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Biology in the Agriculture Classroom: A Descriptive Comparative Study

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Abstract

Agricultural education can take scientific topics to higher levels, emphasize scientific concepts, involve hands-on learning, and develop interrelationships with the other sciences, thus making the living and non-living world around them relevant for students, potentially supporting a STEM curriculum. As such, in 1996, Utah deemed agricultural biology an adequate substitute for general biology in preparing Utah high school students to meet state biology requirements. The appropriateness of that decision was not tested until this 2014 descriptive comparative post-test only analysis of 2008-2012 data from the Utah State Office of Education Data and Statistics. As seen in this study, not only did agricultural biology students tend to score lower than their general biology counterparts, in multiple cases this difference was significant ($p \leq .05$), indicating a potential gap within the agricultural biology curriculum. Further, there were cases where Cohen's d was $\geq .2$, indicating at least a small effect size. This suggests that reevaluation is needed to ensure that biology standards taught in agricultural biology classes are better aligned with content tested by the biology portion of the Utah end-of-course core biology test standards.

Keywords: Biology; academic integration; agricultural education; standardized testing; STEM.

Introduction

As early as 1988, it was clear that the national agricultural education curricula were becoming outdated, being based primarily on production agriculture (National Research Council, 2009). As a consequence of these findings, the State of Utah incorporated a biology curriculum into agriscience courses (Warnick, 1998) to prepare agriculture students for their Utah Basic Skills Competency Test (Utah State Office of Education, 2012). However, prior to 1996, Utah high school agriculture students were required to take a separate traditional biology course to meet the state requirements and to earn one biology credit toward graduation (Warnick, 1998).

Modern 21st century agriculture is a science that includes biology along with other sciences (Baird, Lazarowitz, & Allman, 2006; Myers & Dyer, 2004). Agriculture supporters urged the Utah Board of Education to change the requirement, arguing that if agricultural biology courses followed the same standards as general biology, they should equally prepare students for their biology competency exams. The Utah Board of Education agreed, changing the policy in 1996 so that agriculture students would not be required to take an additional general biology course (Warnick, 1998). However, nearly two decades later in 2014, the supposition that high school agriculture students enrolled in agricultural biology courses would score as well on the end-of-course core biology test as students taking general biology had not been verified (Utah State Office of Education, 2012). The purpose of this study was to, for the first time, assess Utah high school student performance on the end-of-course core biology test to determine if agriculture students were scoring as well as their general biology student counterparts.

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Agricultural education provides an opportunity to take scientific topics to higher levels, emphasize scientific concepts, involve hands-on learning, and develop interrelationships with the other sciences, thus making the living and non-living world around them relevant for students (Hodge & Lear, 2011; Moore, 1993). Edwards (2004) and Nolin and Parr (2013) pointed out that student achievement in an era of "high stakes testing" (Edwards, 2004, p. 227) should support the integration of science into the agriculture curriculum. Agriscience courses place the science disciplines at the forefront of instructional emphasis (Nolin & Parr, 2013), constantly encouraging students to think critically, objectively, and analytically, supporting a continual growth in critical thinking skills throughout the agriscience curriculum (Taylor & Kauffman, 1983). Dormody (1992) took this even one step further, recommending that not only should agriculture teachers continue teaching the more applied agriscience curriculum, but also work closely with traditional science teachers. This combined approach of sharing and developing strategies that promote positive attitudes toward student learning could demonstrate student achievement among both agriscience and traditional science students.

The National Research Council (2009) suggested that all students, beginning with kindergarten and continuing through 12th grade should receive agriculture instruction providing students with higher academic achievement and agriscience knowledge. Parr and Edwards (2004) claimed that it is widely accepted that student learning should take place as a process, linked with opportunities for students to make connections and associations, and to make meaning of their learning as it happens. Inquiry-based learning has been deeply practiced in science education as an active approach to learning (Parr & Edwards, 2004). Furthermore, in schools where active learning methods take place, students demonstrated significantly higher achievement scores (National Research Council, 2009).

