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J. C. Bunch

Louisiana State University, Jcbunch@lsu.edu

J. Shane Robinson

Oklahoma State University

M. Craig Edwards

Oklahoma State University

Pavlo D. Antonenko

University of Florida

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J.C. Bunch

Louisiana State University

J. Shane Robinson

M. Craig Edwards

Oklahoma State University

Pavlo D. Antonenko

University of Florida

This study's purpose was to compare the effectiveness of the traditional, lecture and discussion method to a digital game-based learning (DGBL) approach on students' near and far knowledge transfer abilities in agriculture and mathematics regarding a unit on swine diseases in animal science courses. Two research questions guided the study, which employed a quasi-experimental, between-groups design. No statistically significant differences ($p > .05$) were found between the counterfactual group and the treatment group regarding students' near and far knowledge transfer. Based on this result, it can be recommended that professional development opportunities be created with an emphasis on using serious games to teach course content for in-service teachers without diminishing students' knowledge transfer. Specifically, the creators of this professional development should consider emphasizing Technological Pedagogical Content Knowledge development in teachers. In addition, future investigations should focus on the kind of transfer that occurred, whether positive, negative, or zero.

Keywords: serious digital game, knowledge transfer, digital game-based learning

Introduction

Over the past several years, the need for increased student achievement in mathematics education has been well-documented in the United States (National Center for Education Statistics [NCES], 2000; 2004; 2010; 2011; 2013; 2015). In 2013, the National Assessment of Educational Progress (NAEP) assessed 12th grade students in mathematics from all 50 states (NCES, 2013). The results of this report were displayed as percentages of student performance

Direct correspondence to J. C. Bunch at jcbunch@lsu.edu

at or above three achievement levels: *below basic*, *at or above basic*, and *at or above proficient* (NCES, 2013). The NAEP reported 35% of 12th graders performed *below basic*, 39% *at or above basic*, and 26% *at or above proficient* on the NAEP standardized mathematics examination (NCES, 2013). As such, 74% of our nation's 12th graders scored below *proficient*. Sadly, according to the NCES (2015), there has been no measurable change in students' testing scores since 2009. Despite the challenges, educators and researchers continue to place effort toward increasing students' mathematical proficiency. One known way to assist students in increasing their mathematical proficiency is through contextualized teaching and learning (Lewis & Overman, 2008; National Council of Teachers of Mathematics [NCTM], 2009; Parr, Edwards, & Leising, 2006).

Agricultural education is a useful venue for teaching a contextualized curriculum with the intent of improving student learning in mathematics (Parr et al., 2006). In fact, Shinn et al. (2003) asserted that "secondary agricultural education, through the use of a relevant curriculum delivered from a student-centered perspective by skillful teachers, has high potential for engaging students in active, hands-on/minds-on learning environments rich with opportunities for learning mathematics" (p. 16). The study conducted by Parr et al. (2006) showed that a math-enhanced agricultural power and technology curriculum, aligned with a contextual teaching approach, affected student performance significantly on a mathematics placement examination and showed a *large* effect size regarding the treatment's practical significance. Further, Lewis and Overman (2008) found that students who were interested in Career and Technical Education (CTE) coursework exhibited an increase in their academic performance as a result of core academic content presented in CTE curricula. A study by Slusher, Robinson, and Edwards (2011) found that prospective employers in the animal agricultural industry desired for additional *basic* mathematical competencies to be taught in school-based, agricultural education courses. One way to teach mathematical competencies, in a particular context, is through digital games (Ke & Grabowski, 2007).

Today, agricultural education is faced with the opportunity to serve as a *context* for curriculum integration and thereby provide a more holistic approach to learning (United States Department of Education, 2010). Roberts and Ball (2009) concluded that agricultural education is both *content* for student learning and a *context* in which students learn. The standards identified by the NCTM (2009) strengthened the idea of progressive education dating back to John Dewey by promoting student-centered, inquiry-based learning (Pascopella, 2007). In addition, recent reforms in mathematics education have moved toward the practice of contextual teaching and learning (NCTM, 2009). As Glynn and Winter (2004) stated, "Contextual teaching and learning (CTL) integrates inquiry-, problem-, and project-based learning, cooperative learning, and authentic assessment" (p. 51).

