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How a Serious Digital Game Affected Students' Animal Science and Mathematical Competence in Agricultural Education

J. C. Bunch[1], J. Shane Robinson[2], M. Craig Edwards[3], and Pavlo D. Antonenko[4]

Abstract

The purpose of this study was to compare the effectiveness of the lecture and discussion teaching methods and digital game-based learning on student achievement in agriculture and mathematics regarding a unit on swine diseases in animal science courses offered through secondary agricultural education programs in Oklahoma. Three research questions guided the study, which utilized a quasi-experimental, between-groups design. No statistically significant differences (p >.05) were found between the counterfactual group and the treatment group regarding animal science competency and mathematics achievement. As such, the researcher failed to reject the null hypotheses aligned with the study's research questions. However, this study demonstrated that teachers using a serious digital game in the context of animal science did not diminish their students' achievement. As a result, it can be recommended that teachers should consider incorporating this teaching method into their existing pedagogical practices without fear of decreasing student learning and achievement. Another implication for practice is the importance of providing prolonged and sustained professional development opportunities for in-service teachers to learn how to use a digital game-based delivery method effectively to increase student achievement in agriculture and mathematics.

Keywords: serious digital game, animal science, mathematics, competence

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"Now just over thirty years old, video games have quickly become one of the most pervasive, profitable, and influential forms of entertainment in the United States and across the world" (Squire, 2003, p. 2). The gaming industry is a multi-billion dollar industry in the United States (Van Eck, 2006). In fact, nearly three-quarters of all American households play games. Consumers spent $25.1 billion dollars on video games, hardware, and accessories in 2010, and purchases of digital content accounted for 24% of game sales in 2010, which generated $5.9 billion in revenue (Entertainment Software Association, 2011).

[1] J.C. Bunch is an Assistant Professor of Agricultural Education in the School of Human Resource Education and Workforce Development at Louisiana State University, 283 Coates Hall, Baton Rouge, LA 70803, Email: jcbunch@lsu.edu.
[2] 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, 3048 PIO Building, Stillwater, OK 74078, Email: shane.robinson@okstate.edu.
[3] M. Craig Edwards is a Professor of Agricultural Education in the Department of Agricultural Education, Communications and Leadership at Oklahoma State University, 464 Agricultural Hall, Stillwater, OK 74078, Email: craig.edwards@okstate.edu.
[4] Pavlo D. Antonenko is an Assistant Professor of Educational Technology in the School of Teaching and Learning at the University of Florida, P.O. Box 117048, Gainesville, FL 32611, Email: p.antonenko@coe.ufl.edu.

Games have always been a part of human culture, and digital video games are a new and novel way to facilitate this distinctive form of human social interaction and expression (Fullerton, 2004). Research has indicated that, not including television, playing electronic games, both console and computer, is the most widespread media activity in which young people participate (Heim, Brandtzaeg, Kaare, Endestad, & Torgersen, 2007). So what are digital games? According to Dempsey, Lucassen, Haynes, and Casey (1996), digital games are rule-guided scenarios that have goals, constraints, and consequences and are played by one or more participants. Further, Oblinger (2006) asserted that, "digital games are complex, require collaboration with others, and involve developing values, insights, and new knowledge" (p. 5).

Video games have changed over the years. Games have moved from a desktop computer, or gaming console, interface to a multi-user virtual world interface (Oblinger, 2006). The new games are "psychologically immersive in ways that the world-to-the-desktop interface is not" (p. 6). More important is the fact that, as a result of the gaming influence on American culture, numerous educators have shown interest in the effects digital games have on students, and how some of the immersive aspects could be used to enhance student motivation and facilitate learning (Squire, 2003).

Not all video games are designed for entertainment. The so-called *serious games* are digital gaming environments that are created for the primary purpose of solving a problem (Michael & Chen, 2006). The serious game movement began in 2002. According to Annetta, Murray, Laird, Bohr, and Park (2006), this movement provoked partnerships to be established between educators, the medical field, military, and game designers. Further, this movement supports the power that video games have to interest, engage, and associate gamers in and teach them about important content in the games' relevant concentration areas (Annetta et al., 2006).

