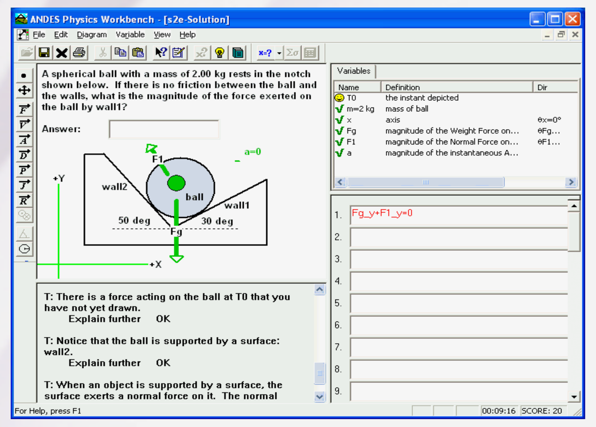
THE GRADUATE SCHOOL
NORTHWESTERN UNIVERSITY

Motivating SimClass: Vicarious Learning in Intelligent Tutoring Systems

Adel D. Lahlou
Mellon Mays Undergraduate Fellow

Doug Downey, Ph. D
Northwestern University EECS Department



Andes Demo, ITS for Physics (ITS 2008)

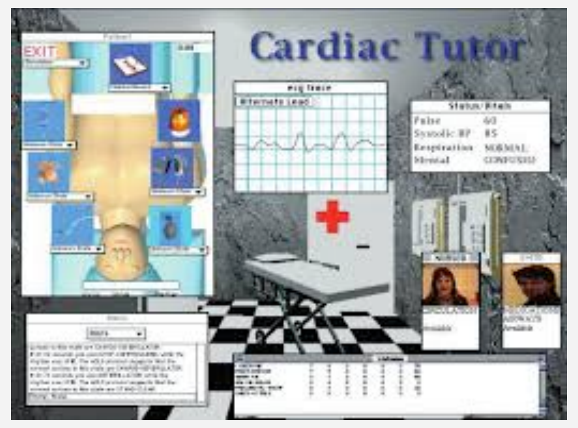
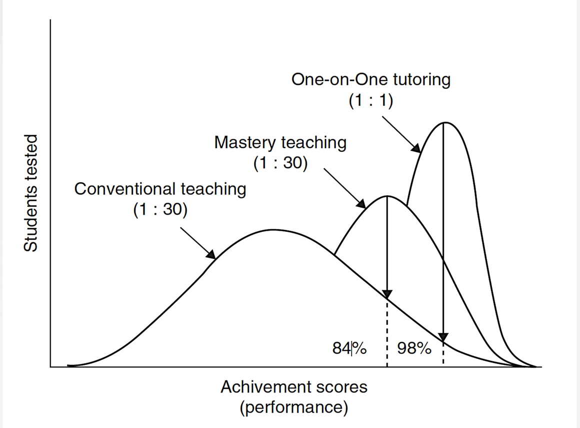
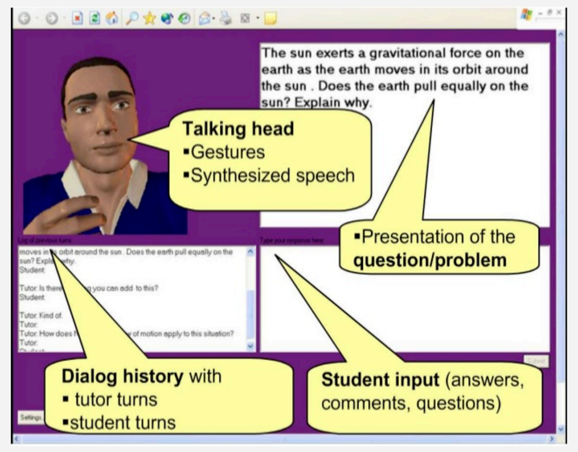


Image of Cardiac Tutor, used for training medical personnel (Woolf 1996)



Graph of benefit of one-on-one learning compared to other styles. (Woolf 2009)



Four-Component Instructional Design, AutoTutor (NCSU 2013)

Graph of benefit of one-on-one learning and examples of Intelligent Tutors

Introduction

Intelligent Tutoring Systems (ITS) traditionally employ multiple agent models and apply pedagogy such as constructivism to replicate the well-founded benefits of one-on-one tutoring for building proficiency in task domains. Previous works on collaborative learning ITS emphasize the importance of group learning and sociocultural communities that improve metacognitive skills such as self-reflection, source analysis, and community identity, but have limited accessibility. Vicarious learning and generative learning are diminished in ITS that lack mixed initiative and comprehensive question-response components. Few works have explored vicarious learning in ITS through simulated learning companions. The very few actually implemented were motivated largely by learning theories. This work motivates SimClass, a vicarious learning experience, in the context of addressing the limitations of current prominent ITS and presents initial design choices.

