Middle School Students and Fractions in WhyPower: Gaming, Repetition and Learning Outcomes

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Abstract. In the WhyPower project, hosted in the virtual world *Whyville*, middle school students analyzed nine weeks of Whyville's virtual power usage history. These activities exercised proportional thinking. Later, 939 students with varying degrees of experience in WhyPower completed a survey. The survey included three proportional reasoning questions. Analysis indicated that students aged 12-14 who played WhyPower answered more questions correctly, at statistical significance and with small to moderate effect size. Analysis indicated less significant differences with older students. High game repetition was negatively associated with correct proportional reasoning answers. The author speculates that repetitive play represented attempts to conquer challenging material. Results suggest that age-appropriate content in real-world context can quickly bring selected students to new levels of understanding.

Introduction

Studies of virtual environments like *AnyTown*, *River City*, *Supercharged!*, and *Whyville* have yielded promising findings relative to deeper learning competencies and critical thinking skills (Warren, Dondlinger, & Barab, 2008; Kafai & Giang, 2007; Nelson, 2007; Nelson, Ketelhut, Clarke, Bowman, & Dede, 2005; Holland, Jenkins, & Squire, 2003). However, echoing Warren et al., it remains true that "the research…is still in a nascent phase…[regarding] student achievement in content areas (Dondlinger, 2007). We still do not know if…learning correlates with improved student reading and writing skills, mathematical reasoning ability, or any other academic activity that is measured by and is at the heart of the accountability movement in the United States" (p. 113). Can immersive environments impact academic learning? Do gains justify the costs?

The current study was performed using the WhyPower education program and curriculum. This program was developed with grant funding from the Texas Workforce Commission and Next Generation Learning Challenges. The program's ongoing purpose is to teach integrated, standards-driven math and science content to middle school students in the context of energy, while also delivering standards-aligned career education content. The program focuses on proportional reasoning skills that are of fundamental importance to middle school students' mathematical learning (Lo & Watanabe, 1997; Cramer & Post, 1993, citing the National Council of Mathematics).

WhyPower is hosted in Whyville. Whyville is a learning-based virtual world created in 1999. Whyville has hosted seven million user accounts, and its activities have been developed with funding from in excess of fifty sponsors representing institutions, academia, government and for-profit entities. WhyPower was specifically designed to address core academic standards in formal education. That design also targeted what the Hewlett Foundation (2010) referred to as "deeper learning competencies" (p. 8); it addressed "learning about [and] learning to use" (Johanning, 2008, p. 281) core academic skills.

In the current study, the general population of Whyville was offered a survey which included a short assessment of the same proportional thinking skills exercised in the WhyPower *Power Planner* activity. Answers were analyzed relative to student age, prior participation level in WhyPower, and whether those students used WhyPower in Texas classrooms as part of the completed formal grant program. The study's purpose was to assess the appropriateness of the proportional thinking content for Whyville-age students, and to assess learning impact. These research questions were considered: (1) *Was the proportional thinking content appropriate for Whyville-age students, and if yes, can the specific age of greatest interest be identified?* (2) *Did playing the WhyPower activities improve proportional thinking skills?* (3) *Did repetition of the WhyPower activity provide additional benefit toward proportional thinking skills?* (4) *Did formal classroom participation in the WhyPower program improve proportional thinking skills, beyond the benefit of virtual world game play in informal settings?*

Young et al. (2012) studied gaming and academic achievement, reviewing in excess of 300 articles, and concluding that while there are potential impacts in non-STEM areas, there is little evidence of impact for science and mathematics. They also suggested where the leading edge of rigorous understanding may lie, using Whyville as an example. They noted that Whyville "offer[s] students the tools necessary to explore and inquire about various facets of Science…[which] would be consistent with Vygotsky's (1978) co-labor within the zone of proximal Development" (p. 71). Meanwhile, studies from Torrente, Moreno-Ger, Martínez-Ortiz and Fernandez-Manjon (2009) and Sappey and Relf (2010) suggested that numerous efforts are underway to integrate inquiry- and game-based approaches into classrooms, and that such approaches incur significant cost. The current study sheds light on whether a virtual world intervention for mathematics learning can lead to worthwhile outcomes.