The Committee on Agricultural Education in the Secondary Schools, part of the National Academy of Sciences (1998), claimed that science has been portrayed as depressing, citing evidence that large numbers of American students avoid science in both secondary and higher education. A major effort within agricultural education has been to restimulate interest in science education (Thompson, 1998). Dailey, Conroy, and Shelly-Tolbert (2001) proposed that agricultural education could provide new student interest in science by offering integrated agriscience courses and presenting topics related to floral design; machinery operation and repair; and knowledge about animal, livestock, and food qualities. The real-world opportunity that the agriscience curriculum offers to students provides the knowledge and structure needed to rekindle science programs within high schools (Dailey et al., 2001). Thompson (1998) stated that policy makers, educators, administrators, scholars, and social critics have advocated that agricultural education and its approach of integrating scientific academic content in the curriculum has improved the image and quality of high school agriculture programs by meeting the needs and demands of a changing educational system.

Connors and Elliot (1995) reviewed research studies showing that agriscience students have performed equally to or better than students in traditionally taught science courses. In fact, at comparable grade levels, agriscience students were leading state science standards compared with students in traditional science classes (Connors & Elliot, 1995). More than just attaining equal learning, Connors and Elliot (1995) claimed that science knowledge differs between students who receive traditional science instruction and those who received agriscience-based instruction. In addition, new and innovative methods of presenting scientific methods in the agriscience approach improve students' achievement and enthusiasm for learning science.

Mowen, Wingenbach, Roberts, and Harlin (2007) suggested the majority of agriculture teachers agree that secondary schools should require more science to be integrated into the agricultural education curriculum to improve the academic content, as well as to help students adequately prepare for science related careers. Conroy and Walker (2000) claimed that when sciences were added into secondary agricultural education it met the need for basic instruction and the concepts required of workers in technical jobs. The added benefits to students enrolled in an agriscience course were that the agriscience approach allowed for further gains in knowledge, information, and understanding of agriculture (Mowen et al., 2007). Mowen et al. (2007) stated, "Agricultural education was the premier vehicle for contextualized teaching and learning within any community setting, and should be meeting both the demands of the agriculture industry, as well as students" (p. 107). Mowen et al. (2007) implied that agriculture teachers must be able to assess and evolve to meet the demands of their environments and students' needs. Through agriscience education, students achieve positive learning impacts and retain high levels of knowledge (Mowen et al., 2007).

The American Association for the Advancement of Science (1990) suggested that the agriscience curriculum be taught by integrating scientific principles with agriculture, and that equal achievements can be obtained by agriscience students, and students taught traditional biology. Dormody's (1992) research suggested that agriculture and biology were natural partners in the classroom. Connors and Elliot (1995) suggested that agriculture provides an amazing means for teaching biological concepts where real examples and hands-on experiences become part of the classroom experimentation and observation. Dormody (1992) stated, "biology in agriculture involves the application of chemistry, biology, and zoology concepts and principles in studies such as agronomy, crop science, animal science, forestry, natural resources, poultry science and horticulture" (p. 23). Dormody (1992) further suggested that it was logical for agriculture teachers to teach biology in their curriculum because of the importance of biology in promoting the agricultural literacy development of their students. Rosentrater (2005) supported the observation that by infusing agriculture curricula with scientific knowledge and skills improves student understanding of biological sciences and their scientific literacy.

Jungwirth and Dreyfus (1973) supported the effectiveness of combining biological principles and agriculture application in meeting the need for student achievement by improving student habits in inductive thinking. In addition, agricultural biology courses provide the means to develop positive attitudes toward the study of biological topics and situations (Jungwirth & Dreyfus, 1973). The agricultural biology approach not only helps emphasize the scientific nature of modern agriculture, but it also helps demonstrate the vast potential of prospective careers that the agriculture industry provides (Roegge & Russell, 1990).

Packer (2009) demonstrated the effectiveness of hands-on learning projects in biology courses, noting that students can learn more academic content because they become interested in how biological issues connect to them and their interests. Students can better understand the importance of biological principles when given the chance to apply these principles to real-world experiences (Packer, 2009). This hands-on focus was a critical aspect of the success because agriscience courses tend to emphasize the hands-on and applied aspects of learning (Dormody, 1992). Packer (2009) claimed that the intent of incorporating science into the agriculture curriculum was to impress upon the students that science is more than a collection of facts; it is an approach to thinking about the world.

