# Enhancing Student Motivation and Learning Within Adaptive Tutors

Korinn S. Ostrow
Worcester Polytechnic Institute
100 Institute Road
Worcester, MA 01609
ksostrow@wpi.edu

## ABSTRACT

My research is rooted in improving K-12 educational practice using motivational facets made possible through adaptive tutoring systems. In an attempt to isolate best practices within the science of learning, I conduct randomized controlled trials within ASSISTments, an online adaptive tutoring system that provides assistance and assessment to students around the world. My work also incorporates big data analytics through the establishment of data driven learning models that promote the use of finite assessment to optimize student modeling and enhance user motivation. This paper highlights a turning point in my research as I transition into PhD candidacy. My contributions thus far and my research goals are discussed, with consult sought on how to best meld the realms of my work moving forward. An iteration of this work has also been published as a Doctoral Consortium at AIED 2015 [4].

## Keywords

Motivation, Learning, Feedback, Choice, Assessment Methodologies, Adaptive Tutoring

## 1. RESEARCH FOCUS

### 1.1 Adaptive Tutoring: ASSISTments

The U.S. Department of Education's National Educational Technology Plan supported the idea that technology will play a key role in delivering personalized educational interventions [14]. Yet there remains a severe lack of research regarding the effectiveness of online learning systems for K-12 education [15]. Adaptive tutoring systems offer interactive learning environments that allow students to excel while providing teachers a unique approach to classroom organization and data-driven lesson plans. Before the development of these adaptive platforms, research within classrooms was costly and generally required a longitudinal approach. As such, much of the evidence that supports K-12 educational practice is generalized from studies conducted by psychologists in laboratory settings with college undergraduates.

My research acts on this deficit, by conducting controlled trials using student level randomization within ASSISTments, an online adaptive tutoring system, to isolate best practices for learning outcomes while enriching the user experience. ASSISTments, commonly used for both classwork and homework, presents students with immediate feedback and a variety of rich tutorial strategies. The platform is also a powerful assessment tool, providing teachers with a variety of student and class reports that pinpoint where students are struggling and enhance classroom techniques using real time data. Further, the platform is unique in that it allows educational researchers to design and implement content-based experiments without extensive understanding of computer programming, serving as a shared collaborative tool for the advancement of the science of learning [3].

### 1.2 Motivational Trinity

Essentially, my work seeks to enhance student motivation and performance by enriching content through optimized feedback delivery, exploring opportunities to make students shareholders in the learning process, and attempting to boost motivation and proper system usage through improved assessment techniques.

#### *1.2.1 Feedback Mediums*

Until recently, virtually all feedback within the ASSISTments tutoring platform was provided using text, typically with font color or typeset signifying important variables. However, adaptive tutoring systems offer the opportunity to utilize a variety of hypermedia elements, as outlined by Mayer's multimedia principles for the optimal design of e-Learning environments [1]. These twelve principles, driven by cognitive theory, promote active learning while reducing cognitive load and accounting for the average user's working memory [1]. Educational technologies that employ video tend to do so in a manner that resembles lectures rather than feedback (i.e., Khan Academy). Thus, the introduction of matched content video feedback to the ASSISTments platform through brief 15-30 second YouTube recordings offered a novel approach to investigating hypermedia within an adaptive setting.

#### *1.2.2 Student Choice*

While platforms like ASSISTments offer a variety of features, few make students shareholders in the learning process. Despite the fact that users can endlessly customize their experiences with commercial products, student preference is not a key element in the realm of education. Choice is an intrinsically motivating force [11] that has the potential to boost subjective control, or a student's perception of their causal influence over their learning outcomes [12]. Feelings of control are balanced by appraisals of subjective value, or a student's perceived importance of her learning outcome. By providing the student with choices at the start of her assignment, it may be possible to enhance

expectancies regarding her performance and thereby enhance achievement emotions such as motivation [12]. Considering the control-value theory within the realm of an adaptive tutoring system for mathematics content may help to explain and ameliorate female dropout in STEM fields [2]. Feedback medium personalization offers one simple method to examine the motivational effect of choice within these platforms.

#### *1.2.3 Improving Assessment*

Adaptive tutoring systems typically function through measures of binary correctness on a student's first attempt or first action within a problem. Within such systems, students who take advantage of tutoring feedback are unduly penalized. This creates an environment in which students are afraid to use the beneficial features of these platforms, or instead, overuse feedback if they have already lost credit (i.e., skipping to the answer rather than reading a series of hints). The establishment of partial credit scoring would help to alleviate these issues, serving to motivate student performance while simultaneously offering teachers a more robust view of student knowledge. Using data mining approaches, partial credit can be defined algorithmically [16] for the purpose of enhancing student modeling. Real time implementation of these data driven models could offer substantial benefits for all parties.

## 2. PROPOSED CONTRIBUTIONS

Thus far, my work has lead to eight peer reviewed articles already published or in press, as well as a multitude of projects that are in progress. Projects that best highlight my goals as I transition to my PhD work are described in the following subsections.

