Building Automated Detectors of Gameplay Strategies to Measure Implicit Science Learning

[1] Elizabeth Rowe
EdGE @ TERC
Cambridge, MA
elizabeth_rowe@terc.edu

[2] Ryan S. Baker
Teachers College
Columbia University
New York, NY
baker2@exchange.tc.columbia.edu

[3]Jodi Asbell-Clarke &
[4] Emily Kasman
EdGE @ TERC
jodi_asbell-clarke@terc.edu
ekasman19@gmail.com

[5] William J. Hawkins
Worcester Polytechnic University
bhawk90@WPI.EDU

ABSTRACT
Educational games have the potential to be innovative methods of assessing learning. This research combines video analysis and educational data mining to measure the implicit science learning that takes place in games. By studying the video data from high school learners playtesting the game *Impulse*, we observed strategic moves that are consistent with an implicit understanding of relevant science concepts and reliably coded those moves in a sample of 69 high school students. This paper reports on work in progress to use educational data mining analyses that leverage coded video segments to build automated detectors of strategic moves from game log data.

Keywords
Automated detectors; Game-based learning; Implicit Science Learning; Game Strategies

1. INTRODUCTION
Nearly all youth and most adults participate in Internet-based games [1]. Games have been shown to foster scientific inquiry and problem-solving, and have enabled the public to participate in breakthrough scientific discoveries [2, 3]. As a result, many educators and researchers see digital games as key potential learning and assessment environments for the 21st century [4].

Our research group is designing web and mobile games that focus on high-school science concepts drawn from the U.S. standards for science education. These games use simplified game mechanics that emphasize the laws of nature and the principles of science. Players are able to dwell in scientific phenomena, building and solidifying their implicit knowledge over time.

It is not our intent that these games teach science content explicitly, but rather that they engage the learner with scientific phenomena in the effort to build their implicit understandings about these phenomena. To measure implicit learning in games, we explore the extent to which we can relate the development of strategies we see players building in the games to classroom learning of similar content. Thus, we address the question: *Do learners' strategic moves in the game correspond to increased implicit understanding of the science content driving the game mechanics?* Success in this design will result in a new way to think about game-based assessments, starting not from prescribed learning outcomes, but from watching what types of strategy development actually takes place. The first step of this research, reported in this paper, is to accurately predict the strategic moves that emerge in a physics-based game from the click data that is generated during gameplay.

2. THE GAME: *IMPULSE*
Our team designed the game *Impulse* to scaffold and measure players' implicit knowledge of forces and motions (Figure 1). In *Impulse,* particles have different masses and thus behave differently under the corresponding gravitational forces. Players use an impulse (made through a click) to apply a force to particles, with the goal of moving a specific particle to the goal while avoiding other ambient particles. If the player's particle collides with any ambient particle, she loses that round. In terms of the science, the player is immersed inside an N-body simulation with accurate gravitational interactions and elastic collisions among up to 30 ambient particles with varying mass.

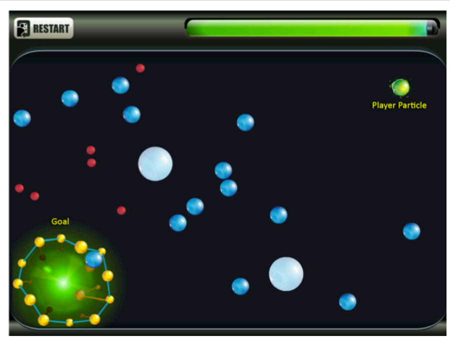

Figure 1: Impulse game

As players reach higher levels, they need to "study" the particles behavior to predict the motion of particles so that they can guide their particle to the goal, not run out of energy, and avoid collision with other particles.

Since there is no known best way for learners to build implicit understanding of these physics phenomena in games, our research captures the myriad of strategies players develop during gameplay. As a first step of this work, we have identified an initial set of strategic moves that we observe players making in the game *Impulse* that we theorize constitute evidence of implicit understandings of the underlying physics.

3. METHODS

Data were collected over six workshops conducted in March-June 2013 with 69 high school students (29 female) from urban and suburban schools in the Northeastern United States. Players were recorded with Silverback [5] that captures players' onscreen game activities and video of their faces and conversations. Students were asked to "think aloud" and explain their activities.