Serious games are designed to run on personal computers or game consoles. They focus, primarily, on training, advertising, simulating, and educating (Michael & Chen, 2006). According to Corti (2006), serious games "[are] all about leveraging the power of computer games to captivate and engage end-users for a specific purpose, such as to develop new knowledge and skills" (p. 1). To that end, the primary intent of serious games is training and educating with definable learning objectives, and not solely for entertainment purposes.

One objective of employing computer games in the learning environment has been to improve students' mathematics aptitudes and knowledge (Ke, 2008; Kebritchi, Hirumi, & Bai, 2010). In the agricultural education literature, focusing on ways to increase the mathematics achievement of students in secondary programs has been a primary focus of numerous researchers (Parr, Edwards, & Leising, 2006, 2008, 2009; Stripling & Roberts, 2013; Young, Edwards, & Leising, 2009). In fact, basic mathematics has been identified as the number one technical skill deemed most important for high school agricultural education graduates who desire entry-level employment opportunities in the animal agricultural industry (Slusher, Robinson, & Edwards, 2010). Because mathematics can be embedded easily into games, a need exists to research the effect of serious games in secondary classroom settings (Kebritchi, Hirumi, & Bai, 2010). However, introducing games in secondary classrooms requires a shift in pedagogy for many teachers (Becker, 2007).

According to Garris, Ahlers, and Driskell (2002), an educational paradigm shift from a traditional, teacher-centric classroom to a more non-traditional, student-centric classroom is occurring. Tapscott (1998) asserted that this shift is a movement from "learning as torture to learning as fun" (p. 147). Research suggests that "children do enjoy learning when they have a sense of their own progression and where the learning is relevant and appropriate to them" (Kirriemuir & McFarlane, 2004, p. 12). In this new paradigm of a student-centric classroom, several attributes of the constructivist philosophy are apparent.

The focus of the constructivist paradigm is on the individual and not the teacher (Schunk, 2008). Constructivism stresses that individuals interact with their environment and formulate an understanding of that environment. Therefore, games have the potential to challenge students to inform their understanding by discovering information on their own, "and put their own quest of knowledge at the forefront of their learning experience" (Ibbitson, 2005, p. 14). Through interactions with their environment, individuals construct conceptualizations and find solutions to complex problems. These conceptualizations and solutions are developed when an individual makes meaningful connections between prior knowledge and a new experience. As a result, constructivists perceive that learning is a result of *mental construction* (Piaget, 1954). In addition, constructivists emphasize that learning is affected by the context and the individual's beliefs and attitudes. Constructivists assert that this type of teaching style equips students to be better problem solvers and to transfer their knowledge to new and novel settings more easily (Doolittle & Camp, 1999; Schunk, 2008).

A teaching method that operationalizes constructivism in an approach to education is digital game-based learning (DGBL) (Oblinger, 2004). One of the advantages of using serious games as an instructional method is that DGBL puts the learner in the *driver's seat* of the educational process (sometimes literally). Therefore, what effect did a student-centric teaching method, such as DGBL, have on student performance in animal science and mathematics?

Purpose

The purpose of this study was to compare the effectiveness of the traditional, lecture and discussion method to a digital game-based learning (DGBL) approach on student achievement in agriculture and mathematics regarding a unit on swine diseases in animal science courses offered through secondary agricultural education programs in Oklahoma.

