013). Feedback and revising in an intelligent tutoring system for writing strategies. In *International Conference on Artificial Intelligence in Education* (pp. 259-268). Springer, Berlin, Heidelberg.

- Foltz, P. W. (2016). Advances in automated scoring of writing for performance assessment. In *Handbook of Research on Technology Tools for Real-World Skill Development* (pp. 659-678). IGI Global.
- Foltz, P. W., & Rosenstein, M. (2015). Analysis of a large-scale formative writing assessment system with automated feedback. In *Proceedings of the Second (2015) ACM Conference on Learning@ Scale* (pp. 339-342).
- Attali, Y., & Burstein, J. (2006). Automated essay scoring with e-rater® V. 2. *The Journal of Technology, Learning and Assessment*, *4*(3).

Fri, Nov. 6
Tutoring Metacognition and Self-Regulated Learning

Core Readings

- Aleven, V., Roll, I., McLaren, B. M., & Koedinger, K. R. (2016). Help helps, but only so much: Research on help seeking with intelligent tutoring systems. *International Journal of Artificial Intelligence in Education*, *26*(1), 205-223.
- Bouchet, F., Harley, J. M., & Azevedo, R. (2016). Can adaptive pedagogical agents' prompting strategies improve students' learning and self-regulation?. In *International conference on intelligent tutoring systems* (pp. 368-374).

Secondary Readings

- Biswas, G., Roscoe, R., Jeong, H., & Sulcer, B. (2009). Promoting self-regulated learning skills in agent-based learning environments. In *Proceedings of the 17th international conference on computers in education* (pp. 67-74).
- Azevedo, R., & Hadwin, A. F. (2005). Scaffolding self-regulated learning and metacognition–Implications for the design of computer-based scaffolds. *Instructional Science.*
- Long, Y., & Aleven, V. (2017). Enhancing learning outcomes through self-regulated learning support with an Open Learner Model. *User Modeling and User-Adapted Interaction*, *27*(1), 55-88.

Fri, Nov. 13
Supporting Affect and Engagement

Core Readings

- DeFalco, J.A., Rowe, J.P., Paquette, L., Georgoulas-Sherry, V., Brawner, K., Mott, B.W., Baker, R.S., Lester, J.C. (2018) Detecting and Addressing Frustration in a Serious Game for Military Training. *International Journal of Artificial Intelligence and Education, 28* (2), 152-193.
- Arroyo, I., Woolf, B. P., Cooper, D. G., Burleson, W., & Muldner, K. (2011). The impact of animated pedagogical agents on girls' and boys' emotions, attitudes, behaviors and learning. In *2011 IEEE 11th International Conference on Advanced Learning Technologies* (pp. 506-510). IEEE.

Secondary Readings

- D'Mello, S., Lehman, B., Sullins, J., Daigle, R., Combs, R., Vogt, K., ... & Graesser, A. (2010). A time for emoting: When affect-sensitivity is and isn't effective at promoting deep learning. In *International conference on intelligent tutoring systems* (pp. 245-254). Springer, Berlin, Heidelberg.
- Arroyo, I., Ferguson, K., Johns, J., Dragon, T., Meheranian, H., Fisher, D., ... & Woolf, B. P. (2007). Repairing disengagement with non-invasive interventions. In *AIED* (Vol. 2007, pp. 195-202).

- Baker, R.S.J.d., Corbett, A.T., Koedinger, K.R., Evenson, S.E., Roll, I., Wagner, A.Z., Naim, M., Raspat, J., Baker, D.J., Beck, J. (2006) Adapting to When Students Game an Intelligent Tutoring System. *Proceedings of the 8th International Conference on Intelligent Tutoring Systems*, 392-401.
- Rajendran, R., Iyer, S., & Murthy, S. (2018). Personalized affective feedback to address students' frustration in ITS. *IEEE Transactions on Learning Technologies*, *12*(1), 87-97.
- D'Mello, S., Lehman, B., Pekrun, R., & Graesser, A. (2014). Confusion can be beneficial for learning. *Learning and Instruction*, *29*, 153-170.
- Mendez, G. R., du Boulay, B., & Luckin, R. (2005). Be bold and take a challenge": Could motivational strategies improve help-seeking. In *Proceedings of the 2005 conference on Artificial Intelligence in Education: Supporting Learning through Intelligent and Socially Informed Technology* (pp. 459-466).

Fri, Nov. 20
Dialogue Tutors

Core Readings

- Nye, B. D., Graesser, A. C., & Hu, X. (2014). AutoTutor and family: A review of 17 years of natural language tutoring. *International Journal of Artificial Intelligence in Education*, *24*(4), 427-469.