Eisen (1998) discussed the importance of students not only having the capacity to learn the fundamental knowledge required of biology students, but also how to present scientific information and the aptitude to see and make connections among the crucial themes of biology. Knobloch (2008) confirmed that students need a continuation of genuine learning involvement to motivate them into developing inquiry skills, applying academic content, and connecting their learning further than the perspective of the classroom. Knobloch (2008) argued that by changing attitudes and connecting biology to agriscience, the integrated topics and activities enhance student learning and their understanding of scientific principles. The agriscience curriculum has provided students hands-on, real-life opportunities to be engaged in experiential learning and connecting content to real-world relevance (Knobloch, 2008). Knobloch (2008) stressed that the interdisciplinary education was the means to foster students into profound thinking about agriculture systems, biology, and their role in society.

Klein (2012) posited that agriscience programs bring life to math, reading, and the sciences for many students. Klein (2012) further claimed that agriscience students were very thirsty and the integrated approach provides them an opportunity to drink, thus giving the students a three-dimensional learning process and proving that students respond better with hands-on learning. Klein (2012) suggested that agriculture education prepares students to work, students who learn how to work become better citizens, and better citizens are those who think critically.

Dreyfus (1987) discussed the importance of understanding the role and potential role of agriculture in science teaching. The potential roles stem from the diversity of agriculture's components and intellectual and practical activities that embrace the elements of modern science teaching (Dreyfus, 1987). Agricultural science thus adds a combination of educational opportunities based on tradition, science, and technology. For example, Connors and Elliot (1995) stated that agricultural education has called for new and innovative approaches to teaching science, resulting in student acquisition of science knowledge that differs from those students who receive traditional science instruction. However, while agricultural education was recognized as a curriculum for several decades and the potential role of agriculture education was fairly well understood, the potential role of teaching science in agriculture has seemed to be a neglected issue (Dreyfus, 1987). Whether incorporating biology into the agriculture classroom has been viable and whether doing so produces biology knowledge comparable to traditional biology curricula remains unproven (Dormody, 1992). Historical trends and information from agriculture programs that have incorporated biology must be evaluated before passing judgment regarding the ability of biology-infused agriculture curriculum to substitute for traditional biology programs, an important step in defending continued efforts in providing agriscience in the agriculture classroom (Dormody, 1992).

Ricketts, Duncan, and Peake (2006) described the accomplishments of agriscience students taking the science portion of the Georgia High School Graduation Test, finding that agriscience students compared favorably with other students. Rather than focusing on individual facts, teaching biology in the agriculture classroom promoted the use of contextual learning through agriscience and demonstrated that agriscience education programs exemplify the necessary factors of constructive pedagogy; providing real, relevant, reflective, and multiple venues for understanding science in the agriscience classroom (Ricketts et al., 2006). Parr and Edwards (2004) also supported the claim that agriculture education encourages students to think creatively and critically, as well as facilitating a deeper understanding of scientific concepts, developing positive attitudes toward scientific learning, and cultivating students with advanced reasoning skills. Furthermore, enrolment in high school agriscience courses has provided a means to develop positive attitudes toward the study of biological topics and situations (Stephens & Latif, 2005).

Dailey et al. (2001) noted that past research studies indicated that students lacked understanding of science and mathematics in traditional classrooms because of both a lack of knowledge and disconnect in being able to utilize or transfer skills to real-world situations. Dailey et al. (2001) claimed that when science is applied to the agriculture curriculum, a culmination of principles of physical, chemical, and biological sciences cause positive and drastic changes in agricultural education. These changes, involving the integration of the sciences, include opportunities for deeper learning and understanding, reinforcement of classroom instruction in mathematics and science, and improving the acquisition of basic processing skills of students (Dailey et al., 2001). Dailey et al. (2001) also showed that student achievement in science and mathematics were higher as a result of participation in agriculture, leading Daily et al. (2001) to claim that when integration of science and agriculture happens, students' attitudes change, personal learning skills improve, and students become involved in their learning.