Approach

Established recognized principles in education and cognitive theory since these vary between ITS. Included learning theories such as behaviorism and constructivism, knowledge components, and media learning.

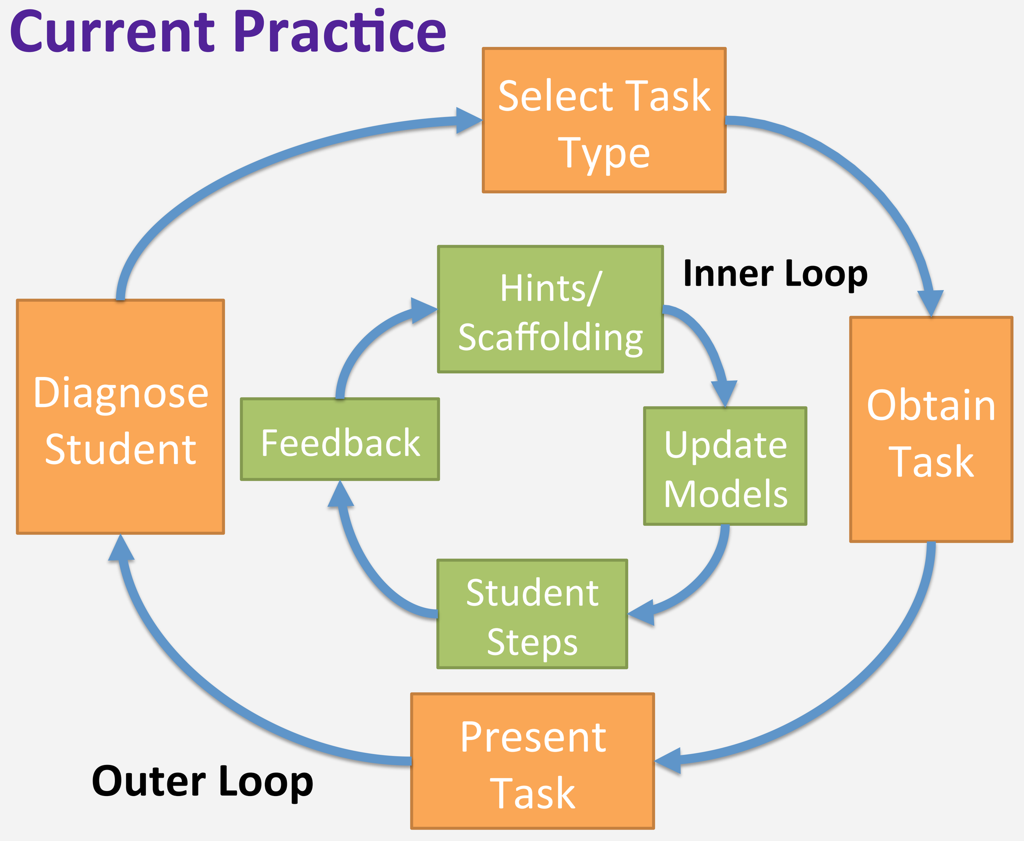
Devised framework that synthesized other frameworks for different ITS components, stated essential ITS features and principles, engineering ease, and discussed value of select evaluation techniques for educational impact.

Evaluated pros and cons of prominent ITS qualitatively based on available literature and framework, focusing on issues of metacognitive skill development, "teaching talk," "meaning making," and remediation.

Designed new components for vicarious learning in ITS based on the pattern of the greatest concerns found during evaluation. Use of simulated learning companions to address engineering, cognitive modeling, and educational limitations was found to be a suitable scheme.