Secondary Readings

- Wood, D. (2001). Scaffolding, contingent tutoring, and computer-supported learning. *International Journal of Artificial Intelligence in Education*, *12*(3), 280-293.
- Heffernan, N. T., Koedinger, K. R., & Razzaq, L. (2008). Expanding the model-tracing architecture: A 3rd generation intelligent tutor for algebra symbolization. *International Journal of Artificial Intelligence in Education*, *18*(2), 153-178.
- Litman, D. J., Rosé, C. P., Forbes-Riley, K., VanLehn, K., Bhembe, D., & Silliman, S. (2006). Spoken versus typed human and computer dialogue tutoring. *International Journal of Artificial Intelligence in Education*, *16*(2), 145-170.
- Millis, K., Forsyth, C., Butler, H., Wallace, P., Graesser, A., & Halpern, D. (2011). Operation ARIES!: A serious game for teaching scientific inquiry. In *Serious games and edutainment applications* (pp. 169-195). Springer, London.
- Boyer, K. E., Phillips, R., Wallis, M., Vouk, M., & Lester, J. (2008). Balancing cognitive and motivational scaffolding in tutorial dialogue. In *International conference on intelligent tutoring systems* (pp. 239-249). Springer, Berlin, Heidelberg.

Wed, Nov. 25
GSE HAS MOVED FRIDAY CLASSES TO WEDNESDAY FOR SHEER CONFUSINGNESS
Embodied Agents

Core Readings

- Graesser, A. C., Moreno, K., Marineau, J., Adcock, A., Olney, A., Person, N., & Tutoring Research Group. (2003). AutoTutor improves deep learning of computer literacy: Is it the dialog or the talking head? In *Proceedings of artificial intelligence in education* (pp. 47-54).
- Baylor, A. L. (2009). Promoting motivation with virtual agents and avatars: role of visual presence and appearance. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *364*(1535), 3559-3565.

Secondary Readings

- Kim, Y., Baylor, A. L., & Shen, E. (2007). Pedagogical agents as learning companions: the impact of agent emotion and gender. *Journal of Computer Assisted Learning*, *23*(3), 220-234.
- Arroyo, I., Woolf, B. P., Cooper, D. G., Burleson, W., & Muldner, K. (2011). The impact of animated pedagogical agents on girls' and boys' emotions, attitudes, behaviors and learning. In *2011 IEEE 11th International Conference on Advanced Learning Technologies* (pp. 506-510). IEEE.
- Conati, C., & Zhao, X. (2004). Building and evaluating an intelligent pedagogical agent to improve the effectiveness of an educational game. In *Proceedings of the 9th international conference on Intelligent user interfaces* (pp. 6-13).
- van der Meij, H., van der Meij, J., & Harmsen, R. (2015). Animated pedagogical agents effects on enhancing student motivation and learning in a science inquiry learning environment. *Educational technology research and development*, *63*(3), 381-403.
- Johnson, W. L., & Rickel, J. (1997). Steve: An animated pedagogical agent for procedural training in virtual environments. *ACM SIGART Bulletin*, *8*(1-4), 16-21.
- Kim, Y., & Baylor, A. L. (2016). based design of pedagogical agent roles: A review, progress, and recommendations. *International Journal of Artificial Intelligence in Education*, *26*(1), 160-169.

Fri, Dec. 4
Games and Gamification

Core Readings

- Jackson, G. T., & McNamara, D. S. (2013). Motivation and performance in a game-based intelligent tutoring system. *Journal of Educational Psychology*, *105*(4), 1036.
- Johnson, W. L., Vilhjálmsson, H. H., & Marsella, S. (2005). Serious games for language learning: How much game, how much AI?. In *AIED* (Vol. 125, No. 1, pp. 306-313).

Secondary Readings

- Lomas, J. D., Koedinger, K., Patel, N., Shodhan, S., Poonwala, N., & Forlizzi, J. L. (2017). Is difficulty overrated? The effects of choice, novelty and suspense on intrinsic motivation in educational games. In *Proceedings of the 2017 CHI conference on human factors in computing systems* (pp. 1028-1039).
- Lomas, D., Patel, K., Forlizzi, J. L., & Koedinger, K. R. (2013). Optimizing challenge in an educational game using large-scale design experiments. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 89-98).
- Shute, V. J. (2011). Stealth assessment in computer-based games to support learning. *Computer games and instruction*, *55*(2), 503-524.
- Kim, Y. J., & Shute, V. J. (2015). The interplay of game elements with psychometric qualities, learning, and enjoyment in game-based assessment. *Computers & Education*, *87*, 340-356.
- Hamari, J., Shernoff, D. J., Rowe, E., Coller, B., Asbell-Clarke, J., & Edwards, T. (2016). Challenging games help students learn: An empirical study on engagement, flow and immersion in game-based learning. *Computers in human behavior*, *54*, 170-179.
- Ketelhut, D. J., Nelson, B. C., Clarke, J., & Dede, C. (2010). A multi-user virtual environment for building and assessing higher order inquiry skills in science. *British Journal of Educational Technology*, *41*(1), 56-68.
- Millis, K., Forsyth, C., Wallace, P., Graesser, A. C., & Timmins, G. (2017). The impact of game-like features on learning from an intelligent tutoring system. *Technology, Knowledge and Learning*, *22*(1), 1-22.