Research Questions & Null Hypotheses

Three research questions guided the study: (1) What were the personal characteristics, such as age, gender, grade level, grade point average, number of agricultural education courses completed, and type of supervised agricultural experience, of students enrolled in selected animal science courses in Oklahoma during the Fall semester of 2011? (2) What was the effect of a DGBL delivery method on student achievement in animal science, as determined by a swine health and management examination? (3) What was the effect of a DGBL delivery method on student achievement in mathematics, as determined by a standardized mathematics examination? Two null hypotheses guided the study's statistical analysis: H_O1: In the population, no statistically significant difference existed ($p > .05$) in achievement between those students who received instruction via lecture and discussion versus those who engaged in DGBL on the swine health and management examination (H_O1: $\mu_{1Counterfactual} = \mu_{2Treatment}$). H_O2: In the population, no statistically significant difference existed ($p > .05$) in achievement between those students who received instruction via lecture and discussion versus those who engaged in DGBL on the standardized mathematics examination (H_O2: $\mu_{1Counterfactual} = \mu_{2Treatment}$).

Methods

The study used a quasi-experimental, between-groups design (Creswell, 2008). Participating high school teachers (n = 9) and their classrooms were assigned randomly to either the treatment (n = 4) or counterfactual (n = 5) groups using Randomizer.org. The resulting unit of analysis was individual subjects rather than intact classrooms (Stevens, 2009). Therefore, each subject's scores were independent of the other subjects' scores (Stevens, 2009).

The students (n = 102) who populated the randomly assigned classrooms were pre-tested to determine the level of homogeneity regarding their prior knowledge of selected swine diseases and metacognitive awareness. To determine homogeneity for prior knowledge of general mathematics, school districts report cards were compared. A quasi-experimental design involves random assignment but not random selection of participants (Creswell, 2008). The researcher chose to use a volunteer sample of agricultural education teachers willing to attend a two-day training session on swine health and pedagogy and who agreed to allow their students to be involved in the study.

The professional development sessions for this study were conducted on July 27 and 28, 2011 at Oklahoma State University, Stillwater campus. Pfizer® Animal Health granted the primary researcher $10,000 to conduct the professional development sessions. The funding provided by Pfizer® Animal Health paid for one night's stay at a hotel on the campus of Oklahoma State University for the teachers, breakfast at the hotel, travel and lodging expenses for Dr. Sarah Miller (veterinarian and game content developer), as well as services provided by Dr. Miller, and *Virtual Walking the Pens® Curriculum Manual*s for each teacher.

On July 27, 2011, the primary researcher, two agricultural education faculty members of Oklahoma State University, and Dr. Miller, DVM, provided an overview and described the study's purpose to all of the teachers. The examinations, pre and post, the Course Interest Survey, and additional reporting documents were also discussed. Second, Dr. Miller, DVM, discussed prevention, symptoms and treatment of the 10 swine diseases to be taught by all of the teachers. In addition, Dr. Miller provided the teachers with the *Virtual Walking the Pens® Curriculum Manual*.

On July 28, 2011, the two groups were split randomly into their respective groups (i.e., treatment and counterfactual). The researcher and Dr. Miller, DVM discussed how to use the digital game, both technical and pedagogical perspectives, with the treatment group teachers. And, an Oklahoma State University agricultural education faculty member discussed effective teaching methods (non-digital game-based methods) with the counterfactual group teachers. Specifically, teachers were exposed to *best practices* regarding effective lecturing and techniques for increasing class discussion amongst students. In total, the teachers involved in this study received 14 hours of professional development.

The treatment was a serious game, known as *Virtual Walking the Pens®*, and was assigned randomly to the teachers' students for 10 consecutive instructional days. This serious game was designed to assist swine producers in learning about production and management practices through digital gaming (S. Miller, personal communication, February 15, 2010). Essentially, *Virtual Walking the Pens®* permitted students to interact with a swine housing facility, equipment, and pigs in a simulated virtual world, i.e., the game allowed students to work in a virtual swine confinement operation. The students performed virtual barn *walkthroughs* where they identified and treated unhealthy pigs in the barn, based on knowledge learned in their animal science classes. In total, the game allowed students to experience 10 swine disease scenarios within a virtual world, which simulated the real-life experiences that a pork producer faces daily. In addition to exposing students to everyday swine management practices, the serious game had basic workplace mathematical problems and calculations embedded in each scenario. For example, the students had to complete a veterinarian report for each scenario, which required the students to solve basic mathematical problems using addition, subtraction, fractions, ratios, and percentages. To ensure fidelity of the treatment, the teachers were asked to complete an online fidelity report at the end of each week.

