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Effects of Human Cadaveric Dissections in High School Biology

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The Next Generation Science Standards (NGSS) focus on hands-on laboratory experiences as vital to the teaching and learning of science (NGSS, 2013). Science education is taught through classroom lectures, but also with laboratory sessions to facilitate hands-on, inquiry-based learning (IBL) for critical thinking and agency outside of the classroom (Freire, 1997; Giroux, 1983; McLaren, 1994; Minstrell & Van Zee, 2000). In addition, IBL facilitates science and engineering practices such as asking questions, developing and using models, carrying out investigations, and constructing explanations from evidence (NRC, 2012). IBL is also an effective learning strategy that helps all learners, especially learners from diverse backgrounds (Meyer & Crawford, 2011). IBL allows learners to draw on prior knowledge to redefine concepts and draw conclusions about science phenomena (NRC, 2012). In doing so, science learning is embedded with the contributions and uniqueness of students from different backgrounds, thus, supporting multicultural perspectives to permeate learning (Suriel & Atwater, 2012). When IBL is carried out with hands-on learning, learners gain first hand experiences that are multisensory, activating more cognitive processes and enhancing the learning experience (Doyle & Zakrajsek, 2013; Robischon, 2016).

However, there has been a decline in the use of IBL traditional hands-on (THO) learning for science students (Sauter et al., 2013). In biology, THO labs are congruent to wet labs conducted in the traditional

manner with biological materials on top of lab benches, physically manipulating objects and often involving liquids (e.g., water, blood, chemicals). In contrast, dry labs use digital tools (e.g., computer simulations, virtual, remote/online learning) to teach science (Merriam Webster Medical Dictionary, n.d.) and represent non-traditional (TN) laboratory approaches. Many science educators are concerned that the lack of THO labs may be a factor driving science students to be less motivated and engaged in learning science (NRC, 2012). The teacher-researcher examined the implementation of THO human cadaveric dissections in a biology human body systems curriculum taught to high school students enrolled in an associate degree curriculum track (ADCT). The study addressed achievement, attitudes, and engagement in learning of ADCT senior students, believing that all learners from diverse backgrounds (Banks, 2006; Zamudio, Russell, Rios, & Bridgeman, 2011) may benefit from the THO learning.

Multicultural Context

In accordance with previous research and Tomlinson, Ford, Reis, Briggs, and Strickland's (2004; 2011) dream of designing schools and classrooms that work for "high potential" students (Tomlinson, Ford, Reis, Briggs, & Strickland, 2004) from diverse cultural backgrounds, and diverse learners with exceptionalities (2008), the authors also believe, like The Journal of Multicultural Affairs (JMA), that the multicultural field is not based solely in one area or owned by a single entity; it is a vast K-16 paradigm (Gabriel, Martinez, Obiakor, 2015; Obiakor & Martinez, 2016). Moreover, multicultural science education suggests providing equitable learning environments for all students to learn science, regardless of race, ethnicity, gender,

intellectual and physical abilities, lifestyle or social class (Atwater, 1996).

The multicultural context of this study is a suburban lottery-based public high school that consisted of high potential students (Tomlinson et al., 2004) from different backgrounds. The goal of the lottery-based student selection approach for the high school (Powers, 2015) is to seek and even out advantages based on students' social class, race, ethnicity, gender, and intellectual and physical abilities (Banks, 2006; Ford, 2011; Nieto, 1996; Zamudio et al., 2011; Valencia, 2010). Implicit in the selection process are students' interest, motivation and commitment for high academic achievement and participation in more rigorous curricula (Powers, 2015). To qualify for the lottery selection, students are required at least a proficiency score in the eighth grade state mandated standardized exam.

High potential students in this study derive from the more inclusive term provided by the National Excellence: A Case for Developing America's Talent (Ross, 1993) report that broadened the definition of giftedness to include "high potential," acknowledging the national responsibility of educators to meet the needs of not only those tested as gifted students, but also those who display potential of giftedness (Tomlinson et al., 2004). Over two decades later, some educators maintain the more traditional view of giftedness through a correlation of gifts and talents in students and high scores on achievement or IQ tests (Frasier & Passow, 1994), as this student population and school setting met this specific framework, with an exception.

Different from the majority of the previous research about gifted education, gifted culturally, linguistically, and ethnically diverse (CLED) children [of immigrants], and/or Gifted CLED students, and the underrepresentation of these

students in advanced classes and programs for students identified as gifted (Ford, 2011), high potential students in this study are 12th grade biology students from diverse backgrounds completing an ADCT. In this context, students' diverse backgrounds are not primarily by race, ethnicity, gender, but first by intellectual ability and social class (e.g., parent income and family resources, see Ford, 2011; Powers, 2015) when admitted to the school and then by intellectual ability when self-choosing to participate in ADCT courses (SIP, 2015). The student body of the lottery-based public school where this study takes place is mostly White students, reflective of the community, while from diverse social class backgrounds (Powers, 2015; SIP, 2015).

Moreover, in contrast to surrounding public schools, the research school aimed to provide a more rigorous curriculum and target opportunities to further high potential students' academic pursuits (Ford, 2011; Powers, 2015). As such, the high school aims to support student achievement, particularly in Science Technology Engineering and Mathematics (STEM), through curriculum enrichment and resources, and to provide student access to best teaching strategies (Carter et al., 2013; Ford, 2011; Gorski, 2013; Powers, 2015). Olszewski and Clarenback (2014) suggest that bringing all students to higher educational standards is desirable to develop STEM literacy. Therefore, teachers are also tasked to help students learn how knowledge is created and how race, ethnicity, gender, and social class influences essential knowledge (Banks, 2006).