Edling (1993) stressed that, "learning is greatly strengthened if concrete examples or situations familiar to the student can be brought in to play in the learning process" (Contextual Learning section, para. 2). As such, today's agricultural education teachers provide concrete examples or situations through teaching core academic content (i.e., math and science) and agricultural content within the *context* of agriculture.

In addition, CTL assists students in transferring knowledge from one context to another (Edling, 1993). Edling (1993) concluded knowledge transfer is a learned behavior, and transfer skills can be developed when students are engaged actively in a contextualized learning environment. Further, he asserted that a high-quality education must be contextualized to produce students who are skilled workers and prepared for postsecondary education. One known method to provide students with a simulated real-world context, albeit virtual, to learn course content is digital game-based learning (DGBL) (Corti, 2006; Garris, Ahlers, & Driskell, 2002; Oblinger, 2006; Stapleton, 2004).

Gaming, or the playing of digital games, is an activity in which most young people in the U.S. participate (Heim, Brandtzæg, Kaare, Endestad, & Torgersen, 2007). In fact, the Entertainment Software Association (2011) reported that nearly 75% of all American households play digital games. As a result of this tendency for gaming among young people, educators have become interested in the effects they have on students academically (Ferdig, 2013; Squire, 2003).

Although most video games played in the American home are focused on fantasy worlds, serious games provide a virtually-simulated, real-world environment (Stapleton, 2004). The term, *serious games*, appears, on the surface, to be an oxymoron (Breuer & Bente, 2010). How can games be both fun and serious at the same time? Zyda (2005) described, "Serious games have more than just story, art, and software, ... they involve pedagogy: activities that educate or instruct, thereby imparting knowledge and skill. This addition makes games serious" (p. 26). The fact that serious games have the ability to allow people to experience learning like never before is powerful.

According to Oblinger (2006), virtual environments produce a sensual and physical immersion, giving the player a sense of belonging in that environment. Further, Oblinger (2006) asserted that:

These immersive environments use authentic contexts, activities, and assessment; they also involve mentoring and apprenticeships in a community of practice. The result is a powerful pedagogy that allows for immersion and intense, extended experiences with problems and contexts similar to the real world. (p. 6)

In addition, immersive virtual environments allow players to experience new worlds that, under normal circumstances, would be inaccessible:

Game designers can make worlds where people can have meaningful new experiences, experiences that their places in life would never allow them to have or even experiences no human being has ever had before. These experiences have the potential to make people smarter and more thoughtful. (Gee, 2004, p. 16)

As a result, players are afforded opportunities they might not have had otherwise to learn how a specific discipline reasons and solves problems in a real-world setting (Oblinger, 2006).

Although serious games provide students with real-world virtual environments (context) to learn content (Corti, 2006; Garris et al., 2002; Oblinger, 2006; Stapleton, 2004), little evidence exists on the effect of DGBL on students' near and far knowledge transfer. Gros (2007) stated, "[a] critical aspect is the transference of the learning experienced. There is little evidence in the research done on this subject and perhaps this is one of the most important challenges we face" (p. 35).

Son and Goldstone (2009) conducted a series of three experiments focusing on the scientific principle of competitive specialization using a serious game. They found that serious games with concrete, more real-world graphics (i.e., anthropomorphism) were less effective regarding students' ability to learn content and transfer knowledge from one context to another than serious games with more idealized (i.e., abstract) graphics. As such, they concluded that idealized graphics enhanced learning and transfer, when compared to highly realistic, anthropomorphic visual representations. Further, Day and Goldstone (2009) conducted two studies focusing on analogical transfer from interaction with a simulated virtual environment. Both studies compared individuals' abilities to transfer a specific task learned in one virtual environment to another. Specifically, participants developed a strategy to increase, decrease, or stabilize the amplitude of an oscillating ball (virtual environment one) to a more dissimilar context, such as developing a strategy to increase, decrease, or stabilize the amplitude of a city's population (virtual environment two). Day and Goldstone (2009) concluded that participation in a simulated, virtual environment enhanced learners' procedural knowledge and assisted in knowledge transfer.