Literature Review

The literature foundation for this study is formed by recent research regarding Whyville and other game-based environments for learning, and by the role of situated cognition. Also considered are recent findings and the theoretical background of constructivist learning approaches to teaching academic content. In addition, the cost of developing game-based and virtual environments for learning is examined as context for considering benefits.

The academic literature on Whyville is mainly focused on descriptions of Whyville and its related affordances, and also on Whyville's ability to drive engagement, motivation, and higher order thinking skills. Kafai and Fields (2013) explored numerous aspects of how connected play in Whyville affects identity, social interactions, science and design. Kafai, Feldon, Fields, Giang and Quintero (2007) provided a thorough description of WhyPox, a simulated virtual virus that caused acne-like symptoms in Whyville avatars. Whyville-wide social immersion, like highly decorated avatars, a built-in economy, and public forums, drove inquiry-based learning regarding the spread of the virus. Galas (2006) found that students worked collaboratively, thought critically about disease spread, gathered data, made hypotheses, worked outside school, posed and researched deep questions, took responsibility for their own open-ended learning, and acted as productive citizens. Neulight, Kafai, Kao, Foley and Galas (2006) provided a quantitative result regarding student use of biological vs. pre-biological explanation for disease spread. They found significant and meaningful improvement in students moving to biological explanations ($N=45$, $p=.001$).

Studies of other virtual, game-based, and constructivist environments reported positive findings. AnyTown (Warren, Dondlinger, & Barab, 2008), was used to teach language arts through journalism. Students reported on various mysterious occurrences in AnyTown. The authors reported more rapid improvements in writing measures compared to a traditionally run comparison classroom. Nelson, Ketelhut, Clarke, Bowman and Dede (2005) and Ketelhut (2007) reported on RiverCity, where students address the problems of a 19th century virtual city. Ketelhut reported improvements in student's self-efficacy. Holland, Jenkins and Squire (2003) described *Supercharged!*, a 3D action racing game that teaches electromagnetism. Their writings suggested that it is important to combine game elements with problem- or inquiry-based pedagogical models; that games are tools in the hands of teachers.

Situated cognition theory is based on the premise that learning is influenced by the situation in which it occurs (Lave & Wegner, 1991; Brown, Collins, & Dugid, 1989). Clancey (1997) wrote that each thought and action is adapted to the environment in which it occurs. In their study of a Virtual Hospital Situated Learning System, HsiuMei and ShuSheng (2011) reported that situated learning improved the motivation to learn—that interaction and collaboration are essential components of situated learning, and that learning context must account for what it takes to accomplish a task in real-world practice.

Underlying these approaches is constructivism. Reported learning outcomes from environments based on constructivism are mixed. Positive results were reported by Geier, Blumenfeld, Marx, Krajcik, Fishman, Soloway and Clay-Chambers (2008); Hmelo-Silver, Duncan and Chinn (2007); and Kozma (1994). The theory that media is secondary and simply the carrier for learning theory was advanced by Clark (1994), Kirschner, Sweller, and Clark (2006) and Mayer (2004). Cognitive load was reported as a concern in immersive environments, per studies from Moos (2011), Chandler (2009), and Dillon and Gabbard (1998). In a study of learning proportionality, Hines and McMahon (2005) reported on the stages students encounter as they develop into proportional reasoning, and the importance of real-world problems as they transition from additive (counting) behaviors to multiplicative (proportional) thinking. Daggett (2007) highlighted how academics and Career and Technical Education (CTE) can integrate to provide the context needed by those applying constructivist, problem- and inquiry-based approaches.