Science Laboratory Activities and Learning

Leaders in engineering, medicine, businesses, and other careers have called for a STEM literate populace, able to think critically and use technology effectively to

improve our lives and better our world (ESSA, 2015; NGSS, 2013). Overall, K-12 schools are not sufficiently producing students, especially students from diverse class backgrounds (Carter et al., 2013; Gorski, 2013; McLaren, 1994), who pursue STEM. As a result, the new Every Student Succeeds Act or ESSA (2015) specifically calls for an increase in the number of students of diverse backgrounds participating in STEM programs that increase STEM literacy and lead to STEM and STEM related careers.

The National Research Council (NRC) has pushed science teachers to use IBL as an effective approach to teaching science (Hunter, 2014). Knowledge is retained better by doing, observing, and analyzing cause and effect relationships among certain variables (NRC, 2012). Students need to experience challenging inquiry-based THO experiences to make science meaningful and motivating (Bassett, Martinez, & Martin, 2014; Fancovicova & Prokop, 2014; Suriel & Atwater, 2012). Compared to paper labs, THO labs maximize learning (National Association of Biology Teachers, 2005; NRC, 2012).

In the biology classroom, cadaveric dissections are an important part of the curriculum (West & Veenstra, 2012) and have been shown to deepen student understanding of the human body and pathological diseases that exist in humans (Fancovicova & Prokop, 2014). When taught through the THO approach, cadaveric dissection can strengthen learning and support content retention (West & Veenstra, 2012). Han, Chung, and Nam (2015) suggest that, “Cadaver dissection not only provides opportunities for hands-on learning, but also offers a forum for students to engage in content-rich discussions and to assist in each other’s learning” (p. 1). Cadaveric dissections can be a valuable tool for students to learn the anatomy and the

medical terminology needed for an increase in student engagement in science. However, a challenge for many schools with limited budgets is providing the necessary resources (Ford, 2011), such as laboratory materials or adequate spaces to facilitate THO investigations. Also, public school biology teachers may lack the training necessary to complete THO labs (Wilson, Schweingruber, & Nielsen, 2015). As a result, there can be a decrease in cadaveric dissections in many biology courses.

Addressing Science Performance: Research School

The mission of many academic science departments includes statements geared toward student achievement, and often these mission statements are required for state mandated school improvement plans (e.g. Idaho Department of Education, n.d.). In the public high school in this study, science teachers focused on the 2015 School Improvement Plan (SIP) mission statement to prepare students to think critically and creatively, work cooperatively, and develop the skills to become self-directed learners. In order for students to increase their STEM literacy, particularly science and technology, and become self-directed learners, they were provided opportunities to participate in laboratory activities that engaged them in the content they were learning.

For biology students participating in the research school’s ADCT, college level lab experiences are required. For students at this level, cadaveric dissections could support college level lab experiences, afford students opportunities to learn scientific concepts more effectively, and have the potential to increase student achievement (Ekwueme, Ekon, & Ezenwa-Nebife, 2015). As such, the teacher-researcher sought to enhance the biology curriculum by exposing biology students to THO cadaveric dissections while utilizing a local university human anatomy

lab and their resources. The curriculum enhancement was also partly based on the teacher-researcher's observations on the predominance of nonIBL approaches such as paper labs in science classrooms at the research school. This study sought to examine if 12th-grade ADCT biology students' achievement, attitudes, and engagement would change in a positive manner after conducting human cadaveric dissections using the THO approach compared to NT human virtual dissections.

Review of the Literature

Research on cadaveric dissections show opposing views as to whether THO cadaveric dissections are more beneficial to students learning human gross anatomy compared to NT virtual and remote labs. However, recent literature on THO versus NT labs suggest that the combination of both approaches may serve students best.

Traditional Hands-On Approach To Cadaveric Dissections

Older (2004) argued that, "Medicine is the compassionate solving of problems by the application of scientific knowledge. This is best achieved by the exposure and examination of the tissues and structures inside the [human] body, and is best revealed by dissection" (p. 79). However, the medical science fields have seen a reduction in the number of hours spent on anatomical science, including working on the post-mortem (Hariri, Rawn, Srivastava, Youngblood, & Ladd, 2004). In educational settings, THO cadaveric dissections as lab activities can be challenging. Qamar et al. (2014) shared three main reasons for the decline of human anatomy THO cadaveric dissection labs in Western universities. For one, the cost of buying and disposing of cadavers are large expenses to universities, often requiring fees and specific procedures.

Secondly, conducting THO cadaveric dissections require extensive lab time. Not only should students be provided ample time to explore and learn from cadavers before they decay, but space to host cadavers may be challenging and often affect the scheduling of lab space for concurrent activities. Lastly, faculty expertise and availability to conduct THO cadaveric dissections may also be a limiting factor.

Moreover, THO cadaveric dissections have also been associated with learners' adverse emotional and physical responses to cadavers. Mulu and Tegabu's (2012) study found that students showed signs of nausea, eye irritation, fear, and stress while working with the cadavers, however, after several labs, the psychological and physical impacts lessened.