Whent (1994) highlighted that agriculture education may be unknown to many traditional educators. In fact, it is not uncommon for agriculture teachers to teach at a high school for many years without knowing other teachers, or what they are teaching. Likewise, Warnick (1998) reported that before, since, and after the 1996 decision in Utah to enable students to take agricultural biology instead of traditional biology, agriculture educators have often been considered and tolerated as a "step child" of the biological science community (p. 26). In relating agriculture to the growing of knowledge, not just crops, Knobloch (2008) suggested that those teachers who do not value agriculture have little knowledge and misconceived ideas about agriculture, thus failing to see the benefits of integrating biology into the agriculture curriculum. However, as 21st century educational trends move toward integration, collaboration, and cross- departmental participation, this may provide new fertile ground for these endeavors to happen and better integrate agriculture teachers with their other teaching colleagues (Whent, 1994).

Theoretical Framework

The underlying philosophy for this study is that since agriculture courses include biology along with other sciences (Manley & Price, 2011), students taking agriculture should be expected to score as well as students taking general biology courses (Clark, 2012; Roegge & Russell, 1990; Rosentrater, 2005; Thompson & Warnick, 2007; Utah State Office of Education, 2012; Warnick, 1998; Wilson & Curry, 2011). However, this philosophy had not been verified since the 1996 decision in Utah (Utah State Office of Education, 2012; Warnick, 1998) to allow high school agriculture students to take only an integrated agricultural biology course rather than having to take a general biology course.

Warnick (1998) asserted that the reconstructive and reorganized effort of the Utah State Office of Education decision of 1996 was needed because "philosophical concepts provide direction for curriculum organization and outcomes" (p. 8). Warnick and Straquadine (2005) and Esters and Retallick (2013) claimed that if the basic assumption was accepted that education should prepare students to think and act purposefully, then the curriculum of the classroom should be selected with this end in view. As the agriculture industry becomes more diverse, the industry requires a broader education than does any other vocation or profession (Maguire, Starobin, Laanan, & Friedel, 2012; Warnick & Straquadine, 2005). Nolan (as cited in Warnick, 1998) claimed that the merging of agriculture and science in secondary education has been a topic that has been discussed and debated prior to the passage of the Smith-Hughes Act of 1917 (Anderson & Anderson, 2012), hence the 1996 decision (Utah State Office of Education, 2012; Warnick, 1998;) was perhaps overdue.

Considerable research provides theoretical support for the inclusion of science into the agriculture classroom (Balschweid, 2002; Clark, 2012; Conroy & Walker, 2000; Dreyfus, 1987; Hillison, 1997; Rosentrater, 2005; Thompson, 1998; Warnick, 1998). However, much of this research results in non-quantifiable claims that agriscience programs bring life to math, reading, and the sciences for many students (Klein, 2012) and providing biology in agricultural education has created a perfect intersection between disciplines (Clemens & McElroy, 2011). Whether incorporating biology into the agriculture classroom or not (Dormody, 1992), only a single statistical comparative study done in Georgia has been completed to make comparisons (Ricketts et al., 2006). Despite the passage of nearly two decades since the 1996 decision by the Utah State Office of Education (2012) approving the agricultural biology course as being the curricular equivalent of general biology in preparing high school students for the Utah end-of-course core biology exam, as of 2014, no statistical verification of this equivalency has been ascertained (Utah State Office of Education, 2012). To properly assess whether the 1996 Utah decision was justified requires statistical rigor in keeping with the national mandate of accountability standards (Clark, 2012; NCLB Act of 2001; United States Department of Education, 2012). The purpose of this study was to address the missing accountability and provide statistical evidence in a rigorous descriptive, longitudinal, comparative analysis that determined if Utah high school agriculture students were performing as well as their general biology counterparts on the Utah end-of-course core biology exam by using data provided by the Utah State Office of Education (2012).