Conceptual Framework

The conceptual framework undergirding this study was knowledge transfer. The term transfer can be defined as knowledge learned in one context that can be applied to another (Barnett & Ceci, 2002; Schunk, 2012). According to Schunk (2012), three kinds of transfer occur as a result of learning in different contexts. The first is positive transfer, which arises when prior

knowledge enables new learning. The second kind of transfer is negative transfer, which occurs when prior knowledge interferes with new learning and makes learning more difficult (Schunk, 2012). Finally, the third kind of transfer is zero transfer. Zero transfer means that prior knowledge had no observable influence on new learning (Schunk, 2012).

Transfer has been categorized into two types: near and far. Near transfer occurs when the contexts, both original (i.e., context taught in) and new (i.e., context tested in), are very similar (Barnett & Ceci, 2002; Schunk, 2012). Typically, transfer occurs as a result of the student acquiring a profound understanding of the content rather than basic rote learning (Barnett & Ceci, 2002; Schunk, 2012). Opposite of near transfer is far transfer. Far transfer occurs when the original context and new context are dissimilar (Schunk, 2012).

Purpose

The findings of this study are part of a larger study (Bunch, Robinson, Edwards, & Antonenko, 2014). The purpose was to compare the effectiveness of the traditional, lecture/discussion method to a digital game-based learning (DGBL) approach on secondary students' near and far knowledge transfer in agriculture and mathematics regarding a unit on swine diseases, as taught in animal science courses.

Research Questions and Null Hypotheses

Two research questions guided the study: 1) What was the effect of a DGBL method on students' near knowledge transfer ability, as determined by four near transfer questions on a swine health and management unit examination? and 2) What was the effect of a DGBL method on students' far knowledge transfer ability, as determined by a standardized mathematics unit examination?

Two null hypotheses guided the study's statistical analysis: H_{01} : In the population, no statistically significant difference existed ($p > .05$) in near knowledge transfer between students who engaged in traditional instruction (i.e., lecture/discussion) and students who engaged in DGBL on a swine health and management unit examination. H_{02} : In the population, no statistically significant difference existed ($p > .05$) in far knowledge transfer between students who engaged in traditional instruction (i.e., lecture/discussion) and students who engaged in DGBL on a standardized mathematics unit examination.

Methods

This study employed a quasi-experimental, between-groups design to compare the effectiveness of the traditional, lecture and discussion method to a DGBL approach on students' near and far knowledge transfer (Creswell, 2012). Ten agricultural education teacher participants were

sampled and recruited purposively for this study. The teachers were then assigned randomly to the treatment and counterfactual groups. As a result of one teacher leaving the profession unexpectedly, nine teachers remained in the study until its conclusion. All participating teachers were required to attend a two-day professional development workshop funded with grant money provided by Pfizer[®] Animal Health. Four major objectives were addressed during the two-day, professional development workshop for the two groups of teachers: 1) provide an overview of the purpose of the study; 2) provide expert content knowledge for teaching the 10 swine diseases; 3) review the DGBL method to accompany the digital game-enhanced lessons with the treatment group teachers; and 4) review non-digital game-based teaching methods, emphasizing lecture and discussion, with the counterfactual group teachers. Teachers in the treatment group were provided pedagogical training specific to using DGBL effectively, such as setting up the problem appropriately and facilitating student learning during various levels of the game. In contrast, teachers in the counterfactual group were provided professional development specific to the qualities of effective lecturing and short-answer discussion. Teachers were prohibited from using discussion as a means of accessing students' prior knowledge. Instead, the use of the discussion method was intended for formative assessments to determine if students were following along correctly. In total, the teachers involved in this study received 14 hours of professional development during a two-day period.

Students enrolled in the teachers' animal science courses ($N = 102$) were asked to participate in the study. All 102 students enrolled in these teachers' animal science courses agreed to participate. Because the researchers were interested in individual student performance, the unit of analysis was student rather than intact classrooms. Therefore, each student's scores were independent of the other students' scores in this study (Stevens, 2009).

The students involved in the study were asked to indicate their personal and educational characteristics in concurrence with their pre-treatment examinations. A total of 102 students completed the personal and educational characteristics questionnaire ($n = 48_{\text{counterfactual}}$; $54_{\text{treatment}}$). The majority of the students involved in this study were males, were White/Caucasian, were enrolled in the tenth grade, were 15 and 16 years of age, had a self-reported grade point average of 3.1 or higher, had completed at least two agricultural education courses, and had livestock-oriented Supervised Agricultural Experiences (Bunch et al., 2014).