Although cadaveric dissections have been routinely performed in classrooms for many years, 15 states restrict educators from participating in THO cadaveric dissections, allowing students the choice to participate (Osenkowski, Green, Tjaden, & Cunniff, 2015). Four other states require parental permission for students to participate in THO cadaveric dissections and in three other states local school districts retain control over curriculum that can block students' access to cadaveric dissections (Hunter, 2014). These laws may force instructors to abandon THO cadaveric dissections that reinforce practical knowledge of human anatomy. The advancement in technology is, however, providing for students alternative activities to THO cadaveric dissections that were not previously available (Oakley, 2011).

Nontraditional Approaches To Cadaveric Dissections

While many human anatomy educators use THO cadaveric dissections, others utilize NT approaches to teach anatomy (Anyanwu & Ugochukwu, 2010). Compared

to THO cadaveric dissections, NT cadaveric dissections require one-time investments, are durable and sustainable, and in the case of digitally accessible labs, afford students more time to learn (Rehman et al., 2012). Consequently, many medical programs have begun to replace THO human cadaveric dissections with NT approaches (Fancovicova & Prokop, 2014; Sauter et al., 2013). Likewise, a variety of NT teaching tools exist to further learn human anatomy.

One NT approach of teaching anatomy is the use of plastic models of organs and organ systems (Fancovicova & Prokop, 2014). Not only are there plastic models of organ systems, but in 1977, Professor Gunther von Hagens created a way to plastinate cadaveric specimens (Azu, Peter, Etuknwa, & Ekandem, 2012). The plastinated specimens are used in some medical schools for teaching anatomy and other medical sciences (Azu et al., 2012). These models are inexpensive compared to real cadavers, however, few recurring expenses exist with these models. Plastinated specimens do not require the same expensive facilities to help maintain embalmed cadavers and are considered dry, odorless specimens.

Computer simulations and virtual dissections are also NT approaches often used to teach anatomy. Virtual patients created by Computer Tomographic scans (CT scans) and Magnetic Resonance Imaging (MRI) of the post-mortem are used in medical schools to improve student learning before time in clinical settings (Jacobson et al., 2009). Also, outside of the medical classrooms, teachers use virtual dissections on various vertebrates instead of THO dissections (Lalley, Piotrowski, Battaglia, Brophy, & Chugh, 2010).

On a study focusing on virtual dissections using three-dimensional interactive models, Sanchez-Diaz (2013) studied optometry students' learning outcomes and motivation.

Sanchez-Diaz found that students who were provided with iPad applications to learn gross anatomy felt that videos on dissections were the most effective form of virtual learning.

Benly (2014), utilized both THO and NT technology tools to enhance the learning of human anatomy through cadaveric dissections. A NT technology infused approach for teaching gross anatomy is the use of medical imaging devices, which are non-invasive methods providing specific anatomical information (Benly, 2014). The ultrasound imaging method is a technique that is used for students to investigate pathological conditions in their cadavers during cadaveric dissections (Schramek et al., 2013). In his study, Benly (2014) showed that computer tomography (CT) imaging is used on embalmed cadavers, and these images enhanced the student learning of gross human anatomy, as well as the ability to identify structures using radiographic images (Schramek et al., 2013).

However, in a study that replaced THO dissections with NT computer-based simulated labs, study findings showed that study participants using simulations missed out on critical laboratory skills that the simulated labs do not offer (West & Veenstra, 2012). West and Veenstra (2012) suggested that, "Hands-on practical work has been deemed an important component of a science course as it allows students to develop a variety of laboratory skills and then apply these skills to the theoretical aspects" (p. 57). Another study has shown that virtual frog dissections can lead to meaningful learning experiences for students (Lalley et al., 2010). However, Lalley et al. (2010) also stated that, "If there is sufficient instructional time, virtual dissection and physical dissection could likely produce better learning outcomes used together than either would individually" (p. 197).

In a study conducted by Moxham and

Moxham (2007), students were asked if computer-generated software was a good alternative for cadaveric dissections. Students found that the computer-generated software was beneficial to their learning process; however, the students felt that the tactile, multisensory experience with a cadaver may be much more valuable.

Analysis of data gathered from biology college students who used the THO approach and NT computer-based dissections showed that both approaches were useful in learning content (Franklin, Peat, & Lewis, 2002). Franklin et al. (2002) continued to offer real cadaveric dissections while also increasing computer-based materials to supplement students' educational needs.

Limitations Of The Research

The research on cadaver dissections discussed above presented several limitations. In their 2002 study of interest in dissections by biology students, Franklin et al. (2012) used only first-year biology students, but not students who majored in biological sciences, which limits the generalizability of the findings. Qamar et al. (2014), who studied the use of cadaveric dissections compared to the use of plastic models, did not collect data on such concerns as tactile reinforcement or the possibility of the diagnosis of physical disorders during cadaver dissections. Rehman et al. (2012) studied the use of computer-generated anatomy software but did not provide information on the amount of time that the students were allotted to work with the new software before the researchers collected data on student learning. The amount of time with the software and student familiarity may affect the student's learning experience. None of the studies within the review of the literature attempted to measure comfort with human body parts.