- Long, Y., & Aleven, V. (2017). Educational game and intelligent tutoring system: A classroom study and comparative design analysis. *ACM Transactions on Computer-Human Interaction (TOCHI)*, *24*(3), 1-27.
- Long, Y., & Aleven, V. (2014). Gamification of joint student/system control over problem selection in a linear equation tutor. In *International Conference on Intelligent Tutoring Systems* (pp. 378-387). Springer, Cham.

Fri, Dec. 11
A/B Testing and Iterative Refinement

Core Readings

- Ostrow, K. S., Heffernan, N. T., & Williams, J. J. (2017). Tomorrow's edtech today: establishing a learning platform as a collaborative research tool for sound science. *Teachers College Record*, *119*(3), 300-306.

Secondary Readings

- Koedinger, K. R., & Sueker, E. L. (2014) Monitored Design of an Effective Learning Environment for Algebraic Problem Solving.
- Savi, A. O., Ruijs, N. M., Maris, G. K., & van der Maas, H. L. (2018). Delaying access to a problem-skipping option increases effortful practice: Application of an A/B test in large-scale online learning. *Computers & Education*, *119*, 84-94.
- Brinkhuis, M. J., Savi, A. O., Hofman, A. D., Coomans, F., van Der Maas, H. L., & Maris, G. (2018). Learning as It Happens: A Decade of Analyzing and Shaping a Large-Scale Online Learning System. *Journal of Learning Analytics*, *5*(2), 29-46.
- Williams, J. J., Ostrow, K., Xiong, X., Glassman, E., Kim, J., Maldonado, S. G., ... & Heffernan, N. (2015). Using and designing platforms for in vivo educational experiments. In *Proceedings of the Second (2015) ACM Conference on Learning@ Scale* (pp. 409-412).
- Sales, A., Botelho, A. F., Patikorn, T., & Heffernan, N. T. (2018). Using big data to sharpen design-based inference in A/B tests. In *Proceedings of the Eleventh International Conference on Educational Data Mining*.
- NeCamp, T., Gardner, J., & Brooks, C. (2019). Beyond A/B Testing: Sequential Randomization for Developing Interventions in Scaled Digital Learning Environments. In *Proceedings of the 9th International Conference on Learning Analytics & Knowledge* (pp. 539-548).

Fri, Dec. 18
Intelligent Tutoring Systems in the Classroom

Core Readings

- Miller, W.L., Baker, R., Labrum, M., Petsche, K., Liu, Y-H., Wagner, A. (2015) Automated Detection of Proactive Remediation by Teachers in Reasoning Mind Classrooms. *Proceedings of the 5th International Learning Analytics and Knowledge Conference*, 290-294.
- Xhakaj, F., Aleven, V., & McLaren, B. M. (2017). Effects of a teacher dashboard for an intelligent tutoring system on teacher knowledge, lesson planning, lessons and student learning. In *European conference on technology enhanced learning* (pp. 315-329). Springer, Cham.

Secondary Readings

- Holstein, K., McLaren, B. M., & Aleven, V. (2019). Co-Designing a Real-Time Classroom Orchestration Tool to Support Teacher-AI Complementarity. Journal of Learning Analytics, 6(2), 27-52
- Feng, M., & Heffernan, N. T. (2006). Informing teachers live about student learning: Reporting in the assistment system. Technology Instruction Cognition and Learning, 3(1/2), 63
- Sales, A. C., Wilks, A., & Pane, J. F. (2016). Student Usage Predicts Treatment Effect Heterogeneity in the Cognitive Tutor Algebra I Program. *Proceedings of the International Conference on Educational Data Mining*.
- Staker, H., & Horn, M. B. (2012). Classifying K-12 blended learning. *Innosight Institute*.
- Rockoff, J. E. (2015). Evaluation report on the School of One i3 expansion. *Unpublished manuscript. New York, NY: Columbia University*.