The effects of blended learning on critical thinking in a high school Earth Science class

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THE EFFECTS OF BLENDED LEARNING ON CRITICAL THINKING

IN A HIGH SCHOOL EARTH SCIENCE CLASS

An Abstract of a Thesis

Submitted

in Partial Fulfillment

of the Requirements for the Degree

Master of Arts

Renee Nicole Borglum

University of Northern Iowa

May 2016
ABSTRACT

This study analyzed the effects of differing levels of technology use in a high school Earth Science class on student performance on the Classroom Test of Scientific Reasoning (CTSR). Blended learning manipulates the combination of hands-on activities, classroom discussions, online discussions, interactive simulations and a variety of assessments that engage, instruct and assess student learning. Critical thinking is the set of skills and dispositions that foster problem solving, reasoning ability and self-regulation. The increasing use of technology in the classroom and fluctuation of content standards prompted this research. The results have implications for the classroom teacher of a wide range of ages and content areas as well as parents.

The control group experienced eclectic and reduced use of technology while the treatment group used a Learning Management System and an increased use of technology. Both groups had the same classroom teacher, curriculum, and assessments. The CTSR was given at the beginning and end of the semester in conjunction with a qualitative survey.

All students improved their CTSR score. There was no statistical difference in CSTR scores between treatment and control groups or between genders or age groups. This implicates that the level of technology used in a classroom does not directly impact critical thinking ability. Future studies could provide a more drastic difference in the amount of technology used or measure growth over an entire academic year.
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This Study by: Renee Borglum

Entitled: The Effects of Blended Learning on Critical Thinking in a High School Earth Science Class

has been approved as meeting the thesis requirement for the

Degree of Master of Arts in Science Education

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ACKNOWLEDGEMENTS

I would like to recognize the support and encouragement from my family and friends throughout my master’s education. My husband Jamie Borglum and my mother-in-law Maxine Borglum kept me going when I was ready to give up. My grandmother Joan Croxdale Sites inspired me to become a teacher in the first place. My daughters Adali, Emilia and Livia, father-in-law Jim Borglum, my parents Marc and Adrian Brideau, my sister Janelle Brideau and Sue Shankland have all given me the incentive I needed throughout the program.

I am grateful to my thesis committee members Dr. Kyle Gray, Dr. Dawn Del Carlo and Dr. Lyn Countryman for their time, feedback and expertise on my Master of Arts in Science Education degree.

I would like to acknowledge my friends and colleagues at Waverly-Shell Rock High School for supporting me throughout my career. I also appreciate all of my students. Without every one of these people, I would not be completing my degree.
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CHAPTER 1
INTRODUCTION

How Does Blended Learning Affect Critical Thinking Skills?

As teachers adopt more computer-based educational technology into their classrooms, it is easy to focus on the tools and not the teaching or the learning. Blended learning is a catch-phrase with multiple meanings, but the focus here is on a combination of hands-on activities, classroom discussions, online discussions, interactive simulations and a variety of assessments that engage, instruct and assess student learning. Unlike traditional teaching, asynchronous interactions are a major component of blended learning. This means that students and teachers do not have to be in the same place at the same time. Interactions may be discussions, assignment submissions, messaging, or other tools that do not require teachers and students to be simultaneously engaged. For instance, some students may do an activity early in the morning, others during the day, and still others in the evening, while the teacher checks in and gives feedback at night.

Instead of focusing on how blended learning helps on standardized tests or improves grades, this study examined whether a systematic blended approach could improve critical thinking skills. Understanding how a blended learning classroom model affects critical thinking skills may be beneficial to teachers of many ages and disciplines, parents and post-secondary students.

Anticipated results included increased critical thinking for all students, a significant difference in the treatment group compared to the control group, a significant preference
for technology in the treatment group compared to the control group and no difference between groups in their science or climate perceptions.

**Literature Overview on Blended Learning and Critical Thinking**

The literature on blended learning gives some insight into why technology is taking such an expanding role in education. Currently, a single, uniform definition of blended learning does not exist. Rather, several definitions have been posed. Oliver and Trigwell (2005), Singh (2003), Sahin (2010) pose various definitions that could be applied to a variety of high quality, face-to-face classrooms that use multiple tools in instruction. The benefits of blended learning have been identified by Suanpang, Petocz, and Kalceff (2004), Taradi, Taradi, Radic, and Porkrajac (2004) and Bonk and Graham (2004). The considerations that should be taken into account when designing a blended classroom have been identified by Gardner (1983) as well as Khan and Granato (2008). Demand for blended learning experiences was studied by Picciano and Seaman (2009).