Purpose of the Study

The purpose of this study was to compare the achievement of ADCT senior students participating in two biology classes, the first using THO cadaveric dissections compared to the second class using only NT, virtual dissections of the human body. The study investigates how the use of THO human cadaveric dissections may affect the achievement, engagement, and attitudes of students and whether these dissections, as compared to NT virtual dissections, improved learning for the high potential biology students. The outcomes of this study may assist science educators, students, parents, and administrators to understand the importance of THO cadaveric dissections compared to NT virtual dissections in learning human gross anatomy, and the importance of public and higher education collaboration.

This study was guided by the following research questions.

1. Will 12th-grade ADCT biology student achievement increase after conducting THO human cadaveric dissections compared to NT human virtual dissections?
2. Will 12th-grade ADCT biology students' attitudes toward learning the gross human anatomy improve after conducting THO human cadaveric dissections compared to NT human virtual dissections?
3. Will 12th-grade ADCT biology students' engagement increase while conducting human THO cadaveric dissections compared to NT human virtual dissections?

Definition of Variables

Achievement. The quality and quantity of a student's work measured by the amount of academic content a student learns in a determined amount of time. Student achievement was defined as the percent increase in the human nervous system

pretest and posttest scores.

Attitude. The expression of like or dislike for the activity. A survey using a Likert scale was used to determine the attitudes of students who performed THO cadaveric dissections compared to the attitudes of students who worked with NT virtual dissections to learn human anatomy.

Engagement. The degree of time, interest, and passion that students showed while learning gross human anatomy. A self-assessment of engagement was administered to students that allowed the teacher-researcher to learn about students' perceptions of their engagement in the THO cadaver lab or in the NT virtual lab.

Associate Degree Curriculum Track (ADCT). Students were enrolled in university-level courses from the affiliated local university and received both high school and university credit toward an associate degree in general studies for successful completion of those courses.

Traditional hands-on (THO) cadaveric dissection. The process of physically disassembling and observing structures of organic organisms.

Non-traditional (NT) virtual dissection. The process of disassembling and observing structures of organisms carried out by software or computer simulations. Virtual dissection was conducted using a learning tool known as the Anatomage Table, a specially designed tool that consists of computerized touch screens embedded in a table the size of a cadaver dissecting table (e.g., students gather around the table to use the radiology software to conduct virtual dissections).

Methods

Setting and Participants

This study took place at a public high school in a suburban area of Idaho. The school district served 36,838 students during

the 2012-2013 school year (School District Press, 2014). According to the United States Census Bureau (2016), there were 90,739 residents in this area, which consisted of 92.4% White, 1.3% Black, 0.8% American Indian or Alaska Indian, 2.6% Asian American, 2.7% two or more races, and 7.7% Hispanic or Latino American.

There were 53 schools in the district, and the school district served 10.2% students with disabilities, 4.5% Gifted or Talented, 5.4% English as a Second Language, and 29% who received free or reduced-price lunches. The current research site was a public high school in this district that had an enrollment of 84% White, 7% Hispanic/Latino, 3% two or more races, 3% Asian, 2% Black, and 1% American Indian/Alaska Native (Great Schools, 2015). The school had a 60% female enrollment, and 40% of the students were males. The research school was recognized for high achievement scores on statewide tests, with 100% meeting the state standards in reading and 97% meeting the standards in mathematics (Great Schools, 2015).

The high potential students attending the research school could choose to graduate with an international baccalaureate degree or an associate degree in general studies from a local state university. The research participants were 12th-grade ADCT students completing the second college level biology course or Biology 1102, and were scheduled to class by administrators based on scheduling requirements or needs of the students and school.

Participating students (N= 65) were escorted to the local university's anatomy lab, which is connected by a hallway to the research school, providing approved and convenient access to the university's lab facilities. The participants were an average age of 17 years old. Of these participants, 59 were White, two were Black, one was Latino, and three reported as Other. There

were 37 female students and 28 male students. These participants were not being served for any special needs or for English as a Second Language. The academic achievement scores on the state Idaho Achievement Tests of all participants were at 100% proficiency (Great Schools, 2015). Participating students in the cadaveric dissection group (intervention group) received the same instructional practices for the body systems that the virtual dissection group (control group), and instruction for both was provided by the teacher-researcher. Table 1 contains a summary of the demographic information for the two groups.

Table 1
Demographic Data for THO Cadaveric Dissection Group and NT Virtual Dissection Group

	Cadaveric Dissection Group <i>n</i> = 34	Virtual Dissection Group <i>n</i> = 31
Race		
White	32	27
Black	1	1
Hispanic	0	1
Other	1	2
Gender		
Male	13	15
Female	21	16
Students with Disabilities	0	0
English Language Learners	0	0
Economically Disadvantaged	5	7

During the study, the teacher-researcher taught one class of students using THO cadaveric dissection techniques and the other class was taught using Anatomage Table for virtual dissection. Both groups studied the gross human anatomy for the body systems.

The teacher-researcher was the instructor for the course. She had been teaching science for 16 years, and had taught biology, chemistry, physics, forensics, anatomy and physiology, but was more focused on the biological sciences. The teacher-researcher had also worked for the university

associated with this study. As such, the professional relationship helped coordinate public and higher education collaboration for the study.

Intervention

Both groups of 12th-grade students participating in the study received 90 minutes of instruction every other day on an A/B block schedule. Over an 8-week period, the students participated in some lessons related to the cardiovascular system, but the majority of the content focused on the nervous system, and that system was the focus of the achievement assessment. Students were chosen for the study using convenience sampling based on assignment to classes and the senior biology course schedule.