Two coders, a designer of Impulse with a physics background and a researcher without, independently watched the videos and coded two randomly selected three-minute segments from each player. The coding system was developed through repeated coding of hundreds of clicks with different play styles. A third coder with no physics background was trained using the coding system and coded randomly selected three-minute segments from all 69 videos. Two additional coders and one of the designers of the coding system double coded the segments from 10 videos. Table 1 includes definitions of the codes with Kappas exceeding 0.70.

Table 1. Video codes, definitions, and Kappas.

Code	Definition	Kappa
Float	The player particle was not acted upon for more than 1 second	0.759
Direction	The direction the learner intended the player particle to move	0.778
Target	Type of particle (player, other, both) the learner intended to move	0.920
Same as Last Target	The learner intended to move the same target as the last action	0.869
Intended strategy: Move toward goal	The learner intended to move the player particle toward the goal	0.809
Intended strategy: Stop/slow down	The learner intended to stop or slow the motion of the player particle	0.720
Intended strategy: Keep player path clear	The learner intended to move non-player particles to keep the path of the player particle clear	0.819
Intended strategy: Keep goal clear	The learner intended to move non-player particles to keep the goal clear	0.832
Intended strategy: Buffer	The learner intended to create a buffer between the player and other particles to avoid collision	0.772

Learner intentions are judged based not only on their screen actions, but also audio commentary and mouse over behaviors. Often players hold their mouse over spots, ready to click if needed, providing visible clues of their intended path. While not directly visible in the clickstream data, these behaviors are observable in video and aid interpretation.

The strategies identified through video analyses may provide evidence of players' implicit understanding of the mechanics related to Newton's first and second law. When a player uses a ***Float*** strategy, particularly when accompanied by a mouseover trailing along with the particle, the player is aware that an external force is not needed to keep the particle moving at a constant speed (Newton's First Law). Similarly, as evidence of an implicit understanding of Newton's Second Law, we are examining whether learners click more times when they are targeting particles of greater mass than they do of particles of lesser mass.

4. BUILDING AUTOMATED DETECTORS OF STRATEGIC MOVES

For each player action, a set of 66 features of that action are automatically distilled and aggregated at the click level to map to the labels provided by the video coders [6]. Classifiers for each code were created within RapidMiner 5.3 that map the student behaviors in the features distilled from the clickstream data to the training labels, using J48 decision trees with 4-fold cross-validation at the student level. (Kappa and A' values in Table 2).

Table 2: Detector Kappa and A' values

Code	Kappa	A'
Float	0.727	0.914
Intended strategy: Move toward goal	0.759	0.914
Intended strategy: Stop/slow down	0.522	0.804
Intended strategy: Keep player path clear	0.864	0.968
Intended strategy: Keep goal clear	0.772	0.943
Intended strategy: Buffer	0.756	0.928

5. CONCLUSIONS

During the playtesting of *Impulse,* we saw several strategic moves that are consistent with an understanding of Newtonian mechanics. Using the codes as ground truth, we are attempting to identify patterns in the clickstream data that predict players' strategic moves. These are early steps in developing an evidence model of implicit physics knowledge demonstrated via gameplay.

6. ACKNOWLEDGMENTS

We are grateful for NSF/EHR/DRK12 grant #1119144 and our research group, EdGE at TERC, which includes Erin Bardar, Teon Edwards, Jamie Larsen, Barbara MacEachern, and Katie McGrath. Our evaluators, the New Knowledge Organization, assisted with establishing the reliability of the coding.

REFERENCES

[1] Lenhart, A., et al. (2010) *Social Media & Mobile Internet Use Among Teens and Young Adults*. Washington, DC: Pew Internet & American Life Project.

[2] Steinkuehler, C. and Duncan, S. (2008). Scientific Habits of Mind in Virtual Worlds. *Journal of Science Education and Technology* 17(6): 530-543.

[3] Cooper, S., et al. (2010). Predicting protein structures with a multiplayer online game. *Nature, 466*(7307), 756-760.

[4] National Research Council. (2011). *Learning Science Through Computer Games and Simulations. Committee on Science Learning: Computer Games, Simulations, and Education*. M. Honey & M. Hilton (Eds.). Washington, DC: National Academies Press.

[5] Clearleft Ltd. (2013) Silverback (Version 2.0) [Software]. Available from http://silverbackapp.com.

[6] 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