

Assessment and Learning of Qualitative Physics in Newton's Playground

Matthew Ventura, Valerie Shute, and Yoon Jeon Kim

Florida State University, Tallahassee FL
{mventura, vshute, yk06c}@fsu.edu

Abstract. This study investigated the learning and assessment efficacy of a physics video game we developed called Newton's Playground. 165 8th and 9th graders played Newton's Playground for roughly five hours. Findings include significant pre-post physics gains and notable correlations between performance in Newton's Playground and physics pretest knowledge. Suggestions are given on how to develop assessments in video games to enhance learning.

Keywords: stealth assessment, qualitative physics, learning in games.

There is growing evidence of video games supporting learning (e.g., Tobias & Fletcher, 2011; Wilson et al., 2009). However, learning in games has historically been assessed indirectly and/or in a post hoc manner. We need to understand more precisely how and what kinds of knowledge and skills are being acquired in games. This paper introduces a way to assess learning in video games called “stealth assessment” (Shute & Ventura, in press). Similar to other performance-based assessment in games (e.g., DiCerbo & Behrens, 2012), stealth assessment refers to evidence-based assessments that are woven directly and invisibly into the fabric of the gaming environment. During game play, students naturally produce rich sequences of actions while performing complex tasks. Evidence needed to assess the skills is thus provided by the players' interactions with the game itself. In this paper we describe our stealth assessment of qualitative physics in a game we created called Newton's Playground.

1 Newton's Playground

Research into what's called “folk” physics demonstrates that many people hold erroneous views about basic physical principles that govern the motions of objects in the world, a world in which people act and behave quite successfully (Reiner, Proffitt, & Salthouse, 2005). Recognition of the problem has led to interest in the mechanisms by which physics students make the transition from folk physics to more formal physics understanding (diSessa, 1982) and to the possibility of using video games to assist in the learning process (Masson, Bub, & Lalonde, 2011).

We developed a game called Newton's Playground (NP) to help middle school students understand qualitative physics (Ploetzner, & VanLehn, 1997). We define qualitative physics as a nonverbal understanding of Newton's three laws, balance,

mass, conservation of momentum, kinetic energy, and gravity. NP is a 2D game that requires the player to guide a green ball to a red balloon. The player can nudge the ball to the left and right (if the surface is flat) but the primary way to move the ball is by drawing/creating simple machines on the screen that “come to life” once the object is drawn. Everything obeys the basic rules of physics relating to gravity and Newton’s three laws of motion. The 74 problems (split into 7 playgrounds) in NP require the player to draw/create four simple machines: inclined plane/ramps, pendulums, levers, and springboards.

For example, in the “golf problem” (see Figure 1), the player must draw a pendulum on a pin (i.e., little circle on the cloud) to make it swing down to hit the ball. In the depicted solution, the player also drew a ramp to prevent the ball from falling down a pit. The speed of (and importantly, the impulse delivered by) the swinging pendulum is dependent on the size/mass distribution of the club and the angle from which it was dropped to swing.

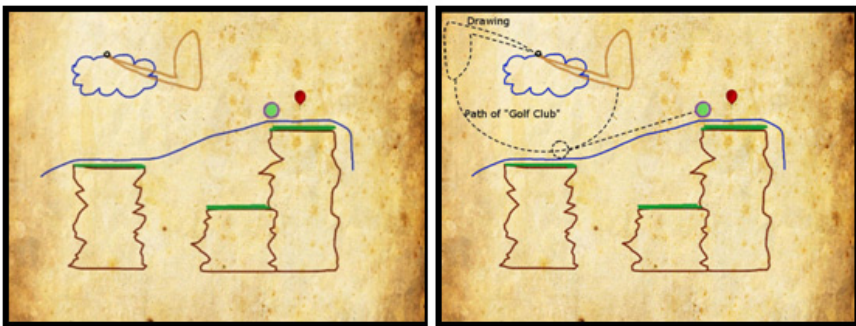


Fig. 1. Golf problem in NP (left is solution; right is path of motion)

NP displays silver and gold trophies in the top right hand part of the screen which represent progress in the game. A silver trophy is obtained for any solution to a problem. Players can also receive a gold trophy if a solution is under a certain number of objects (the threshold varies by problem, but is typically < 3). A player can receive one silver and one gold trophy per problem.

2 The Present Study

This study aims to show how playing NP can improve understanding of qualitative physics (i.e., simple machines). Additionally, we examine how performance in NP relates to existing understanding of qualitative physics. Establishing the validity of the stealth assessment in NP lays the foundation for developing diagnostic support mechanisms in NP (e.g., feedback). We have two hypotheses in this study. First, players will learn qualitative physics as a function of playing NP. Second, performance in NP will relate to existing qualitative physics knowledge. There are two main indicators from log files that we predict will be related to qualitative physics knowledge: (1) number of gold trophies per agent, (2) number of silver trophies per agent.