To determine the effects that the DGBL instructional method had on student achievement in animal science, a criterion-referenced, swine health and management examination (SHME) was developed by *Virtual Walking the Pens®* game content developer, Dr. Miller, DVM. It consisted of 50 multiple-choice questions designed to assess student conceptual knowledge in swine health and management. The SHME had a maximum possible score of 46 because four items were removed for analysis outside of this study. The raw score for this part of the examination was based on the number of questions answered correctly by the student. According to Wiersma and Jurs (1990), criterion-referenced tests, such as the SHME, do not require reliability estimates, such as Cronbach's coefficient alpha, to establish reliability. Rather, they require abiding by eight criteria to ensure reliability (Wiersma & Jurs, 1990). The eight criteria and the actions taken to meet those criteria are listed in Table 1.

Table 1

Actions Taken to Ensure Reliability of the Swine Health and Management Criterion-Examination

Criteria	Action Taken
Homogeneous Items	The SHME criterion-examination was created to assess students' content knowledge in the area of swine science. Examination items were linked directly to the curriculum's objectives. All items were multiple-choice in form.
Discriminating Items	To be discriminative, game content developer, Dr. Miller, DVM, and a panel of experts in agricultural education confirmed that the examination's items had a range of difficulty.
Enough items	The examination consisted of 50 items. Attention was given to creating an examination with an adequate amount of items to assess student learning.
High Quality Copying and Format	The examination was formatted professionally with adequate spacing, stapled, and printed on a high quality laser printer. In addition, the test included high-resolution, colored pictures. A panel of experts in agricultural education assessed the examination for face validity and formatting issues.
Clear Directions for the Students	Students were provided written and verbal directions that explained how to respond properly to the examination's items. The panel of experts in agricultural education also provided feedback concerning the written examination's directions.
A Controlled Setting	All study participants were provided the examination and a pencil to complete it during a regularly scheduled class period. The examination was administered by a testing liaison at each participating school.
Motivating Introduction	The students were cognizant of the study's purpose and the helpful suggestions the results could have on future courses. The information was included in the consent form signed by each student, reiterated by the teacher, and stated again by the testing liaison before the examination was administered.
Clear Directions for the Scorer	The game content developer created an examination key for the lead researcher for the purpose of scoring. The lead researcher used the examination key to score all examinations. Further, the lead researcher entered all examination scores into SPSS version 18 for data analysis.

To determine the effects that the DGBL instructional method had on student achievement in mathematics, a standardized mathematics examination (SME) was employed. The SME was designed, originally, by the state of Texas Education Agency to examine eighth grade students' proficiency in general math. The ability to use basic mathematics has been recognized as the most important technical skill desired by animal science industry experts who hire high school graduates (Slusher et al., 2011). The Texas Education Agency's SME was used because it was unlikely that students in Oklahoma would have been exposed to the examination in the past. A high school mathematics teacher in Oklahoma reviewed the examination and "cross walked" its questions with the Oklahoma Priority Academic Skill Standards (PASS) (Oklahoma Department of Education, 2011) to ensure face and content validity of the SME.

The SME consisted of 50 multiple-choice questions designed to assess student conceptual knowledge in (a) predicting the effect on the graph of a linear equation when slope or y-intercept changes; (b) inequalities model, write, solve, and graph one-two step linear inequalities with one variable; (c) use rules of exponents including integer exponents to solve problems; (d) find area of a 'region of a region' for simple figures and the area of cross sections of regular geometric solids; (e) graphs using the number line; (f) problems using scientific notation; and (g) measure of central tendency, mean, mode, median and range (Oklahoma Department of Education, 2011; D. Watts, personal communication, July 11, 2011). The SME had a maximum possible score of 50. Similar to the SHME, the number of questions answered correctly by the student determined the raw score of this examination.