Meanwhile, virtual environments drive direct and indirect costs. Torrente et al. (2009) identified a major barrier to games in education as "the complexity that they introduce in the learning process. While a lecture does not require any technology investment, video games require up-to-date computers and controlled environments" (p. 361). Though focused on higher education, Sappey and Relf (2010) highlighted similar issues when they noted that schools adopting ICT for learning encounter “additional workload…[for] ecommunication and monitoring…professional development…academic teachers’ multi-media literacy need[s] to be an integral part” of a system to support classroom teaching (p. 10).

Method and Data Collection

Prior to development of this study, some Whyvillians had participated in WhyPower’s Power Planner activity. Some learned of the activity in Whyville and chose to play informally. A selected number participated through formal grant activities, programs and curriculum in Texas classrooms. The Power Planner activity led students through a systematic analysis of Whyville’s virtual power usage history. This history, while *virtual*, nevertheless represented actual Whyville usage; it was *real* in the sense that it reflected virtual megawatts used throughout Whyville. During Power Planner activities, students considered various scenarios, interpreting pie and bar charts. Students adjusted sliders and numeric controls. While systematic, students were also given space to factor in personal values regarding energy sources. The end result of the analysis was placing a vote. That vote selected the student’s preferred mix of coal, natural gas, nuclear, hydroelectric, wind and solar energy to be allowed in Whyville for the coming week. The community’s collective vote determined the next week’s power policy.

This study was developed after completion of the original grant activities. A seven-question survey was developed to support quantitative analysis. The survey was specifically designed to be offered on Whyville’s home page, resulting in a convenience sample. Three of the questions were multiple choice and exercised the same proportional thinking skills found in the WhyPower Power Planner activity: simple chart interpretation, complex chart interpretation, and number sequencing to determine a proportion above a certain value. The remaining questions requested a student’s age, gender, and prior participation in WhyPower and Power Planner. The total number of questions was limited to seven at the recommendation of Whyville staff, to encourage participation.

Over a two-week period during the spring of 2013, 1,019 students completed the seven-question survey offered on Whyville’s home page. Student participation was optional. N=939 fully completed surveys were retained for analysis. The survey was completed once and only after completing all WhyPower activities, which often involved multiple rounds of game play/power requirements analysis.

Results

Table 1 lists descriptive statistics. Of note is the high percentage of female responses; however, this is somewhat expected since Whyville’s population approaches 70% female. Also noted is the significant number of respondents above middle school age. Nevertheless, 54.1% of respondents remain between ages 12 and 16.

Question 1: *Was proportional thinking content appropriate for Whyville-age students, and if yes, can the specific age of greatest interest be identified?* Descriptive statistics show a substantial increase in the number of correct answers between ages 10 and 15, from 1.50 to 2.23 (of three questions total). The data showed an anomalous drop at age 14; otherwise, it suggests a proper age focus.

Question 2: *Did playing the WhyPower activities increase proportional thinking skills?* A t-test for means comparison was performed for the full sample, for students age 12 to 14, and for students age 15 to 16. The results are noted in Table 2. The game impacted students between ages 12 and 14 (change=+0.27, p=.02, effect=.14); less impact was seen on older students. This result also tends to confirm the age group focus.

Question 3: *Did repetition of the WhyPower activity provide additional benefit toward proportional thinking skills?* Review of the mean number of correct answers by rounds played showed a small benefit to playing 1-5 rounds. Benefits tended to appear early. After five rounds, surveys showed fewer correct answers, on a clear downward curve as more rounds were played. When further analyzed by age, it was again the case that students aged 12 to 14 received greater benefits (comparing 0 rounds to 1: change=+0.40, p=.01, effect=.23). Table 3 summarizes the findings. Sample sizes past 3-5 rounds were small and help explain greater variability in those values. At age 14, the effect size for one round played was 0.34; in effect, for 14-year olds, every other student answered an additional question correctly if they played one round of Power Planner.

Question 4: *Did formal classroom participation in the WhyPower program impact proportional thinking skills, beyond the benefit of virtual world game play in informal settings?* Limiting analysis to only students who played Power Planner, comparison was made of the scores of students who played in classrooms vs. those who did not. Lower scores of high significance were seen for in-classroom students. Even after controlling for age (most in-classroom students were younger), these differences remained. The ideal comparison is of students from the same school playing inside formal classrooms vs. outside formal classrooms; such data is not available.