### 2.1 Published Works

#### *2.1.1 Video vs. Text Feedback*

The ASSISTments platform was used to conduct a randomized controlled trial featuring matched content video and text feedback within the realm of middle school mathematics [7]. Results suggested significant effects of video feedback, showing enhanced learning outcomes on next question performance after receiving adaptive video tutoring, as well as increased efficiency. Further, through self-report it was observed that students perceived video as a positive addition to their assignment. This study was the first of its kind to explore the potential for replacing text feedback, already shown to be successful within ASSISTments [13], with an alternate medium. A scaled-up replication of this study is currently underway. This work inspired an influx of video content into the ASSISTments platform, providing new opportunities to examine the subtleties of video feedback, including a crowd-sourced approach to feedback creation.

#### *2.1.2 Dweckian Motivation*

Moving beyond the use of video feedback and into the realm of pedagogical agents, my co-authors and I sought to investigate the motivational effects of Dweckian inspired mindset training within ASSISTments feedback [10]. A six-condition design was used to examine how growth mindset messages promoting the malleability of intelligence delivered with domain based feedback effected motivation and learning outcomes. Conditions differed on elements of audiovisual message delivery, ranging from plain text to an animated pedagogical agent. Although limited by a small sample size and ceiling effects, analyses across five mathematics skills revealed that mindset messages altered student performance as measured by persistence, learning gain, and self-reported enjoyment of the system (trends, $p \approx 0.1$). Trends also pinpointed gender differences in response to messages delivered using the pedagogical agent.

#### *2.1.3 Partial Credit Assessment*

By data mining log files from ASSISTments usage spanning the 2012-2013 school year, this work established a simple student modeling technique for the prediction of next problem correctness (time $t + 1$) using algorithmically defined partial credit scores at time $t$ [5]. Although traditional modeling approaches and most adaptive tutors are driven by binary metrics of student correctness, employing partial credit can enhance student motivation and promote proper use of system features such as adaptive feedback, while allowing teachers a more robust understanding of student ability and simultaneously enhancing predictive modeling. Predictions gathered using a tabling approach based on maximum likelihood probabilities were able to compete with standard Knowledge Tracing models in terms of model accuracy, while drastically reducing computational costs [5].

### 2.2 Works in Press or in Progress

#### *2.2.1 Student Choice*

This work served as a pilot study on the addition of student choice into the ASSISTments platform [8]. This line of research examines motivation and learning when students are able to invest in the learning process. Students were randomly assigned to either Choice or No Choice conditions within a problem set on simple fraction multiplication. Those given choice were asked to select their feedback medium, while those without choice were randomly assigned to receive either text or video feedback. Results suggested that even if feedback was not ultimately used, students who were prompted to choose their feedback medium significantly outperformed those who were not. A second iteration of this study is currently underway using a new If-Then navigation infrastructure that was built because of the significant effects observed in the pilot. If previous results are replicated, these findings may be groundbreaking in that the addition of relatively inconsequential choices to adaptive tutoring systems could enhance student motivation and performance.

#### *2.2.2 Content Delivery Patterns*

Motivation and learning outcomes can also be improved by making content delivery more adaptive. Recent work within ASSISTments has revealed the benefit of interleaving (or mixing) skill content within homework settings [9]. Serving as a conceptual replication of previous work in the field, our goal was to isolate the interleaving effect within a brief homework assignment, as measured by learning gains on a delayed posttest. Using a randomized controlled trial, a practice session was presented featuring either interleaved or blocked content spanning three math skills. This study was unique in that rather than relying on a formal posttest, a second homework assignment was used to gauge learning gains through average score, hint usage, and attempt count. The use of tutoring feedback during posttest provided additional dependent variables for analysis while allowing students continued learning opportunities. Observations revealed that interleaving can be beneficial in adaptive learning environments, and appears especially significant for low performing students.

#### *2.2.3 Assessment Enhancing Motivation*

An extension of the work presented in 2.1.3, this research examined partial credit scoring using a grid search of 441 algorithmically defined models through per hint and per attempt

penalizations [6]. Binary scoring, as utilized by most adaptive tutoring systems, can serve to demotivate students from engaging with tutoring feedback and rich system features that are intended to excel beyond traditional classroom practices. For each of the 441 models examined, tables were established using maximum likelihood probabilities to predict binary next problem correctness (time $t + 1$), given the partial credit score on the current question (time $t$). Findings suggest that a data driven approach to defining partial credit penalization is possible and that an optimal penalization range can be isolated using model accuracy. Further, findings suggest that within the optimal range, lower penalizations do not differ significantly from higher penalizations, allowing leeway for content developers and teachers to enhance student motivation through reduced penalization.

## 2.3 Goals & Insight Sought

As I delve into my dissertation I expect my work to grow and meld into a unified construct surrounding the enhancement of student motivation and learning within adaptive tutoring systems. It is clear that the facets discussed here will link the two underlying realms of my research (i.e., randomized controlled trials and data mining), but it is not yet clear how. Through continued investigation of feedback, student choice, and assessment methodologies, I hope to establish a unique line of research that remains broad and yet powerful. Advice on how to drive a broad topic dissertation is sought. Essentially, I hope to gain an external expert's opinion on how to best merge the facets of my research. Advice on future endeavors within individual facets would also be appreciated.