Limitations

As a result of confounding variables outside of the researcher's control, certain limitations existed for this study. For example, one teacher and his students in the treatment group dropped out of the experiment due to the teacher leaving the profession unexpectedly. In addition, one teacher in the counterfactual group and two teachers in the treatment group did not return all of the student assessment instruments; so, incomplete data sets existed. Therefore, the study's sample size was decreased. As a consequence, the overall power to detect a treatment effect suffered, and the chances of committing a Type II error increased (Field, 2009). As for variables within the researcher's control, random selection of teachers for this study did not occur. As a result, readers are cautioned against generalizing the results of this study.

Data Analysis

The data were analyzed using Predictive Analytics SoftWare® (PASW®) version 20.0 for Windows™. Responses were coded for computer analysis. The pre-test measure used to determine the homogeneity of groups was analyzed using an independent *t*-test. Ary, Jacobs, and Razavieh (2002) posited that an independent *t*-test is an ideal statistical method for determining if statistically significant differences exist between groups. Research question one used descriptive statistics to summarize the personal characteristics of students involved in the study. Research questions two and three were analyzed using a multivariate analysis of variance (MANOVA) procedure. MANOVA was conducted to determine the effect of the delivery method – DGBL versus lecture and discussion – on the two dependent variables – the swine health and management examination (SHME) score and the standardized mathematics examination (SME) score. The SHME and the SME provided mean scores of student achievement.

To address the assumptions of parametric tests, examination score data were determined to be interval and independent. Further, data were tested for normality and homogeneity.

The K-S test was used to determine if the distribution of examination scores differed significantly from a normal distribution. The results of the K-S test revealed that the SHME scores were not significantly non-normal for either the counterfactual group ($D(47) = 0.20$, $p >$

.05) or the treatment group ($D(50) = 0.10$, $p > .05$). Therefore, the assumption of normality was not violated, and the SHME scores were included in the MANOVA.

Regarding the SME scores, the counterfactual group's scores ($D(48) = 0.07$, $p > .05$) were not significantly non-normal, but the treatment group's scores ($D(50) = 0.13$, $p < .05$) were. As a result of non-normality in the treatment group, the scores were transformed using the log transformation to normalize the data (Field, 2009). After completing the transformation, the K-S test revealed that the SME scores were not significantly non-normal for either the counterfactual group ($D(48) = 0.09$, $p > .05$) or the treatment group ($D(50) = 0.06$, $p > .05$). Therefore, the SME scores were included in the MANOVA. As a result of the transformation, these data were back transformed (10^X) for the purpose of interpretation (Field, 2009).

To examine homogeneity, Levene's test for equality of variances was conducted (Field, 2009). The Levene's test revealed that the variances were equal for the counterfactual and treatment groups regarding scores on the SHME ($F(1, 99) = 0.00$, $p < .05$). In addition, the Levene's test showed that the variances were equal for the counterfactual and treatment groups concerning scores on the SME ($F(1, 96) = 0.01$, $p < .05$). Therefore, the assumption of homogeneity was not violated.

Findings

Research question one sought to determine the personal and educational characteristics, such as age, gender, grade level, grade point average, number of agricultural education courses completed, and type of supervised agricultural experience of the students enrolled in the selected animal science courses during the Fall semester of 2011. The students were asked to indicate their personal and educational characteristics in concurrence with their pre-test examinations. A total of 102 students completed the personal and educational characteristics questionnaire ($N = 48_{\text{counterfactual}}$; $54_{\text{treatment}}$). Two students in the counterfactual group and one student in the treatment group did not identify their personal and educational characteristics. The personal and educational characteristics data were analyzed using modes of variability (i.e., frequencies and percentages).