Participating classes were taught using the same instructional practices by the teacher-researcher throughout the study, except for method of cadaveric dissection. The NT virtual dissection group of participants (control group) received instruction that included using the Anatomage Table for dissection. The Anatomage Table located in the university's virtual lab depicts a life-size, digital cadaver that is three-dimensional. An Anatomage Table has touch-screen capabilities that allowed participants to dissect or virtually remove various parts of the virtual cadaver. Participants were administered a pretest and posttest before and after the teacher-researcher taught the unit on the nervous system. Next, the teacher-researcher led lecture for two class periods with each class; then students participated in classroom activities that reinforced the gross anatomy of each body system. Students were placed in groups of four by the teacher-researcher to work on the Anatomage Tables in the lab. The NT virtual dissection group was administered a survey and a questionnaire after the unit to determine the attitudes and

engagement of the students using the Anatomage Table to learn the gross human anatomy.

The THO cadaveric dissection group of students (intervention group) received instruction on human body systems in the local university cadaver lab with the use of several cadavers and prosections (i.e., dissection of parts of the cadaver for instruction). Participants were administered a pretest and posttest before and after the teacher-researcher taught the unit on the nervous system. Participating students were placed in groups of four by the teacher-researcher, where they worked together to identify structures for a body system using a human cadaver. The teacher-researcher provided the groups with the structures' list for the body system being studied. The THO cadaveric dissection group was administered the same survey and questionnaire as the NT virtual lab group after the unit to determine the attitudes and engagement of the students using the human cadavers to learn the gross human anatomy.

Data Collection

Methods of data collection used for this study consisted of pretests and posttests for comparing academic achievement. An attitude survey provided information for analysis of student perceptions of quality of dissection activities in terms of contribution to learning. Data were collected on student engagement evidenced by self-reported participation in class.

Assessments. At the completion of the study of the nervous system unit, data were collected by means of pre- and post-unit tests administered by the teacher-researcher. The tests consisted of multiple choice questions with diagrams that students had to label. The data collected from each group were used to determine the overall student performance on the nervous system content. The assessment was written and established

by Pearson Education (Marieb, 2010). The THO cadaveric dissection group and NT virtual dissection group were administered both tests with a 90-minute time frame to complete each of the tests. Data were analyzed using descriptive statistics including means and standard deviations (M , SD), and statistical inferences were determined by using a one-tailed t test.

Attitude Survey. Attitude toward learning the human gross anatomy was determined using a five-point Likert scale with the following ratings: *strongly agree*, *agree*, *neutral*, *disagree*, and *strongly disagree*. For both classes, the Likert scale consisted of eight descriptors that measured the students' attitude or motivation toward the learning activity that involved the cadaveric dissection and the virtual dissection. The survey was derived from Med Teach (Svirko & Mellanby, 2008). The teacher-researcher analyzed the data using a two-tailed t test, means, and standard deviations to determine whether there was any significant difference in achievement between the THO cadaveric dissection group and the NT virtual dissection group (Creswell, 2015). Both groups were administered the survey after the nervous system unit was completed.

Engagement Questionnaire. Engagement in the learning process was measured using a questionnaire (Kuh, 2001). The questionnaire consisted of statements that the students rated using a numerical system of 1-10. The number 1 represented the feeling of *Strongly Disagree* and the number 10 on the scale represented the feeling of *Strongly Agree*. This scale allowed the students to show their participation, study habits, collaboration, and preparation for the units being studied. The teacher-researcher calculated the data using a two-tailed t -test from each of the students' ratings of the statements (Creswell, 2015). The questionnaire was completed by both groups of students at the end of the nervous system

unit.

Fieldnotes. Fieldnotes were used to record qualitative data on the students' behaviors in the laboratory exercises. The researcher noted dialogue related to instruction and learning, behaviors of each of the groups of students, and specific words or phrases, such as comments indicating understanding, excitement, newly discovered knowledge, and other dialogue that dealt with the lab activities during either NT virtual dissection lab activities or THO cadaveric dissection labs. The teacher-researcher used descriptive and reflective fieldnotes to provide triangulation for statistical findings (Creswell, 2015).

Results

The teacher-researcher conducted this study to examine the effects of THO cadaveric dissection and NT virtual dissection on the achievement, attitude, and engagement toward learning with 12th-grade ADCT students in a suburban public high school in Idaho. All participants were administered whole-group instruction on the nervous system unit in their College Biology 1102 class for three class periods, which were 90 minutes long. The participants ($n = 31$) in the NT virtual dissection group were escorted across the hall to the university's virtual anatomy lab for a 90-minute class period. Likewise, the THO cadaveric dissection group ($n = 34$) were escorted down the hall to the connected local university's anatomy lab where they were allowed to work with human brains and spinal cords. A pre/posttest on the human nervous system served as the data collection instrument used to measure the effectiveness of the NT virtual and THO cadaveric dissections.

Achievement

Table 2 provides statistical analysis of two comparisons of achievement for the two groups of students. The first comparison is of each group's pretest and posttest scores for the purpose of establishing whether use of each strategy produced statistically significant achievement gain. The second comparison provides a statistical comparison of the gains of the two groups to determine whether cadaveric dissection was associated with statistically greater achievement gains than was virtual dissection.