The immediate impact of my research is already evident through continued improvements to the ASSISTments platform. The work presented here has inspired content expansion as well as infrastructure changes to enhance future research design. Within the next three years I expect that my research will continue to refine ASSISTments while increasing intellectual merit in my field. The broader impact of my work will be measured in long-term achievements that affect systemic change in education and promote data driven practices and individualized learning via adaptive tutoring platforms.

## 3. ACKNOWLEDGEMENTS

Funding for my work has been granted by a U.S. Department of Education GAANN fellowship (P200A120238), an Office of Naval Research grant (N00014-13-C-0127), and a PIMSE fellowship (NSF DGE-0742503). Thanks to S.O. & L.P.B.O.

## 4. REFERENCES

[1] Clark, R.C. & Mayer, R. E. (2003). e-Learning and the science of instruction: proven guidelines for consumers and designers of multimedia learning. San Francisco, CA: Pfeiffer

[2] Frenzel, A.C., Pekrun, R. & Goetz, T. (2007). Girls and mathematics – A "hopeless" issue? A control-value approach to gender differences in emotions towards mathematics. Eur. J of Psych of Ed. 22 (4). pp. 497-514.

[3] Heffernan N. & Heffernan C. (2014). The ASSISTments Ecosystem: Building a Platform that Brings Scientists and Teachers Together for Minimally Invasive Research on Human Learning and Teaching. Int J Art Intel in Ed.

[4] Ostrow, K. (In Press). Motivating Learning in the Age of the Adaptive Tutor. To be included in Conati, C., Heffernan, N., Mitrovic, A., & Verdejo, M. (Eds.), Proceedings of the 17th Int Conf on AIED.

[5] Ostrow, K., Donnelly, C., Adjei, S., & Heffernan, N. (2015). Improving Student Modeling Through Partial Credit and Problem Difficulty. In Russell, Woolf, & Kiczales (Eds.), Proceedings of the 2nd ACM Conf on L@S. pp. 11-20.

[6] Ostrow, K., Donnelly, C., & Heffernan, N. (In Press). Optimizing Partial Credit Algorithms to Predict Student Performance. To be included in Romero, C., Pechenizkiy, M., Boticario, J.G., & Santos, O.C. (Eds.), Proceedings of the 8th Int Conf on EDM.

[7] Ostrow, K.S. & Heffernan, N.T. (2014). Testing the Multimedia Principle in the Real World: A Comparison of Video vs. Text Feedback in Authentic Middle School Math Assignments. In Stamper, J., et al. (Eds) Proceedings of the 7th Int Conf on EDM. pp. 296-299.

[8] Ostrow, K. & Heffernan, N. (In Press). The Role of Student Choice Within Adaptive Tutoring. To be included in Conati, C., Heffernan, N., Mitrovic, A., & Verdejo, M. (Eds.), Proceedings of the 17th Int Conf on AIED.

[9] Ostrow, K., Heffernan, N., Heffernan, C., Peterson, Z. (In Press). Blocking vs. Interleaving: An Attempt to Replicate the Concept of Comparing Schedule Types Within One Night of Math Homework. To be included in Conati, C., Heffernan, N., Mitrovic, A., & Verdejo, M. (Eds.), Proceedings of the 17th Int Conf on AIED.

[10] Ostrow, K.S., Schultz, S.E. & Arroyo, I. (2014). Promoting Growth Mindset Within Intelligent Tutoring Systems. In CEUR-WS (1183), Gutierrez-Santos, S., & Santos, O.C. (eds) EDM 2014 Extended Proceedings: NCFPAL Workshop. pp. 88-93.

[11] Patall, E.A., Cooper, H., & Robinson, J.C. (2008). The Effects of Choice on Intrinsic Motivation and Related Outcomes: A Meta-Analysis of Research Findings. Psychology Bulletin. 134 (2), pp 270-300.

[12] Pekrun, R. (2006). The Control-Value Theory of Achievement Emotions: Assumptions, Corollaries, and Implications for Educational Research and Practice. Educational Psychology Review, 18 (4), pp. 315-341.

[13] Razzaq, L. & Heffernan, N.T. (2006). Scaffolding vs. hints in the ASSISTments system. In Ikeda, Ashley & Chan (Eds). *Proceedings of the Eighth International Conference on Intelligent Tutoring Systems*. Springer-Verlag: Berlin. 635-644.

[14] U.S. Department of Education, Office of Educational Technology. (2010a). Transforming American Education: Learning Powered by Technology. Washington, D.C.

[15] U.S. Department of Education, Office of Planning, Evaluation, and Policy Development. (2010b). Evaluation of Evidence-Based Practices in Online Learning: A Meta-Analysis and Review of Online Learning Studies. Washington, D.C.

[16] Wang, Y. & Heffernan, N. (2011). The "assistance" model: leveraging how many hints and attempts a student needs. In Proceedings of the *Florida Artificial Intelligence Research Society Conference* (FLAIRS 2011).