The treatment used in this study was *Virtual Walking the Pens*, developed by Pfizer Animal Health. *Virtual Walking the Pens* is a digital, interactive, three-dimensional (3D) game designed originally for swine producers to learn best practices regarding swine production and management through interactive digital game play (S. Miller, personal communication, February 5, 2010). However, for this study, *Virtual Walking the Pens* was used with high school students enrolled in animal science courses offered through secondary agricultural education programs in Oklahoma. The game allows players to become immersed in a simulated, virtual swine

confinement operation. The virtual world simulation affords players the opportunity to virtually interact with a swine barn, operation equipment, and livestock (ForgeFX Simulations, 2011).

The students were required to perform virtual barn walkthroughs of a wean-to-finish operation where they observed the interaction of pigs in the barn and identified unhealthy pigs based on vital signs. As unhealthy pigs were identified, decisions on how to treat those pigs were made. Ultimately, the decisions of whether or not to treat the pigs and how to treat the pigs affected outcomes in the facility and the profitability of the entire swine enterprise. Specifically, the game allowed students to experience 10 swine disease scenarios within the virtual environment similar to those real-world experiences faced by a pork producer daily.

Not only does the game focus on swine production and management practices, but it also includes basic mathematical principles that are embedded in each of the 10 scenarios. For example, players complete a veterinarian report for each scenario, which requires the player to solve basic mathematic problems involving addition, subtraction, division, multiplication, ratios, and percentages. Slusher et al. (2011) concluded, based on the views of animal science experts, these are the types of basic skills necessary for employment in the animal agricultural industry.

Quantitative, descriptive data measurements were employed to ensure a reliable assessment of the fidelity of the treatment in this study. During the research period, teachers from both the treatment and counterfactual groups were requested to complete two electronic reports. Specifically, teachers were asked to identify the instructional topics, types of curriculum sources, and instructional methods used during each class period.

To determine the effects the DGBL instructional method had on students' near and far knowledge transfer, a swine health and management examination (SHME) and a standardized mathematics examination (SME) were administered. The SHME was used to determine near knowledge transfer, and the SME was used to determine far knowledge transfer. The SHME consisted of 50 multiple-choice questions designed to measure conceptual knowledge regarding swine health and management. Further, 4 of the 50 questions were designed to measure students' near knowledge transfer. The near knowledge transfer questions had a designated point value; the maximum possible score was 4. The raw score was based on the number of questions the student answered correctly. Regarding reliability of the SHME, criterion-referenced tests do not require reliability estimates; however, they must adhere to eight criteria to establish reliability (Wiersma & Jurs, 1990). These eight criteria were met during the construction of the examination; for detail on meeting the criteria, please reference Bunch et al. (2014), p. 61.

The SME consisted of 50 multiple-choice questions designed to measure students' knowledge of basic mathematics (Bunch et al., 2014). The SME was developed by the Texas Education Agency to assess eighth grade students' proficiency in general mathematics. The decision to use

the SME was based on the assumption that students in Oklahoma would not have been exposed to the examination in the past because the SME was used to assess students in another state. To determine homogeneity for prior knowledge of general mathematics, school district report cards were compared. The maximum possible score a student could make on the SME was 50. Therefore, the number of questions answered correctly by the students determined their raw score on this examination. Finally, determining the difference in far knowledge transfer between groups was based on students' raw scores for the SME. To ensure face and content validity, an Oklahoma mathematics teacher reviewed the examination (Bunch et al., 2014).

Limitations

One limitation of this study was attrition (Creswell, 2012), i.e., one teacher and his students from the treatment group dropped out as a result of that teacher changing careers. In addition, two teachers who populated the treatment group and one teacher in the counterfactual group did not return all data required, which resulted in an incomplete data set. Finally, according to the weekly reports, the teachers in the counterfactual group used teaching methods outside of the prescribed lecture/discussion methods. Because of these three limitations, the overall power to detect a treatment effect was decreased and the probability of committing a Type II error was increased (Field, 2009; Kirk, 2010). As such, the reader should take caution when generalizing the results of this study (Creswell, 2012; Field, 2009; Gay, Mills, & Airasian, 2009).