The counterfactual group students consisted of 25 males (52.1%) and 21 females (43.8%). One student (2.1%) was 14 years of age, 16 (33.3%) were 15 years of age, 14 (29.2%) were 16 years of age, 11 (22.9%) were 17 years of age, and 4 (8.3%) indicated they were 18 years of age. Of those who responded, 39 students (81.1%) self-reported their race/ethnicity classification as White/Caucasian. None of the students selected their classifications as African-American or Asian. Three students (6.3%) self-selected their classification as American Indian/Alaskan Native/Pacific Islander, and three students (6.3%) identified their race/ethnicity as *other*.

In regard to grade classification, 18 students (37.5%) were tenth graders, 16 (33.3%) were eleventh graders, and 11 (22.9%) were twelfth graders. One student (2.1%) was a ninth grader, and no students from the counterfactual group represented the eighth grade. The grade point average category with the most students was the range of 3.6 to 4.0 ($f = 18$; 37.5%). Fourteen students (29.1%) indicated having had a grade point average of 3.1 to 3.5. The grade point average category with the fewest students was 2.5 to 3.0 ($f = 7$; 14.6%).

Fifteen students (31.2%) indicated that they had taken two agricultural education courses, nine students (18.8%) reported having taken four courses, eight students (16.6%) specified they had taken five agricultural education courses, seven students (14.6%) reported taking three courses, and seven students (14.6%) had taken one course. As for students' supervised agricultural experience (SAE) classifications, 21 students (43.6%) selected entrepreneurship. Eleven students (22.9%) indicated having a placement SAE, nine students (18.8%) chose the response, I do not have an SAE, and three (6.3%) reported having a research SAE. The SAE classification with the fewest students was the *other* category ($f = 1$; 2.1%).

The SAE enterprise with the most students was beef cattle (*f* = 10; 20.8%), followed by the horse and horticulture enterprises, which consisted of five students each (4.2%). In addition, the swine (8.3%) and *other* SAE types included four students each. The landscape SAE type was identified by three students (6.3%). The SAE categories with the least frequent involvement were the goat (*f* = 2; 4.2%), sheep (*f* = 2; 4.2%), and poultry (*f* = 1; 2.1%) enterprises. It was found that none of the students in the counterfactual group indicated having dairy cattle, cereal crops, fiber crops, or oil crops as SAE enterprises.

The treatment group respondents consisted of 37 males (68.5%) and 16 females (29.6%). Twenty-one (38.9%) were 16 years of age, 18 (33.2%) were 15 years of age, nine (16.7%) were 17 years of age, five (9.3%) indicated they were 18 years of age, and none of the students were 14 years of age. Thirty-seven students (68.4%) self-reported their race/ethnicity classification as White/Caucasian, and 15 students (27.8%) self-selected their classification as American Indian/Alaskan Native/Pacific Islander; one student (1.9%) indicated African-American.

In regard to grade classification, 32 of the students (59.1%) indicated they were tenth graders, 11 (20.4%) were eleventh graders, and nine (16.7%) were twelfth graders. One student (1.9%) represented the ninth grade, and none of the students from the treatment group indicated they were in the eighth grade. As for grade point average, the category with the most students was 3.6 to 4.0 (*f* = 17; 31.4%). Fifteen students (27.8%) indicated having a grade point average of 2.5 to 3.0, and nine students (16.7%) reported a grade point average of 3.1 to 3.5. The grade point average with the fewest students was 2.4 and below (*f* = 2; 3.7%).

Twenty-five (46.3%) students had taken two agricultural education courses, 14 (25.8%) indicated they had taken three, seven (13.0%) had taken one, five (9.3%) reported they had taken four, and two students (3.7%) indicated they had taken five courses. As for students' SAE classifications, 25 students (46.3%) selected entrepreneurship as their classification, and 10 students (18.5%) indicated having a placement SAE. Nine students (16.7%) indicated, *I do not have a SAE*. The SAE classification with the fewest students was the *other* category (*f* = 8; 14.8%).