Methods

A descriptive, comparative within-participants posttest only design (Christensen et al., 2011) with a five-year analysis of variance (Neuman, 2006; Steinberg, 2008) was used in this study. A descriptive comparative quantitative study was an appropriate approach for this study because it involved within-participants only serving as their own control by participating in all of the experimental conditions, with all variables and prior experience remaining constant over the duration of the study (Christensen et al., 2011).

This study involved the examination of test scores on the Utah end-of-course core biology test scores (Utah State Office of Education, 2012) from a comparably gender-stratified random sample of 37.2% of Utah high school students taking agricultural biology and test scores of a comparably gender-stratified random same of 37.2% of Utah high school students taking general biology for each year from 2008 through 2012. The data were provided in an electronic file that was scrubbed of personal identifiers by the Utah State Office of Education with permission from and support for the study from the state specialist for agricultural education and the state specialist for science education.

An independent *t* test for correlated means was used to determine whether there was a statistically observed difference of $p \leq .05$ between the agricultural biology and general biology students on the posttest dependent variable (Utah end-of-course core biology test score) for each of the five years of data from 2008 through 2012. A representative 37.2% sample equal from each test group was used to produce a power of 0.05 alpha and generate a 99% confidence level. In addition to considering the *t* test comparison for the overall Utah end-of-course core biology score, the 10 individual standard scores (see Table 1) were also compared via independent *t* analysis, prior to conducting a five-year analysis of variance of longitudinal test scoring results. Cohen's *d* was also calculated, with $d \geq 0.2$ indicating a small effect size.

Table 1
Individual Standards of the Utah End-of-Course Core Biology Exam

Standard	Short Title	Full Description
1	Environmental Interaction	Living organisms interact with one another & their environment
2	Molecular Biology	Organisms are composed of one or more cells that are made of molecules… & perform life functions
3	Structure & Function	Relationship between structure & function of organs & organ systems
4	Genetics	Understand the importance of the genetic information coded in DNA
5	Evolutionary Diversity	Biological diversity is a result of the evolutionary processes
6	Science & Thinking	Use science process and thinking skills
7	Science Concepts	Demonstrate understanding of science concepts, principles & systems
8	Communication	Communicate effectively using science language and reasoning
9	Science Awareness	Demonstrate awareness of social & historical aspects of science
10	Nature of Science	Demonstrate understanding of the nature of science

Note. Short titles are used in subsequent tables for brevity.

Two hypotheses were established to evaluate the underlying philosophy that since agriculture courses include biology along with other sciences (Manley & Price, 2011); students taking agriculture should be expected to score as well as students taking general biology courses (Clark, 2012; Roegge & Russell, 1990; Rosentrater, 2005; Thompson & Warnick, 2007; Utah State Office of Education, 2012; Warnick, 1998; Wilson & Curry, 2011).

> H1o: No significant ($p > .05$) difference in Utah core end of course biology scores exists between students who took agricultural biology vs. general biology.
>
> H2o: No significant ($p > .05$) difference in the Utah core end of course biology individual standard scores exists between students who took agricultural biology and those who took general biology.

Results and Discussion

Table 2 shows sample sizes for the both test groups for each of the five years of data.

Table 2
Number of End-of-Course Core Biology Test Scores Analyzed from 2008 through 2012 Testing Periods

	Testing Period				
Student Group	*2008*	*2009*	*2010*	*2011*	*2012*
General Biology	*9,269*	*9,350*	*9,746*	*9,195*	*8,902*
Agricultural Biology	855	991	1,102	905	904

Hypothesis 1: Composite End-of-Course Core Biology Test Score Difference

In reviewing the results of independent one-tailed *t*-tests shown in Table 3, the mean difference for the general biology group was nearly 3.44 percentage points higher than the for the agricultural biology group, with there being a significantly ($p \leq .05$) higher result in 2009 and 2010. Only in 2009 was Cohen's $d \geq 0.2$, indicating a small effect size. While the difference was not statistically significant ($p > .05$) in 2008, 2011, and 2012, general biology students still tended to score higher on the end-of-course core biology test than did agricultural biology students.