Data Analysis

The near knowledge transfer questions included in the SHME and the questions included in the SME provided mean scores of near and far knowledge transfer. Each dependent variable was tested for the assumptions of normality and homogeneity. The assumptions of normality ($D(47) = 0.18, p < .05_{\text{counterfactual}}$; $D(54) = 0.23, p < .05_{\text{treatment}}$) and homogeneity ($F(1, 99) = 5.90, p < .05$) were violated for the near knowledge transfer variable per research question one. Therefore, the Mann-Whitney statistic, a non-parametric test, was used. Further, it was determined by the K-S test of normality that the treatment group scores for the SME were statistically significant ($D(50) = 0.13, p < .05$). The treatment group scores were then transformed using the natural log transformation to normalize the data (Field, 2009). Therefore, the mean scores from research question two were entered as a dependent variable into the larger study's MANOVA.

Findings

Research question one sought to determine what effect a DGBL delivery method had on students' near knowledge transfer, as determined by four near transfer questions on the SHME. To address research question one and its aligned hypothesis, the SHME, including the four near knowledge transfer questions, was administered after the study's treatment.

Data were analyzed from raw scores (0 to 4). As a result of violating the assumption of normality, group medians were used in the analysis instead of group means (Field, 2009). The counterfactual group students had a group median of 2.00 ($SD = 1.23$). The treatment group's mean was 2.00 ($SD = 0.94$; see Table 1).

Table 1. Near Knowledge Transfer Scores of the Counterfactual Group and Treatment Group Students

Group	Mdn	SD
Counterfactual Group ($n = 47$)	2.00	1.23
Treatment Group ($n = 50$)	2.00	0.94

Note: Near knowledge transfer score range was from 0 to 4.

The Mann-Whitney U test was conducted to determine the effect of the DGBL method versus the traditional lecture/discussion method on near knowledge transfer. The Mann-Whitney U did not reveal a statistically significant difference between the counterfactual and treatment groups as a result of the treatment ($U = 1190.00$, $z = -0.56$, $p > .05$; see Table 2). As such, the null hypothesis was accepted.

Table 2. The Effect of a DGBL Delivery Method on Students' Near Knowledge Transfer Ability

Effect	Mann-Whitney U	z	p -value
Between-Groups	1190.00	-0.56	.576

Research question two sought to determine what effect a DGBL method had on students' far knowledge transfer. To address research question two and its aligned hypothesis, the SME was administered after the treatment to examine and compare the far knowledge transfer of the counterfactual group and treatment group students. Data were analyzed from back transformed scores (Field, 2009). The counterfactual group students had a mean score of 25.70 ($SD = 1.51$). The treatment group's mean score was 21.38 ($SD = 1.51$; see Table 3).

Table 3. Far Knowledge Transfer Scores of the Counterfactual Group and Treatment Group Students

Group	Untransformed		Natural Log Transformation		Back Transformation	
	M	SD	M	SD	M	SD
Counterfactual Group ($n = 47$)	26.17	9.97	1.41	0.18	25.70	1.51
Treatment Group ($n = 50$)	22.22	9.72	1.33	0.18	21.38	1.51

Note: Texas Assessment of Knowledge and Skills (TAKS) 8th Grade Mathematics. The examination's score range was from 0 to 50.

The multivariate test statistic, Pillai's trace, did not reveal a statistically significant difference between-groups as a result of the treatment ($V = 0.04$, $F(2, 94) = 1.84$, $p > .05$; see Table 4). Therefore, the null hypothesis was accepted.

Table 4. The Effect of a DGBL Delivery Method on Students' Far Knowledge Transfer Ability

Effect	Pillai's Trace	F	df	Error df	p-value
Between-Groups	.04	1.84	2.00	94.00	.165

Conclusions

The serious digital game failed to make a statistically significant difference on students' near knowledge transfer. Based on the findings of this exploratory study, digital games are equally effective as the traditional lecture and discussion method regarding near knowledge transfer. This result supports research conducted by Barnett and Ceci (2002) who concluded that the more context dependent knowledge is, the more difficult it is to transfer such learning to another context, even if it is somewhat similar.