Evaluation & Design

Current Practice



Limitations

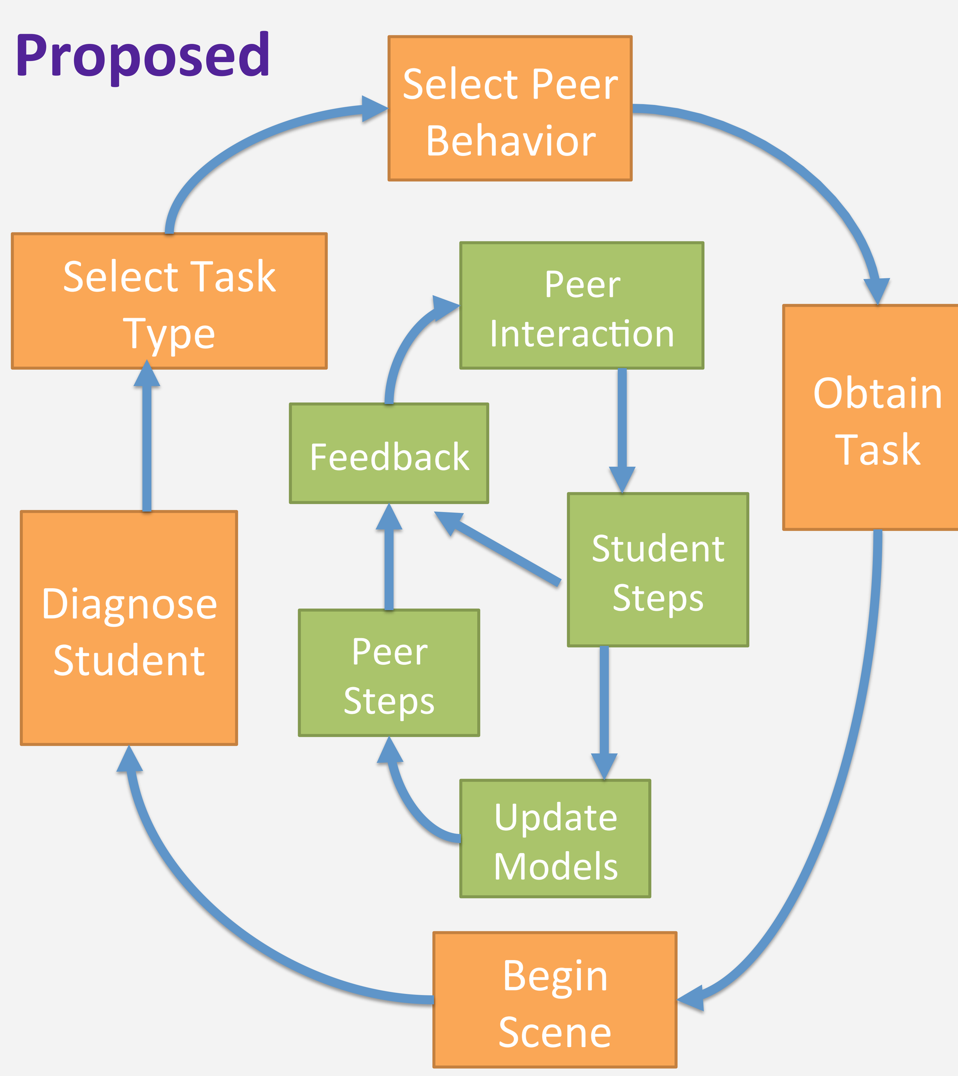
Outer Loop (OL):
- Naturally breaks coherence principle.
- In directed ITS, pace is non-adaptable.
- Macroadaptive task generation is rare leading to redundancy of tasks.
- Task driven learning can be frustrating or boring depending on preferences.

Inner Loop (IL):
- Student steps are only form of assessment event, which constrains diagnosis, GUI, and KC modeling.
- Multiple misconception remediation difficult without extensive testing.
- Little room for tutor error.
- Feedback and hint systems often discourage student questioning.

Engineering
- More time making powerful models than grabbing "low-hanging fruit."
- Collaborative scripts are complex.

Overview of the generalized Outer-Inner Loop Model of recent Intelligent Tutors

Proposed



Motivation of Choices

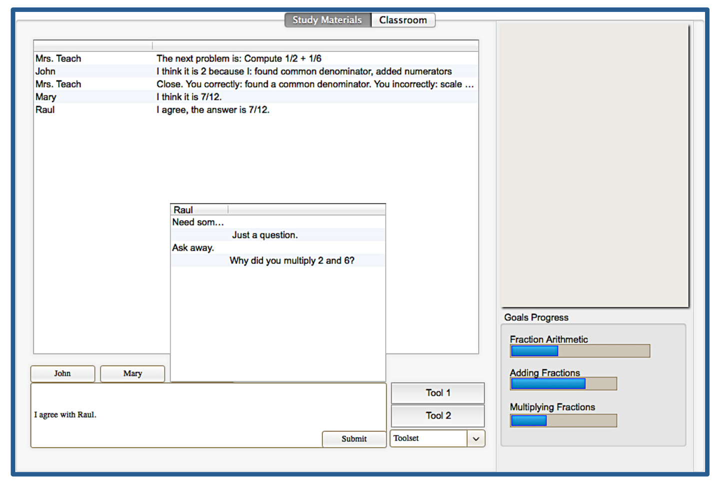
Adapting Peer Behavior:
- Changes the behavior of peers to encourage different types of learning (observational, generational, etc.) based on student performance. Macroadaptive.