**Blended Learning Compared to Online Learning**

If a blended environment has benefits, why not go all the way to an online classroom? With the technology boom, educators are seeking the best ways to use computers and online tools in the classroom. Allen, Seaman, and Garrett (2007) outlined some statistics that illustrate the sweeping movement for college classrooms integrating technology. They found that at the Bachelor’s level, 16.3% of program offerings were online and 13.8% were blended. The largest increase in the percent of course sections taught online occurred at colleges and universities with enrollments over 15,000 students. In 2003, 3.47% of all courses at these schools were taught online, but by 2005 that number had
increased to 10.35%. In fact, the demand far surpassed the supply for blended and online classes.

However, subjects that are abstract, controversial, or complex require concrete learning experiences and are not good candidates for fully online courses (Rossett, Dougls & Frazee, 2003). Experiential learning is heavily documented and is the foundation for hands-on experiences such as lab activities (Kolb, 1984). Experiential learning focuses on learning as a continual process of understanding that evolves as new experiences are compared to those of the past. Because science is complex, uses experiential learning, can be abstract, and is at times controversial, a fully online science course would not be as successful as one that is blended.

Blended Learning Compared to Traditional Learning

One outcome of the expansion and implementation of blended learning is a shift in roles in the classroom. Comas-Quinn (2011) identified the pedagogical shift that has to take place for blended learning to be successful. Teachers fade from the ultimate dispenser of knowledge to a facilitator of learning, while students transition from information sponges to active seekers of knowledge. This model closely parallels inquiry-based and constructivist methods of instruction. Collaboration and problem solving in a student-driven setting is prevalent. This pedagogy does not necessarily require technology for implementation.

So is a blended classroom actually better than a traditional classroom for fostering critical thinking skills? Several studies suggest that using computer technology improves more than academic performance, and multiple studies have shown that the sense of
community, engagement, and collaboration are improved (Dziuban, Moskal, & Hartman, 2005; Rovai & Jordan, 2004; So & Brush, 2007). However, there is very little research on how critical thinking is benefited by blended learning.

Critical Thinking

Critical thinking encompasses the skills and dispositions that foster problem solving, reasoning ability and self-regulation. A study of college students found a direct correlation between scores on a critical thinking assessment and GPA (Facione, 2011). Critical thinking is the focus of this study because the content standards are always fluctuating. When students leave school and become active members of society, reciting facts may not be a marketable skill. However, being able to solve problems, self-regulate, analyze, and interpret information are valuable life skills that good critical thinking develops (Facione, 2011).

Several instruments have been developed to measure critical thinking skills including the Test of Logical Thinking, Group Assessment of Logical Thinking, Watson-Glaser Critical Thinking Assessment-Form S, the Cornell Critical Thinking Test (CCTT) and the Classroom Test of Scientific Reasoning (CTSR).

The Missing Pieces

This study attempts to fill in the gap between the push to use technology in the classroom and the need to develop critical thinking skills in students. As teachers replace traditional tools and activities with an assortment of Web 2.0 tools, more classrooms are blended. By using a blended-learning approach, the roles of teachers and students change. Students are given more control over their learning and teachers facilitate more than they
directly instruct. There is ample access to Web 2.0 tools that teachers can exchange for traditional lessons in their classrooms as well as multiple Learning Management Systems (LMS) that aggregate many tools into one user interface. This makes blended learning a possibility for any classroom teacher with student access to devices and the internet. In an Australian study, it was found that universities had a better understanding of the technology than the educational pedagogy behind implementing a LMS (Ellis & Calvo, 2007).

Over the past 100 years, reform movements within science education have swung like a pendulum from dedicating the majority of class time on content to inquiry oriented science instruction (DeBoer, 1991). To date, no happy medium has been found due in part to the constraints of time in the classroom and ever-changing content standards that must be met. Understanding how to use one tool to build a skill such as critical thinking may allow teachers more flexibility to incorporate the best of both worlds. The experiential learning can be done in the classroom, and the content can be emphasized using technology. At the same time, a life skill such as critical thinking may be fostered. While critical thinking has several measures, there are qualitative pieces of blended learning that have been evaluated as well. Qualitative surveys about how students perceive their understanding of the material (Suan pang et al., 2004), their value of technology, their collaborative effectiveness (So & Brush, 2007), their involvement in the class as a community (Rovai & Jordan, 2004), and their level of engagement have helped to paint a complete picture of the differences between blended and traditional classrooms.
The Benefits of this Study