Gender		Age									Played Before?	
M	F	<10	10	11	12	13	14	15	16	>16	Played PP	Classroom
19%	81%	2.3%	3.6%	4.2%	6.3%	12.1%	11.9%	10.8%	12.0%	36.7%	56.3%	8.9%
2.11	2.19	1.31	1.50	1.92	1.98	2.18	2.04	2.23	2.35	2.32	<<< # Correct	

Table 1. Descriptive Statistics: Gender, and % Respondents and Mean # of Correct Answers by Age

	Mean, did not play	Mean, played	Change	p	Effect size
Full sample	2.05, N=410	2.27, N=529	+0.22	.00	.11
Ages <12	1.50, N=48	1.77, N=47	+0.27	n/s	.12
Ages 12-14	1.93, N=122	2.20, N=163	+0.27	.02	.14
Ages 15-16	2.24, N=97	2.33, N=117	+0.09	n/s	.05
Ages >16	2.22, N=143	2.40, N=202	+0.18	n/s (.09)	.09

Table 2. T-tests for Difference in Mean Number of Correct Answers, by Age

Rounds played	0	1	2	3-5	6-10	11-20	>20	p, 0 vs. 1	Effect size
Full Sample	2.17	2.36	2.20	2.32	1.75	1.20	1.71	.03	.10
Ages <12	1.67	1.85	1.71	1.50	1.17	0.00	1.60	n/s	.08
Ages 12-14	2.05	2.45	2.13	2.19	2.00	1.33	1.22	.01	.23
Ages 15-16	2.34	2.17	2.33	2.43	2.00	2.00	1.86	scores lower after 1 rd	
Ages >16	2.34	2.54	2.31	2.59	1.75	1.11	1.94	n/s (0.11)	.12

Table 3. Number of Correct Answers, by Rounds Played, by Age

Discussion

Age was the most reliable indicator of proportional thinking abilities, with students ages 16 and above proficient in answering the questions posed. Students ages 12-14, and to a lesser degree, age 15, showed less proficiency. The data tend to confirm that our game and study design targeted students who need improved proportional reasoning. At ages 12-14, students who played 1-5 rounds improved their scores, with the first round generally being the most impactful. At age 14, the effective impact was that every other student answered one additional question correctly. Overall, effect sizes were small, with slightly better results in the age 12-14 group.

At greater game play repetitions, students showed increasingly lower scores. It should be emphasized that students were not tested after each round. Rather, they were surveyed after completing all repetitions, and for students participating in formal classrooms, this activity was several months after completion of the grant-funded program. This author hypothesizes that decreasing scores for students with a higher number of repetitions may indicate: (1) presence of a history or maturation threat (simply put, students became bored); and/or a self-selection effect, where students kept playing to improve accuracy. Such players would by definition be producing incorrect answers to material they found challenging, which might cast their ongoing play in a positive light. It is also possible that students were playing for entertainment or other reasons unrelated to producing quality answers.

Regarding students in formal classrooms, while one must consider that the in-classroom program was the cause of lower scores, it is more likely that these 8.9% of students differed from the overall sample. For example, Whyville's population is reported as 68% female (Kafai et al., 2007) and these classes were likely more evenly distributed. Also, Whyville's population may be self-selected to a greater extent than in public schools.

Conclusion

Developing virtual environments for academic learning is an involved and expensive process. Such a process should begin with a clear understanding of learning goals and how the affordances of a virtual world can impact those goals. While generalizing from this study is questionable, the current study suggests that the move from additive to multiplicative thinking can benefit from the context provided by virtual environments. It is reasonable to ask if the intervention in fact led to small, rapid improvement for some students, or if the study design simply stratified students based on their current proportional thinking skill. Given the importance of proportional thinking in mathematical development, additional research is warranted. Intentional testing of proportional thinking after each round of WhyPower Power Planner could help isolate factors at work.

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