Nine students (16.7%) self-reported their SAE enterprise as landscape, eight students (14.8%) identified beef cattle, and six students (11.1%) specified swine as their SAE enterprise. Four students (7.3%) self-selected goat, and students were distributed evenly among the poultry (*f* = 2, 3.7%), sheep (*f* = 2, 3.7%), and horticulture (*f* = 2, 3.7%) SAE enterprises. One student (1.9%) represented the horse SAE enterprise, and one (1.9%) identified having a cereal crops SAE enterprise. Eleven students (20.4%), however, identified *other* as their SAE enterprise type.

Research questions two and three were analyzed using a multivariate analysis of variance (MANOVA) procedure. MANOVA was conducted to determine the effect of the DGBL instructional method versus the lecture and discussion method on the dependent variables SHME score and SME score. The counterfactual group students (*n* = 47) who took the SHME had a group mean of 25.89 (*SD* = 6.29); the treatment group (*n* = 50) mean was 25.46 (*SD* = 5.47) (see Table 2).

Table 2

Swine Health and Management Examination Scores of Counterfactual and Treatment Groups

Swine Health & Management Examination	Min. & Max.	*M*	*SD*
Counterfactual Group	3 to 37	25.89	6.29
Treatment Group	14 to 39	25.46	5.47

Note. The examination's score range was from 0 to 46.

As for group means regarding the SME, the counterfactual group students (n = 47) had a back transformation group mean of 25.70 (SD = 1.51); the treatment group (n = 50) back transformation group mean was 21.38 (SD = 1.51) (see Table 3).

Table 3

Standardized Mathematics Examination Scores of the Counterfactual and Treatment Groups

Texas Assessment of Knowledge and Skills 8th Grade Mathematics Examination	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. The examination's score range was from 0 to 50.

The multivariate test statistic, Pillai's trace, did not reveal statistically significant between-group differences as a result of the treatment (V = 0.04, $F(2, 94)$ = 1.84, p > .05) (see Table 4). Further, the treatment effect size, as calculated using partial eta squared, resulted in a *negligible* (Thalheimer & Cook, 2002) effect (Partial η^2 = .04). As such, the null hypotheses H_o1 and H_o2 were accepted, indicating that the DGBL instructional method did not have a statistically significant effect (p > .05) on students' animal science competence or their mathematics competence, as measured by the study's examinations.

Table 4

The Effect of a DGBL Delivery Method on Students' Animal Science Competence and Mathematical Competence

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

Conclusions

When considering students' competence in selected animal science content knowledge, it was concluded that the use of a serious digital game, as developed by Pfizer® Animal Health, did not have a statistically significant effect (p > .05) on students' performance, as determined by the SHME. As such, digital games were found to be equally effective as the traditional lecture and discussion method for teaching swine health and management. This refutes research conducted by Bottage, Rueda, Kwon, Grant, and LaRoque (2007) who concluded that anchored instruction had a positive effect on students' performance levels. However, this finding supports research conducted by Parr et al. (2008) and Young et al. (2009) who found that agricultural content knowledge did not diminish when the agricultural curriculum was integrated with mathematical concepts.

Likewise, the use of *Virtual Walking the Pens*® failed to make a statistically significant difference ($p > .05$) on improving students' mathematical performance, and was found to be equally effective as using the lecture and discussion method. Therefore, this result does not support the assertion that teaching with technology promotes student learning of mathematics (National Council of Teachers of Mathematics, 2009) at a significantly improved level when compared to the lecture and discussion method of instruction. This finding supports research by Parr et al. (2009), who concluded that a math-enhanced agricultural curriculum did not have a statistically significant effect ($p > .05$) on students' mathematics ability, as determined by a traditional mathematics examination or by an authentic assessment of students' ability to use math to solve workplace problems. The non-significant findings of this study also align with research done outside of agricultural education that found no causal relationship existed when assessing the effect of digital games on cognitive achievement regarding students' performance in mathematics (Dempsey, Rasmussen, & Lucassen, 1996; Ke, 2008).