Table 2
Achievement Data Collection on THO Cadaveric Dissection Group and NT Virtual Dissection Group

	Pretest		Posttest		<i>t</i> value	<i>p</i>	Mean Gain	<i>t</i> value	<i>p</i>
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>					
Cadaver ($n = 34$)	35.02	14.99	83.81	10.06	-15.49	< .001***	48.88	.042	0.48
Virtual ($n = 31$)	33.49	14.03	82.49	8.10	-16.55	< .001***	49.06		

* $p < .05$; ** $p < .01$; *** $p < .001$

In the first comparisons, both *t*-test values support a conclusion that the two strategies were effective in producing statistically significant achievement gains from pretest to posttest for the cadaveric dissection group ($t(33) = -15.49, p < .001$) and the virtual dissection group ($t(30) = -16.55, p < .001$). Teaching biology using either THO cadaveric dissection or NT virtual dissection were beneficial to student achievement.

To determine whether THO cadaveric dissection was more effective than NT virtual dissection in improving achievement, the mean gains between the two groups were compared, and those results are also in Table 2. There was not a statistically significant difference ($t(64) = .042; p = .48$) between

the mean achievement gains for the cadaveric group ($M = 48.88$) and the virtual group ($M = 49.06$). The data confirmed that there was no difference in the achievement of the students using the THO cadaveric dissection compared to the NT virtual cadaver lab.

Attitude

The two groups of participants were administered an 8-item survey after the end of the intervention period. The purpose of the survey was to measure the students' attitudes toward completing the virtual and cadaver lab activities. Though students participated in only the labs completed by their class, they were aware of the lab activities of the other class. Survey responses were given using a Likert scale of *Strongly Agree*, *Agree*, *Neutral*, *Disagree*, or *Strongly Disagree*. Results are reported in Table 3 listed as percentages for each question that the participants answered.

Table 3
Attitudes Toward Dissection Method for THO Cadaveric Dissection Groups and NT Virtual Dissection

Item	Cadaveric Dissection Group			Virtual Dissection Group		
	SA/A	N	D/SD	SA/A	N	D/SD
1. I would prefer cadaveric dissections.	61%	21%	18%	62%	19%	19%
2. I would prefer virtual dissections.	21%	40%	39%	23%	35%	42%
3. By using the cadavers, I would remember the human body systems units better.	61%	33%	6%	68%	23%	9%
4. By using the virtual lab, I would remember the human body systems units better.	27%	40%	33%	32%	26%	42%
5. I will not remember the body systems by using the cadavers.	3%	55%	42%	16%	32%	52%
6. I prefer to use the cadavers for all labs in the future.	64%	33%	3%	61%	23%	16%
7. I prefer to use virtual labs for all labs in the future.	15%	40%	45%	36%	29%	35%
8. Completing physical labs would motivate me more than virtual labs.	49%	33%	18%	68%	16%	16%

Note: SA/A = Strongly Agree/Agree; N = Neutral; D/SD = Disagree/Strongly Disagree

Survey items 1, 3, 6, and 8 collectively asked participants about whether they would have a stronger preference for working with the cadavers compared to the virtual technology. The results for the questions 1, 3, 6, and 8 showed that a large percentage of both the cadaveric group and virtual dissection group preferred cadaver dissections. Both groups had a majority of *Strongly Agree/Agree* responses for the questions 1, 3, 6, and 8. The participants, including those who did and those who did not have experience with human cadavers, reported feeling that working with human rather than virtual cadavers would increase their motivation to learn the content. Items 3 and 4 addressed whether students believed the anatomy lessons would be more memorable with one of the two strategies. Results from Item 7, however, revealed that over half of the students in both classes were either neutral about conducting all labs virtually in the future or supported that idea, which may indicate that students saw value in labs using the Anatomage Table. Most students felt that THO dissections with cadavers would be memorable, but responses about virtual labs promoting content retention were mixed.

Overall, the participants believed that THO cadaveric dissections could improve their attitudes toward the learning process, but they were not overwhelmingly negative about virtual dissections. These results support the conclusion that students may have seen value in either types of dissections.

Engagement

After the intervention period, all participants were administered a questionnaire to gauge their level of engagement in the THO cadaver lab or NT virtual lab. The participants used a 10-point scale to rate each of the 12 questions in the questionnaire. The scale choices ranged

from 1 (*strongly disagree*) to 10 (*strongly agree*). The mean response for each question for each group was analyzed to determine whether there was a difference between the two groups of participants. Responses are provided in Table 4 for both the THO cadaver dissection group and NT virtual dissection group.

Table 4
Engagement Questionnaire Responses from THO Cadaver and NT Virtual Dissection Participants

	<i>Mean Response Cadaver Group</i>	<i>Mean Response Virtual Group</i>
1. Asked questions and contributed to unit discussions.	7.71	8.42
2. Came to class prepared.	7.81	7.94
3. Memorized topics on the human body systems.	7.67	6.78
4. Applied knowledge of human body system to real-life situation	7.51	6.23
5. Appeared happy to be working in virtual lab.	3.39	6.74
6. Appeared happy to be working in cadaver lab.	7.09	2.34
7. Explained material to one or more students.	3.45	4.65
8. Prepared for exams by working with unit with other students.	4.12	3.25
9. Skipped or miss class for any reason	1.30	1.40
10. Worked with other students on course projects or assignments	6.36	5.78
11. Worked harder on this unit more than other units.	8.67	7.92
12. Participated in teacher-led discussions on the topic.	8.00	8.14

Items 2, 5 and 6, and 9 showed similar responses from the two student groups. Both groups saw their preparation for class as strong, both were similarly happy to be participating in their labs, and both indicated low rates of absences from class. Students' reporting of working with other students (Items 7, 8, and 10) received some of the lower ratings from both groups, and those ratings were around or just below the mid-range of 5 on the scale of 1 to 10. Students'

mean ratings of their work with other students in preparing for exams, having explained content to others, or working with others on assignments were neither high nor low for either group. Participants in these two classes did not have widely differing perceptions of their engagement in class activities during the study.