By examining the quantitative results on a critical-thinking assessment tool and the qualitative results of surveys, this study may benefit teachers of any age group or discipline. Secondary Science is the area studied; however, there are parallels in elementary settings as well as post-secondary and graduate levels. The skill of critical thinking is applicable to nearly all age groups and settings. Understanding the extent to which blended learning affects critical thinking may enable teachers and professors to mindfully decide when to use technology. In addition, parents contemplating online schools for grades K-12 may be interested the impact of blended learning on critical thinking. Lastly, post-secondary students who are investigating online degree programs could apply these findings to their decision making process. The emphasis of this study is to measure how a blended learning environment impacts the development of critical thinking skills.
CHAPTER 2

LITERATURE REVIEW

What is Blended Learning?

Blended learning is a broadly used but poorly defined term. Blending can refer to mixing e-learning with traditional learning, mixing online learning with face-to-face instruction, mixing media, mixing contexts, mixing learning theories, or mixing pedagogies (Oliver & Trigwell, 2005). With such a broad definition of blended learning, it would be easier to identify what unblended learning is. Nearly every teacher at every level uses some level of blending. “A single mode of instructional delivery may not provide sufficient choices, engagement, social contact, relevance, and context needed to facilitate successful learning and performance” (Singh, 2003, p. 51). Sahin (2010) defined blended learning as a continuum from entirely face-to-face instruction to an entirely online experience.

To create a blended-learning situation, not only does the content need to be presented in a variety of ways, but the various learning needs of the students should to be taken into account. Learners with high linguistic intelligence may excel at absorbing pages of text while students with other strengths may struggle with this particular task (Gardner, 1983). Khan’s Octagonal Framework (2008) identified eight angles to consider while developing, delivering, managing, and evaluating blended learning. Ethical dilemmas, institutional restrictions, pedagogical boundaries, technological limitations, interface design issues, evaluation requirements, management practices, and resource support availability are the eight angles to keep in mind while instituting a blended-learning
program (Khan & Granato, 2008). This framework aids in planning, development, management, and evaluation of blended-learning programs so that a meaningful learning environment can be created (Singh, 2003). Bonk and Graham (2004) found the strengths of combining a computer-mediated environment and a face-to-face environment include flexibility, participation, depth of participation, human connection, and spontaneity. All of these benefits could not be achieved in just one mode of instruction. A study of 1,000 undergraduate statistics students found significant increases in their attitudes toward statistics for those students who experienced online learning compared to students who experienced a traditional setting (Suanpang et al., 2004). Blended learning is worth the investment because there is significant evidence that students achieve at a higher level than traditional courses without losing student satisfaction (Taradi et al., 2004).

This study defines blended learning as the combination of hands-on activities, classroom discussions, online discussions, interactive simulations, and a variety of assessments that engage, instruct, and assess student learning. According to Alonso, Lopez, Manrique and Vies (2005), “The most efficient teaching model is a blended approach, which combines self-paced learning, live e-learning, and face-to-face classroom learning” (p. 234).

Creating a Blended Learning Environment

While many instructors already use a variety of media to teach, there are some specific tools that are proven to improve the blended learning experience. Blogging or online discussions are one way to have students communicate asynchronously and communicating in this manner expands student learning (Colombo & Colombo, 2007).
Once students leave the traditional brick-and-mortar setting, they typically don’t think about the material until the next class session. Using asynchronous communication encourages students to reflect on what they learned in class and to apply it to themselves. Blogs can be used to reinforce, review, enrich, and introduce new material (Colombo & Colombo, 2007).

Online calendars allow the teacher to continually update information and send alerts to students as events approach. A traditional posted calendar can still be updated and inform students where relevant content can be found; however, content posted online can be rich with hyperlinks and videos and has the advantage of being accessible when and where the student chooses. Delivering content face to face and via paper requires the student to be present and to physically have the content in order to make up for an absence. Submitting assignments online allows the teacher to know precisely when it was turned in. It can be graded conveniently with numerical, text, and voice feedback. Material assignments allow more free-form feedback but must be handled repeatedly between collecting, grading, and returning.

Beyond traditional assignments, a new set of online tools, commonly referred to as Web 2.0, provide a host of innovative ways to apply student learning. Teachers now have access to a large array of online tools that are interactive rather than passive sources of information. Typically, Web 2.0 tools are software applications built on the Web as opposed to on a desktop and include, but are not limited to, tests and quizzes, surveys, bookmark sharing, picture sharing, social networking, tools to create posters, and sites where students can create and share presentations. Presentation tools include Prezi,
Toontastic, Pic Collage, Educreations, iMovie and many more. Videos, animations, voice recordings, sound effects, and more can be incorporated into these presentations.