Table 3
Comparison of General Biology and Agricultural Biology End-of-Course Core Biology Test Scores 2008-2012

	Testing Period				
Group	2008	2009	2010	2011	2012
General Biology	66.2%	63.9%	66.2%	64.3%	66.1%
B/AS	62.9%	60.3%	62.8%	62.6%	63.5%
Difference p-value	0.0629	0.0305	0.0276	0.8073	0.1136
Cohen's *d*	0.1869	0.2048	0.1957	0.0987	0.1437

Concern with the lower overall end-of-course core biology test scores supported the second hypothesis that investigated the 10 individual sub-scores to determine where the agricultural biology deficiencies were most pronounced.

Hypothesis 2: Individual End-of-Course Core Biology Standards Difference

Tables 4-8 present the independent one-tailed *t*-tests comparing the individual standard end-of-course core biology sub-scores between general biology and agricultural biology each year from 2008-2012. General biology scores exceeded those of agricultural biology in all but the 2012 Genetics sub-score (see Table 8), but the significance of these differences varied with a Cohen's $d \geq .2$ infrequent.

Table 4
Comparison of 2008 End-of-Course Core Biology Standard Scores: General Biology vs. Agricultural Biology

Individual Standard	General Biology	B/AS	P-Value	Cohen's *d*
Environmental Interaction	65.3%	63.0%	0.1859	0.0851
Molecular Biology	61.6%	58.7%	0.1028	0.1113
Structure & Function	64.2%	62.9%	0.4478	0.0544
Genetics	60.8%	58.5%	0.1894	0.0968
Evolutionary Diversity	58.8%	56.4%	0.1653	0.1031
Science & Thinking	66.6%	65.5%	0.5193	0.0395
Science Concepts	64.4%	63.1%	0.4662	0.0513
Communication	51.6%	48.0%	0.0477	0.1387
Science Awareness	57.7%	56.2%	0.3908	0.0659
Nature of Science	64.3%	60.6%	0.0306	0.1314

Table 5
Comparison of 2009 End-of-Course Core Biology Standard Scores: General Biology vs. Agricultural Biology

Individual Standard	General Biology	B/AS	P-Value	Cohen's *d*
Environmental Interaction	62.9%	60.8%	0.1863	0.0835
Molecular Biology	57.7%	56.0%	0.3015	0.0694
Structure & Function	61.4%	60.7%	0.6473	0.0265
Genetics	59.3%	56.8%	0.1153	0.1099
Evolutionary Diversity	59.9%	56.1%	0.0214	0.1518
Science & Thinking	58.8%	56.6%	0.1801	0.0904
Science Concepts	62.7%	60.1%	0.1075	0.1142
Communication	57.4%	54.1%	0.0472	0.1221
Science Awareness	59.3%	57.3%	0.2129	0.0824
Nature of Science	59.8%	56.8%	0.0694	0.1165

Table 6
Comparison of 2010 End-of-Course Core Biology Standard Scores: General Biology vs. Agricultural Biology

Individual Standard	General Biology	B/AS	P-Value	Cohen's *d*
Environmental Interaction	69.1%	66.3%	0.0527	0.1098
Molecular Biology	60.5%	56.2%	0.0052	0.1751
Structure & Function	55.9%	51.3%	0.0035	0.2000
Genetics	61.1%	58.9%	0.1577	0.0931
Evolutionary Diversity	64.9%	60.5%	0.0037	0.1714
Science & Thinking	65.3%	61.5%	0.0118	0.1591
Science Concepts	60.7%	56.6%	0.0076	0.1758
Communication	58.9%	53.8%	0.0011	0.2048
Science Awareness	64.1%	60.0%	0.0069	0.1715
Nature of Science	65.2%	59.9%	0.0004	0.1726

Table 7
Comparison of 2011 End-of-Course Core Biology Standard Scores: General Biology vs. Agricultural Biology