Recommendations for Additional Research

Because the research period was only ten days, this study should be replicated to reflect a semester-long period to provide enough time to produce a magnitude of effect that would result in detectable differences, assuming such an effect existed. Further, this study should be replicated with a larger sample of teachers and students. This would increase the power of the study and assist in detecting treatment effects and lower the chance of committing a Type II error (Kirk, 2010). In addition, the teacher participants and their students were sampled conveniently, which likely increased external threats to validity (Creswell, 2008). As such, this study should be replicated with teachers and their students who are selected randomly to minimize external threats to validity and make the results more generalizable.

Previous research has shown that barriers may affect teachers' use of technologies in the classroom (e.g., Bauer & Kenton, 2005; Berge, Muilenburg, & Haneghan, 2002; Gammill & Newman, 2005; Hernandez-Ramos, 2005; Hope, 1998; Judson, 2006; Kotrlik, Redmann, & Douglas, 2003; Levin & Wadmany, 2008; McGrail, 2005; Murphrey & Dooley, 2000; Nelson & Thompson, 2005). Therefore, future research should be conducted to determine the barriers teachers face when incorporating serious games into their existing pedagogical practices. This type of inquiry stands to enhance the ability of researchers to identify barriers specific to the use of serious games. This knowledge may be beneficial when introducing pre-service teachers to DGBL in teaching methods courses, and when providing in-service teachers with professional development.

In addition, a qualitative study should be conducted with the treatment group teachers and students to better understand their experiences using a serious digital game in the teaching and learning process. Further, future inquiries should examine how much learning was retained. For example, did the students in the treatment group retain knowledge longer than the students in the counterfactual group as a result of the intervention? Additional research is warranted to answer these and related questions.

Recommendations for Practice

Although no statistically significant differences were found, this study showed that using a serious digital game in the context of animal science did not diminish student achievement when compared to the traditional lecture and discussion method. As a result, it is recommended that teachers incorporate this teaching method into their existing pedagogical practices without the fear of decreasing student achievement. In addition, professional development opportunities should be created for in-service teachers to develop the Technological Pedagogical Content Knowledge (Koehler & Mishra, 2009) required to integrate the DGBL method such that student engagement is prolonged and intensified. An emphasis should be placed on not only helping teachers understand how to teach via a DGBL delivery method, but also how to teach using more student-centric pedagogy in general.

Although 14 hours of professional development in-service was offered to the treatment group teachers in this study, not all of that time was devoted to pedagogy. In fact, only roughly five hours were devoted to preparing teachers to deliver the learning content digitally. Therefore, more intense efforts are needed to help teachers increase their confidence for using digital delivery modes and media. Further, the creators of these professional development opportunities should consider offering in-service workshops designed to assist teachers in overcoming perceived barriers associated with using technology in their classrooms (Bauer & Kenton, 2005; Berge et al., 2002; Gammill & Newman, 2005; Hernandez-Ramos, 2005; Hope, 1998; Judson, 2006; Kotrlik et al., 2003; Levin & Wadmany, 2008; McGrail, 2005; Murphrey & Dooley, 2000; Nelson & Thompson, 2005). In addition, teacher educators of agricultural education may wish to consider incorporating DGBL into their teaching methods courses for pre-service teachers. As such, teacher education programs could influence pre-service teachers' decisions in regard to integrating technology into their classrooms effectively in the future (Bai & Ertmer, 2009).

Finally, it should be noted that DGBL is one of numerous teaching methods that can be implemented by teachers in their classrooms. By itself, it is not a *be all, end all* answer to students' learning needs. Numerous other pedagogies also exist. As such, instructors should recognize that games are *tools* that cannot, and will not, alone serve as a, substitute for or replace good teaching. Although DGBL is a relatively new and cutting-edge method that has the potential to improve student learning and achievement in the 21st century, this study further justified the need for teachers to employ a variety of instructional strategies, rather than relying on only one.

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