3 Method

3.1 Sample

165 8th and 9th grade students (76 male, 91 female) enrolled at the Florida State University School participated in the study. Each student was paid \$25 for participation.

3.2 Procedure

Students played NP for around 4 hours (split into five 45-minute sessions over the course of 2 weeks). We tested around 20 students at a time in a large computer lab. Students were not allowed to talk or look at other student's gameplay. We administered our qualitative physics pretest at the beginning and a posttest at the end of the study (both online). After completing the pretest, the students were told about NP and that the person with the most gold trophies at the end of the study would receive a special prize (an extra \$25). Proctors were instructed to tell players to watch the agent tutorial videos if they were stumped on a problem.

3.3 Measures

Working with a physics professor, we developed a qualitative physics test consisting of 24 pictorial multiple choice items. Its purpose is to assess implicit knowledge of Newton's three laws, balance, mass, conservation of momentum, kinetic energy, and gravity (see Masson, Bub, & Lalonde, 2011; Reiner, Proffitt, & Salthouse, 2005). We split the qualitative physics test into two forms that were counterbalanced between pretest and posttest (Form A = 12 items; Form B = 12 items).

4 Results

Reliability for the qualitative physics test was acceptable (Form A: $\alpha = .72$; Form B: $\alpha = .73$). Regarding overall learning as a function of NP gameplay, we found a significant difference between the pretest and posttest ($t(154) = 2.12, p < .01$). Table 1 displays the correlations among the indicators and pretest knowledge. The gold trophies per agent relate significantly to the pretest. Silver springboard use relates to pretest.

Table 1. Correlations between pretest scores and NP trophies

	Posttest	PSg	SBg	LEg	RAg	PSs	SBs	RAs	LEs
Pretest	.60**	.34**	.41**	.23**	.24**	-.02	.15	.09	-.04

* = $p < .05$; ** = $p < .01$ (PS = pendulum strike; SB = springboard; LE = lever; RA = ramp; g = gold; s = silver)

5 Discussion

This study is the first of its kind to show that specific behavior in a video game can be used for assessment purposes. We found that performance related to creating and using various agents in NP correlated to qualitative physics knowledge. Additionally, we found preliminary evidence that playing NP can lead to improved understanding of qualitative physics knowledge without any explicit instruction.

Regarding future research, the stealth assessment in NP has the potential to be useful for diagnostic and support purposes. For example, if a student has trouble using a particular agent, certain gameplay features could inform the most likely reasons why that's the case. For instance, a player's lever solution may have failed because: (a) the wrong mass of an object was used on one side of the lever, (b) the fulcrum was positioned inaccurately, and/or (c) the size/length of the lever was too short or too long. Based on this information, NP can give feedback as to how to correctly draw agents of force and motion.

Acknowledgements. We would like to thank the Bill and Melinda Gates Foundation for their funding of this project. We would also like to thank Matthew Small, Lubin Wang, and Don Franceschetti for their work on this project.

References

- DiCerbo, K.E., Behrens, J.T.: Implications of the digital ocean on current and future assessment. In: Lissitz, R., Jiao, H. (eds.) *Computers and their Impact on State Assessment: Recent History and Predictions for the Future*, pp. 273–306. Information Age Publishing, Charlotte (2012)
- diSessa, A.A.: Unlearning Aristotelian physics: A study of knowledge-based learning. *Cognitive Science* 6, 37–75 (1982)
- Masson, M.E.J., Bub, D.N., Lalonde, C.E.: Video-game training and naive reasoning about object motion. *Applied Cognitive Psychology* 25, 166–173 (2011)
- Ploetzner, R., VanLehn, K.: The acquisition of qualitative physics knowledge during textbook-based physics training. *Cognition and Instruction* 15, 169–205 (1997)
- Reiner, C., Proffitt, D.R., Salthouse, T.: A psychometric approach to intuitive physics. *Psychonomic Bulletin and Review* 12, 740–745 (2005)
- Shute, V.J., Ventura, M.: Measuring and supporting learning in games: Stealth assessment. White paper for MIT series. Published by the MacArthur Foundation (in press)
- Tobias, S., Fletcher, J.D. (eds.): *Computer games and instruction*. Information Age Publishers, Charlotte (2011)
- Wilson, K.A., Bedwell, W., Lazzara, E.H., Salas, E., Burke, C.S., Estock, J., ... Conkey, C.: Relationships between game attributes and learning outcomes: Review and research proposals. *Simulation & Gaming* 40(2), 217–266 (2009)