Conventional presentations such as speeches, posters, brochures, and scrapbooks provide a variety of media to be used as well. All of these tools can be used as outlets for students to express themselves and to interact with the material in ways that are not possible in the brick-and-mortar setting of traditional classrooms. To measure learning, online assessment tools take testing to another level.

Online assessment tools can be formatted to match a paper and pencil test. Multiple question formats can be used; however, the ability to shuffle questions means that students are not looking at the same question at the same time. Instant feedback lets the student know how they did and what they did wrong. Some are even adaptive and modify the content based on the responses. Teachers have access to statistical reports that help point out concepts that need re-teaching or expansion. Standard assessments have many of the same features but require more time on behalf of the teacher. A combination of all of these tools is called a Learning Management System (LMS).

An LMS is a centralized system hosted by a university or school district which enables students to access, submit and receive feedback on assignments, hold discussions, take quizzes, access learning material and interact with the instructor along with a myriad of other functions. There are a number of social networking sites and other Web 2.0 tools that can accomplish some of these same objectives. Using an LMS is superior to an aggregation of tools because it concentrates all of those tools on one platform. This allows for deeper communication between students and between student and teacher,
there is consistency for students, and long term documents such as e-portfolios can be recorded. Furthermore, accessibility is guaranteed, and there is a filter for inappropriate materials (Sclater, 2008). There are several LMSs available such as WebCT, BlackBoard, Canvas, Sakai, and dotLRN. In some countries such as Denmark, Finland, and South Korea, one LMS is adopted nationwide (U.S. Department of Education, 2011). Of these choices, faculty and students have rated Instructure’s Canvas a superior option when compared to Blackboard’s Learn from an academic standpoint (Robertshaw, 2015). Faculty that piloted Canvas noted that it was easier to set up a course and easier to grade in Canvas compared to Blackboard. Students commented that access to grades and files was better on Canvas than Blackboard. It is essential that the users be familiar with the functions and expectations of the technology before content is delivered, observed Melton (2006). It is unlikely that using an LMS can transform education. Many LMS systems restrict teaching pedagogy by providing a framework that tends to be self-contained and focused on delivering information (Goodwin-Jones, 2012). As teachers are exposed to alternative ways of using technology, different teaching pedagogies can be used within an LMS.

Comparing Blended Learning to Traditional Methods

As education has evolved, learning theories have developed from behaviorism and conditioning to constructivism and inquiry. “Constructivism learning theory, which focuses on knowledge construction based on learner’s previous experience, is a good match for e-learning” (Koohang, Riley, & Smith, 2009, p. 91). Teachers are no longer the dispensers of knowledge. Instead, they are facilitators, mentors and providers of tech
support while they are constantly updating and renovating both online and face-to-face aspects of their courses. Making this shift is more than learning a few technological tools, it is a pedagogical shift that takes time and training (Comas-Quinn, 2011). This same pedagogy can be applied without the technology; however, for blended learning to be effective, it is essential.

Similarly, the students are not empty vessels to be filled and tested. Blended learning allows for more frequent formative assessment because the responses are automatically recorded and provide the data in a variety of helpful ways such as by student or by question to inform instruction. Input from students about what they like and dislike can be collected anonymously and influence changes in the course. In addition, test scores and student satisfaction were significantly higher in a blended setting versus a traditional setting (Taradi et al., 2004).

Comparing Blended Learning to Online Learning

A blended classroom can take on three different forms. First, it depends on the content, the teacher, and the students to determine whether face-to-face, blended, or online learning is most appropriate. Courses that are abstract, complex, or controversial need more than a purely online interface (Rossett et al., 2003). A well-blended classroom can be customized, integrated, flexible, and contain redundancy (Rossett et al., 2003). The number of both fully online and blended course offerings have significantly increased, especially in higher education (Allen et al., 2007). The technology explosion has led to an increase in classes that utilize blended learning tools. Currently, undergraduate institutions offer more online courses (64%) than blended courses (55%);
Because online is outpacing blended, it has been suggested that blended courses are simply a stepping stone to being fully online. However, the number of blended courses is too high to justify this claim (Allen et al., 2007). Based on a survey completed by Eduventures, the demand for online or blended courses far exceeds the supply, and there is ample room for growth in this area (Allen et al., 2007).

**Benefits of Blended Learning**

The “learning” in blended learning usually gets much less attention than the “blended.” The benefits of blended learning include an increased sense of community (Rovai & Jordan, 2004), higher levels of engagement and interaction (Dziuban et al., 2006) and improved collaboration (So & Brush, 2007). Yet, there is a lack of studies that explore the link between blending and improved learning.