Fieldnotes

Fieldnotes recorded by the teacher-researcher documented actions and dialogue of the students throughout the laboratory activities. The teacher-researcher noted when the students showed excitement or lack of interest when in a lab. It was also noted that some students did not react positively to the human cadavers at first, and they were allowed to leave the cadaver lab, but it was explained that this experience does happen, and students were encouraged to participate in further labs. Mulu and Tegabu (2012) found that students can move past the negative feelings with further experiences. The fieldnotes recorded more enthusiasm in students performing the THO cadaveric dissection than for students in the NT virtual lab.

Discussion

Data collection took place during an 8-week unit on the nervous system in a senior ADCT biology class. The lab experiences were conducted at the local university and were either in the carried out as THO cadaveric dissections with the use of a human cadaver or NT virtual dissections using Anatomage Tables. The teacher-researcher measured achievement data using pretest and posttest scores from the unit test on the nervous system. Student attitude and engagement toward learning were measured using a Likert-scale attitude survey and an engagement questionnaire.

The results support the conclusion that,

for this study, there was not a statistically significant difference in achievement when comparing the mean point gain between pretest and posttest for the THO cadaveric dissection group ($M = 48.88$) and the mean gain for the NT virtual dissection group ($M = 49.06$). A previous study showed that students who completed THO cadaveric dissections to learn gross anatomy scored higher on academic tests than those students who used a non-cadaveric-based study (Anyanwu & Ugochukwu, 2010). This study did not support those findings. It is important to note that the Anatomage Table virtual dissection tool was one of the most advanced virtual dissection tools available, and it simulated both the physical act of students gathering around a full-size human dissection table and the use of advanced software. Such an advanced tool might mitigate some differences that would be present in other studies using less advanced virtual tools. However, this study's findings are aligned with Brinson's (2015) findings of the review of the literature on THO and NT labs. Students benefit from both approaches.

Participants were administered a survey to determine the attitude toward learning human anatomy by using THO cadaveric dissections and NT virtual dissections. Whether students conducted THO or NT virtual cadaveric dissection, participants' opinions were skewed toward the opinion that they could learn more by conducting THO cadaver dissections, though they also perceived that there was value in the virtual dissection in which one class participated. Research shows that high potential students (Tomlinson et al., 2004) need to experience more challenging inquiry-based or hands-on laboratory experiences to make science more meaningful (Fancovicova & Prokop, 2014), and Rehman et al. (2012) found that students preferred THO dissections over virtual dissections due to the tactile,

multisensory encounter during the lab. Students may have also expressed a value for real-world experiences. In summary, learning in biology courses requiring dissection experiences may depend on the quality of the designed experiences.

Students self-assessed their engagement in the lessons, and the engagement responses of the two classes were compared. Students in both classes had similar perceptions of their work in the courses, and there were not wide differences in their perceptions of their work. It is noted that students who are completing college credit courses while in high school may be more motivated and more confident of their work habits, and there would be fewer differences in perceptions of engagement in a course, even if experiences were different from students in another section of the same course.

Limitations

Over the intervention period, time restraints may have affected the outcome of the results. Study participants spent limited class time completing cadaveric dissections labs. Hands-on learning time was restricted to other tasks such as transition to the lab, lab safety, lab instructions, learning how to use the Anatomage table, or how to handle the extremely vulnerable tissue found in the brain and spinal cord. These issues limited the time students spent on learning anatomy and may have affected student achievement. Also, this study did not attempt to measure comfort with human body parts. It would have been helpful to know the effects of touching and feeling a human cadaver, or its organs, compared to a virtual one. Lastly, because students were transported to the university setting for conducting dissections with cadavers, the excitement of traveling and of being on the university campus may have affected attitudes toward both methods of learning.

Significance/Impact on Student Learning

The 12th-grade students who participated in the study were identified as high potential students (Tomlinson et al., 2004) who are required to complete a more challenging curriculum (Banks, 2006; Ford, 2011). Studies have shown that hands-on lab activities increase student achievement (Fancovicova & Prokop, 2014). However, because of budget constraints and limited resources, there has been a decrease in the use of THO labs for dissection purposes (Sauter et al., 2013). The use of virtual dissection technology has increased in education due to the lower costs to schools (Franklin et al., 2002). The research school's vision and mission statements for the science department showed a need for students to be pushed academically to have a more meaningful education in science (School Improvement Plan, 2015). The intervention provided to the participants allowed the students to experience hands-on laboratory experiences and created a learning environment that was more challenging, as well as more engaging for the students (Bassett et al., 2014). The THO cadaveric dissection students felt that using the cadavers was a more challenging experience academically that had them more engaged to learn about the human anatomy.