Peer Steps and Feedback to Peers:
- Encourages observational learning and reduces opportunity for "gaming" hints.
- Provides scaffolding organically with less chance of causing frustration.
- Employs dialogue based learning which has been shown to be more effective.
- Allows multiple misconception remediation without need for new model

Peer Interaction:
- Facilitates learning through questioning.
- Develops skills to identify misconceptions such as source analysis and reflection.

Challenges of this Design:
- Same, if not greater, complexity of collaborative scripts but more accessible
- Needs to apply model to choose behavior
- Simple elements of mixed initiative needed, though nothing novel.

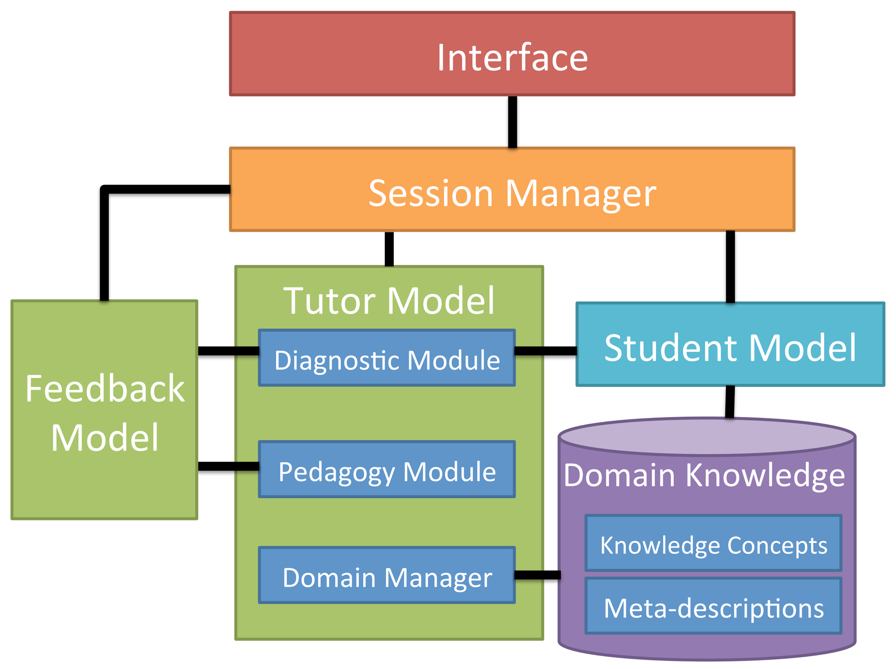
Proposed behavior of SimClass to employ vicarious learning using simulated learning companions



An image of a simple mockup of SimClass that uses an all text interface. This concept uses a shared class chat component that facilitates observational learning and scaffolding. Scripted private chat options with different students should facilitate deeper learning through questions and promote skills such as source analysis. Peer tutoring could be integrated, but would greatly increase complexity.

References

[1] B. P. Woolf, *Building intelligent interactive tutors: Student-centered strategies for revolutionizing e-learning*. Morgan Kaufmann, 2010.
[2] D. M. Driscoll, S. D. Craig, B. Gholson, M. Ventura, X. Hu, and A. C. Graesser, "VICARIOUS LEARNING: EFFECTS OF OVERHEARING DIALOG AND MONOLOGUE-LIKE DISCOURSE IN A VIRTUAL TUTORING SESSION," *Journal of Educational Computing Research*, vol. 29, no. 4, pp. 431–450, Feb. 2004.
[3] B. Gholson and S. D. Craig, "Promoting Constructive Activities that Support Vicarious Learning During Computer-Based Instruction," *Educ Psychol Rev*, vol. 18, no. 2, pp. 119–139, Jul. 2006.
[4] M. T. H. Chi, M. Roy, and R. G. M. Hausmann, *Observing Tutorial Dialogues Collaboratively: Insights about Human Tutoring Effectiveness from Vicarious Learning*.
[5] Koedinger, K.R., Corbett, A.T., Perfetti, C.: The Knowledge–Learning–Instruction (KLI) framework: toward bridging the science-practice chasm to enhance robust student learning. Technical report, Carnegie-Mellon University, Human Computer Interaction Institute, Pittsburgh (2011)