Individual Standard	General Biology	B/AS	P-Value	Cohen's *d*
Environmental Interaction	69.4%	65.2%	0.0093	0.1463
Molecular Biology	61.2%	55.5%	0.0008	0.2045
Structure & Function	55.4%	51.7%	0.0302	0.1326
Genetics	62.7%	60.2%	0.1412	0.0738
Evolutionary Diversity	63.0%	57.8%	0.0025	0.1698
Science & Thinking	65.5%	62.3%	0.0579	0.1036
Science Concepts	61.5%	57.6%	0.0213	0.0829
Communication	60.0%	54.6%	0.0017	0.2184
Science Awareness	66.2%	62.7%	0.0338	0.1122
Nature of Science	59.9%	55.3%	0.0072	0.1725

Table 8
Comparison of 2012 End-of-Course Core Biology Standard Score: General Biology vs. Agricultural Biology

Individual Standard	General Biology	B/AS	P-Value	Cohen's *d*
Environmental Interaction	60.5%	59.1%	0.4060	0.0558
Molecular Biology	62.3%	59.6%	0.1127	0.1064
Structure & Function	61.9%	60.4%	0.3881	0.0573
Genetics	66.0%	66.0%	0.9940	0.0005
Evolutionary Diversity	62.2%	61.3%	0.6056	0.0331
Science & Thinking	64.1%	62.5%	0.3646	0.0614
Science Concepts	62.2%	59.4%	0.1031	0.1100
Communication	60.7%	57.5%	0.0591	0.1485
Science Awareness	61.0%	61.3%	0.8315	-0.0337
Nature of Science	66.5%	63.2%	0.0469	0.1207

Accounting only for significant differences ($p < .05$) between general biology and agricultural biology in the 10 mean individual end-of-course core biology standard scores, two scores were different in 2008 (see Table 4) and 2009 (see Table 5); eight were different in 2010 (see Table 6) and 2011 (see Table 7), including seven highly significant ($p \leq .01$) sub-scores in 2010 and five in in 2011; and only a single sub-score difference in 2012 (see Table 8). In terms of effect size, Cohen's $d \geq 0.2$ occurred in only two individual mean scores for both 2010 and 2011. In general comparison, two individual standards, Communication and Nature of Science had a consistently statistically significant difference ($p \leq .05$) between agricultural biology and general biology students. Table 9 shows that in four of the five years, agricultural biology students scored significantly ($p \leq .05$) lower than general biology students in both standards. A small effect size, noted by Cohen's $d \geq 0.2$ occurred for Communication in both 2010 and 2011. These standards (see Table 3) are to communicate effectively by using science language and reasoning and to understand the nature of science, standards that would seem critical in understanding the very nature of science and the ability to communicate or explain it (Utah State Office of Education, 2012). Yet, in the more advanced topic of genetics (Wright & Campbell, 2014), in no year did general biology students statistically ($p > .05$) outscore agricultural biology students (see Table 9). This finding presents a quandary in comparing what students are learning in agricultural biology versus what they are learning in general biology.

Table 9
Significant Agricultural Biology vs. General Biology End-of-Course Core Biology Standard Scores Differences

Individual Standard	2008	2009	2010	2011	2012
Environmental Interaction				0.0093	
Molecular Biology			0.0052	0.0008	
Function			0.0035	0.0302	
Genetics					
Evolutionary Diversity		0.0214	0.0037	0.0025	
Science & Thinking			0.0118		
Science Concepts			0.0076	0.0213	
Communication	0.0477	0.0472	0.0011	0.0017	
Science Awareness			0.0069	0.0338	
Nature of Science	0.0306		0.0004	0.0072	0.0469

With no explanation for why there was such a dramatic difference in 2009 and 2010 with not only was the end-of-course core biology overall score being significantly ($p \leq .05$) higher for general biology students than for agricultural biology students (see Table 3), but so too the scores on 8 of the 10 individual standards (see Tables 5-6, 9), perhaps more problematic is the seemingly continued lower performance of the agricultural biology students, even when not significant ($p > .05$). This suggests the need for an analysis of the longitudinal variance of the end-of-course core biology test score results.