Based on the results of this study, the teacher-researcher will utilize both THO and NT virtual cadaveric dissection labs in the future to increase the achievement, attitudes, and engagement of the students in the biology classroom. Most importantly, students were afforded the opportunity to utilize the local university resources. As such, (a) students experienced THO approaches and state of the art technology that facilitated IBL, (b) financial and instructional costs were minimized, and (c) and more equitable learning environments were supported. The collaboration between the high school and the local university

benefitted both entities by supporting students' science achievement, engagement and interest in science and technology, and potentially in STEM careers.

After the study was completed, the teacher-researcher and colleagues spoke with a medical research specialist about virtual and cadaver lab experiences for learning about human anatomy. The medical doctor agreed that, even though there was not a significant academic difference in this study, students learned two important things. First, virtual cadaveric labs may show bodies that are closer to real cadavers compared to actual real cadavers, so specific content knowledge may be conveyed clearly because of the visuals. Compared to virtual cadavers, real cadavers usually have a level of decomposition, and previous work may destroy organs and organ tissue that may cause the cadavers not to be quite as exact. The medical doctor also shared that the value of working with cadavers is being in the presence of bodies and getting accustomed to that setting, and an academic assessment cannot measure that factor. For high school students who desire a future as medical professionals, the personal experience has special value, which is likely not captured within an assessment. As previously mentioned, the teacher-researcher agrees that such insight about high potential students may guide future implications for further study, and that this and most studies do not measure comfort with human body parts.

Teachers must learn and then in return help other educators teach students about how knowledge is created and influenced by social class (e.g., privilege and access), and include how race, ethnicity, and gender may influence essential knowledge (Atwater, 1996; Banks, 2006). Previous research and Tomlinson, Ford, Reis, Briggs, and Strickland's (2004; 2011) dream of designing schools and classrooms that work

for high potential students and diverse learners with exceptionalities (2008), the researchers believe that this study may help high potential learners and all learners in a multicultural society be successful in science (Suriel, 2016). Multicultural teachers and educators are encouraged to continue exploring science education in a variety of settings, investigating differences in locality, school structure, and race/ethnicity (Powers, 2015; Tomlinson et al., 2004; Zamudio et al., 2011) to examine the aforementioned learner differences to collaboratively develop and share successes and failures to enhance academic achievement for all high school science students.

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Appendix A

Table 1
Demographic Data for THO Cadaveric Dissection Group and NT Virtual Dissection Group

	Cadaveric Dissection Group <i>n</i> = 34	Virtual Dissection Group <i>n</i> = 31
Race		
White	32	27
Black	1	1
Hispanic	0	1
Other	1	2
Gender		
Male	13	15
Female	21	16
Students with Disabilities	0	0
English Language Learners	0	0
Economically Disadvantaged	5	7

Appendix B

Table 2
Achievement Data Collection on THO Cadaveric Dissection Group and NT Virtual Dissection Group

	Pretest		Posttest		<i>t</i> value	<i>p</i>	Mean Gain	<i>t</i> value	<i>p</i>
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>					
Cadaver (<i>n</i> = 34)	35.02	14.99	83.81	10.06	-15.49	< .001***	48.88	.042	0.48
Virtual (<i>n</i> = 31)	33.49	14.03	82.49	8.10	-16.55	< .001***	49.06		

p* < .05; *p* < .01; ****p* < .001

Appendix C

Table 3
Attitudes Toward Dissection Method for THO Cadaveric Dissection Groups and NT Virtual Dissection

Item	Cadaveric Dissection Group			Virtual Dissection Group		
	SA/A	N	D/SD	SA/A	N	D/SD
1. I would prefer cadaveric dissections.	61%	21%	18%	62%	19%	19%
2. I would prefer virtual dissections.	21%	40%	39%	23%	35%	42%
3. By using the cadavers, I would remember the human body systems units better.	61%	33%	6%	68%	23%	9%
4. By using the virtual lab, I would remember the human body systems units better.	27%	40%	33%	32%	26%	42%
5. I will not remember the body systems by using the cadavers.	3%	55%	42%	16%	32%	52%
6. I prefer to use the cadavers for all labs in the future.	64%	33%	3%	61%	23%	16%
7. I prefer to use virtual labs for all labs in the future.	15%	40%	45%	36%	29%	35%
8. Completing physical labs would motivate me more than virtual labs.	49%	33%	18%	68%	16%	16%

Note: SA/A = Strongly Agree/Agree; N = Neutral; D/SD = Disagree/Strongly Disagree

Appendix D

Table 4
Engagement Questionnaire Responses from THO Cadaver and NT Virtual Dissection Participants

	<i>Mean Response Cadaver Group</i>	<i>Mean Response Virtual Group</i>
1. Asked questions and contributed to unit discussions.	7.71	8.42
2. Came to class prepared.	7.81	7.94
3. Memorized topics on the human body systems.	7.67	6.78
4. Applied knowledge of human body system to real-life situation	7.51	6.23
5. Appeared happy to be working in virtual lab.	3.39	6.74
6. Appeared happy to be working in cadaver lab.	7.09	2.34
7. Explained material to one or more students.	3.45	4.65
8. Prepared for exams by working with unit with other students.	4.12	3.25
9. Skipped or miss class for any reason	1.30	1.40
10. Worked with other students on course projects or assignments	6.36	5.78
11. Worked harder on this unit more than other units.	8.67	7.92
12. Participated in teacher-led discussions on the topic.	8.00	8.14