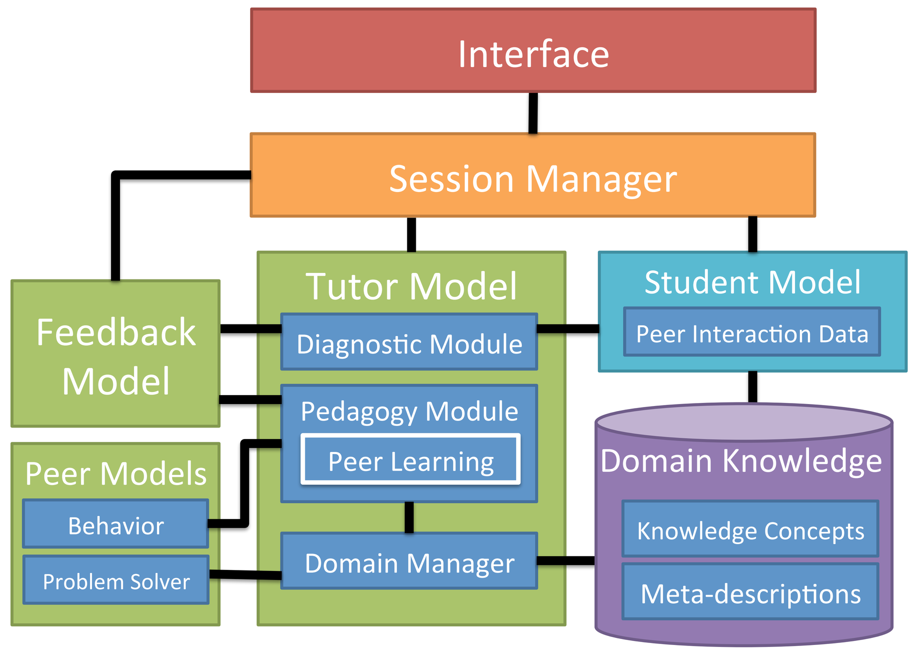


Existing Architecture

This diagram generalizes the architecture used by typical, complete Intelligent Tutoring Systems. Improvement of current ITS architecture depends on making advances in encoding domain knowledge, interpretation of mined education data, natural language processing, and models. These present difficult engineering challenges that require specific AI/technical skills, which are usually not available. This design is inflexible and does not support different education styles, causing poor diagnosis and misconception remediation. Collaborative scripts offer some answers to these problems.

Extended Architecture

The key takeaway is that this suggested architecture is meant to be an extension, to avoid presenting many new engineering challenges. This architecture should also benefit from the same advances that the existing ITS do. The introduction of a peer model component is to support different modes of learning, especially social learning. Given the precedent of collaborative scripts, it is expected that Peer Behavior can be scripted by task domain experts without extensive programming or AI knowledge. Components in need of development are behavior selection and generating "buggy" problem solvers.



Discussion

Most, if not all, literature motivated the utility of vicarious learning (VL) in ITS by applying learning theories. This work motivated VL prescriptively in the context of addressing shortcomings of existing ITS. The greatest limitations found in Cognitive Tutors and Constraint-Based Tutors were:

- Ideal solution modeling is difficult/impossible to engineer, constraining diagnosis of student error and preventing more in depth feedback,
- Greedy uncertainty models used to identify student misconceptions restrict remediation of multiple misconceptions by constricting focus, causing violations of the coherence and redundancy learning principles.
- Collaborative scripts require multiple willing students, complex scripted interaction, and do not ensure the higher order questioning needed.
- Devising cognitive scaffolding that maintains an authentic experience varies between task domains, causing duplicity of engineering.
- Analysis of reflective free prompt responses require extensive Natural Language engineering or greater human teacher input.
- Challenges of mixed initiative remain great despite ongoing research.

Vicarious learning via scripted simulated learning companions present a "low-hanging fruit" solution that presents relatively few new engineering obstacles and indeed addresses limitations in existing ITS. Future work will implement design choices and evaluate educational impact in a user study.

Acknowledgements

I would like to thank Professor Doug Downey for his guidance. I would also like to thank the Northwestern University Graduate School's SROP for making this possible.