Longitudinal Analysis of Variance

Table 10 presents the ANOVA longitudinal comparison across all five years of the study comparing overall end-of-course core biology test scores between general biology and agricultural biology students. A significant ($p \leq .001$) between group comparison (p = .000271, F criteria = 2.578739) resulted, indicating little change in the gap between agricultural biology and general biology overall end-of-course core biology test scores from 2008 through 2012.

Table 10
ANOVA Results

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0.965406	4	0.241352	6.649195	0.000271	2.578739
Within Groups	1.633404	45	0.036298			
Total	2.59881	49				

Table 11 expands the longitudinal comparative analysis to compare the year-to-year difference in end-of-course core biology scores between general biology and agricultural biology students. The positive mean difference of 2008 vs. 2009 and 2010 vs. 2011 indicate general biology student end-of-course core biology test scores increased compared to agricultural biology students, while negative values in 2009 vs. 2010, 2011 vs. 2012, and 2008 vs. 2012 indicate that agricultural biology student scores increased versus their general biology counterparts. However, in none of these comparisons was there a significant difference, indicating the gap remained consistent ($p > .05$).

Table 11
Year-to-Year Longitudinal Comparison End-of-Course Core Biology Test Differences

Year-to-Year Comparison	Difference Between Means	Standard Deviation of Difference Between Means	P-Value
2008 versus 2009	0.0033	0.1388	0.4447
2009 versus 2010	-0.0015	0.0661	0.5264
2010 versus 2011	0.0090	0.3830	0.3509
2011 versus 2012	-0.0165	0.6756	0.7504
2008 versus 2012	-0.0057	0.2337	0.5924

Conclusion

Upon reviewing the literature (Connors & Elliot, 1995; Degenhart et al., 2007; Morgan, Parr, & Fuhrman, 2011; Nolin & Parr, 2013; Parr & Edwards, 2004; Roegge & Russell, 1990; Thompson & Warnick, 2007) one would think that students who are enrolled in a curriculum so saturated in biology principles (i.e. agricultural biology), heavily laden with plant, animal, and environmental sciences (Nolin & Parr, 2013), would perform well on a biology test like the Utah end-of-course core biology test. Further, the main body of research indicates numerous advantages associated to hands on and minds on learning (Degenhart et al., 2007; Morgan et al., 2011; Nolin

& Parr, 2013; Parr & Edwards, 2004; Thompson & Warnick, 2007). This is where the agriscience curriculum has claimed it excels because of its intrinsic hands-on learning approach (Parr & Edwards, 2004), with Connors and Elliot (1995) showing that agriscience taught students have performed equally to or better than students in traditionally taught science courses.

Yet, as seen in this study, not only did agricultural biology students tend to score lower than their general biology counterparts, in multiple cases this difference was significant ($p \leq .05$). This contrary finding challenges the theoretical foundation of this study. This first time effort to evaluate the appropriateness of that decision, taking place nearly two decades post-decision (Utah State Office of Education, 2012) found that agricultural biology students did not score as equal to or better to their general biology counterparts on the Utah end-of-course core biology test, and in fact scored significantly ($p \leq .05$) below the general biology students in a number of aspects. Beyond addressing concerns expressed about the lower than expected performance of agricultural biology students on the end-of-course core biology competency exam, the findings from this study suggest the need for continued research, looking at efforts to improve the agricultural education curriculum so that students are better prepared for excellence on performance measures such as the end-of-course core biology test. The results of the study indicate that change is needed, but this change must be assessed so that an 18-year gap does not occur again between the implementation of a program or its evaluation.

Agriculture classes host a myriad of potential to increase student interest in science and science-related careers (Warnick, 1998). Yet, as this study has shown, the potential of agriculture in meeting its potential has not yet been met. However, this study was just a starting point in this effort, providing foundational fodder for future studies that can continue to take advantage of standardized testing's comparative abilities (Warnick & Straquadine, 2005) and further investigate the ability of agriculture to play a valuable role in providing students an applied alternative to traditional core subjects (Warnick, 1998) while potentially increasing STEM-motivated graduates (Asunda, 2011) to pursue more advanced study and enter much needed STEM-related career fields (Asunda, 2011).

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