Further, the serious digital game failed to make a statistically significant difference on students' far knowledge transfer, as well. Therefore, the use of a serious digital game, in this context, was found to be just as effective as the traditional lecture and discussion method when examining far knowledge transfer. Prior research (Parr et al., 2006; Young, Edwards, & Leising, 2009) found that students learned mathematics better in the context of agriculture. However, the serious game and associated curriculum were designed to be content specific (S. Miller, personal communication, February 5, 2010). In support, Barnett and Ceci (2002) found that general concepts appeared to transfer more effectively than did specific learning or knowledge objects.

Recommendations for Additional Research

Because the findings of this study conflict with much of the current literature on the importance of gaming on learning (Corti, 2006; Garris et al., 2002; Oblinger, 2006; Stapleton, 2004), additional research is warranted in the area of DGBL in agricultural education. Specifically, qualitative studies that assess how playing games assist students in processing information, connecting to the content emotionally, solving problems, making decisions, and thinking critically are instrumental to understanding the gaming phenomenon (Dempsey, Haynes, Lucassen, & Casey, 2002). Therefore, a follow-up qualitative study should be conducted with the participants in the treatment group (both students and teachers) to determine if playing the game affected them in acquiring the abovementioned skills necessary for employment in the swine industry.

Finally, the SHME included four near knowledge transfer questions. It is recommended that additional near knowledge transfer questions be added to assist in increasing the test's reliability. Future investigations should focus specifically on the kind of transfer that occurred, whether positive, negative, or zero.

Recommendations for Practice

The fact that the technology used in this study did not affect student learning is not overly shocking (Willingham, 2010). However, helping teachers understand *when* and *how* to use technology can make a difference in student engagement and learning. Therefore, it is recommended that professional development emphasize a variety of pedagogies that support effective teaching and learning practices generally, instead of focusing entirely on DGBL. As technologies such as DGBL become more prevalent, perhaps it is most important to focus on developing teachers' general Technological Pedagogical Content Knowledge (Koehler & Mishra, 2009), so they can feel confident to effectively implement a variety of strategies and technologies into their classrooms.

In addition, Edling (1993) concluded that knowledge transfer is a learned behavior, and through students engaging actively in a contextualized learning experience, their transfer skills can be developed. Therefore, efforts are needed to help teachers increase their understanding and knowledge of contextualized teaching and learning through the use of serious games that support the teaching of agricultural content.

Discussion

The findings of this study are encouraging because they support the notion that the availability of technology alone does not equate to student learning. Instead, the use of technology is only as impactful as the teacher who uses it (Willingham, 2010). This finding is especially important for smaller, more rural agricultural education programs that may have fewer resources and less access to technology.

In the end, "good teaching is good teaching" (Ragan, 2000, p. 13), regardless of the mode of educational delivery. Improving student engagement in various learning activities should always be the intent of teachers (Shernoff, Csikszentmihalyi, Shneider, & Shernoff, 2003). What is more, the idea of student learning should be considered as a guide for determining which pedagogies teachers choose to use. Some teachers are more technologically-inclined, while others resist technology integration. This study supported the fact that teachers can be effective without relying on the newest technologies available. However, introducing teachers to new methods and media, such as DGBL, should continue because that will only increase the tools available for teachers to use in the future. The biggest obstacle with using technology is

preparing teachers for when to use it appropriately. Teachers should be asking themselves, “What do I want students to learn, and will technology help them to learn it?” rather than, “How can I use this particular piece of technology in my classroom?” In summary, the purpose of the learning experience should determine the teacher's practice, including the method of instruction used and the technology employed to augment it.

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J.C. Bunch is an Assistant Professor of Agricultural Education in the Department of Agricultural and Extension Education and Evaluation at Louisiana State University.

J. Shane Robinson is an Associate Professor of Agricultural Education in the Department of Agricultural Education, Communications and Leadership and Associate Director for Teaching and Learning Excellence in the Institute for Teaching and Learning Excellence at Oklahoma State University.

M. Craig Edwards is a Professor of Agricultural Education in the Department of Agricultural Education, Communications and Leadership at Oklahoma State University.

Pavlo D. Antonenko is an Assistant Professor of Educational Technology in the School of Teaching and Learning at the University of Florida.

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