A skill that may be enhanced in a blended classroom is critical thinking. Critical thinking, like blended learning, is difficult to define. There are numerous cognitive skills and personal dispositions that constitute critical thinking. Critical thinkers interpret, analyze, evaluate, and infer (Facione, 2011). Critical thinkers are able to self-regulate, explain, and inquire. They are well-informed, trustful, open-minded, flexible and honest. A prevalent pattern is that critical thinking is measured to a far greater degree at the postsecondary level than at the secondary level. A Google Scholar search for “critical thinking postsecondary” resulted in 65,000 articles. Of those articles, 63% were included in a search with addition of “online.” A similar search for “critical thinking high school” yields a higher initial number of 267,000. However, only 32% of that remains when “online” is added to the search. This is important to study at the high school level if it is
expected at the postsecondary level. Additionally, critical thinking is necessary for a rational and democratic society.

**Measuring Critical Thinking**

There are several measures of critical thinking: the Test of Logical Thinking (TOLT), the Group Assessment of Logical Thinking (GALT), the Watson-Glaser Critical Thinking Appraisal: Form S (WGCTA-FS), the California Critical Thinking Skills Test (CCTST) and the Classroom Test of Scientific Reasoning (CTSR).

The TOLT measures the ability to control variables, while using proportional, combinatorial, probabilistic, and correlational reasoning (Tobin & Capie, 1981). The test contains ten items that each require both a correct response and justification for that response. Trials on grades 6 through college were shown to be reliable (Tobin & Capie, 1981). The TOLT has been used to predict performance in conceptual chemistry, conditional reasoning performance, and mechanics conceptions (Jiang, Xu, Garcia, & Lewis, 2010). Low TOLT scores indicate a need for concrete instruction and development of formal reasoning.

The GALT measures six logical operations by presenting 21 problems that require an answer and a justification (Roadrangka, Yeany & Padilla, 1983). GALT scores were used to correlate students’ problem solving ability and their risk of failure in college chemistry and microbiology grades (Jiang et al., 2010).

Both the TOLT and the GALT are paper and pencil exams requiring respondents to select an answer and justify it. The main difference is that the GALT measures concrete thinking while the TOLT measures reasoning skills.
The WGCTA-FS consists of 40 items that measure five critical skills: inference, recognition of assumptions, deduction, interpretation, and evaluation of arguments. This test was designed to measure students’ ability to recognize assumptions, evaluate arguments, and appraise inferences (Norris, 1985). An examination of this assessment found that the sub-categories are not telling, and the test should be used only as a general measure of competency (Bernard et al., 2008).

A fourth measure, the CCTST, has succeeded in “detecting the growth in critical thinking skills which is hypothesized to occur during college level instruction” (Facione, 1990, p. 13). This test measures five cognitive skills: analysis, evaluation, inference, deductive reasoning, and inductive reasoning. The 34-item multiple choice test successfully detects growth in critical thinking skills in college courses (Facione, 1990). Terry and Ervin (2012) did not find any variable that was statistically significant of age, gender, grade point average, standardized test scores, ethnic background, major, and transfer students. Although not statistically significant, students who had completed more than 18 hours of coursework online scored slightly lower than average. When used as a pre-test and post-test, the CSTR measures improvement in student critical thinking, and students who begin with a low score tend to see more improvement than those who begin with a high score (Phillips, Chestnut, & Rospond, 2004).

Finally, the CTSR has 24 multiple choice questions that measure concrete, early-formal and formal thinking skills (Lawson, 1978). It has been used as a pre and post-test to measure growth in student thinking skills (Lawson, 2001). Coletta and Phillips (2005) suggest using the CTSR with a Forced Concept Inventory to “measure the effectiveness
of alternative interactive engagement strategies” (p. 1). A nation-wide assessment of grades 7-12 used the CTSR to establish grade level norms (O’Donnell, 2011). The 24 multiple choice questions are usually paired, asking first for the correct answer and then the correct reason for that answer.

This study is needed because the majority of studies performed about blended learning have focused on postsecondary experiences. However, the number of K-12 students who were enrolled in online courses jumped 47% from 2005-2006 to 2007-2008 (Picciano & Seaman, 2009). The purpose of this study is to determine how critical thinking skills are affected by a blended learning environment as measured by the CTSR as a pre-test and post-test as well as a qualitative survey completed at the beginning and end of the study.
CHAPTER 3

METHODS

Data Collection

During this study, the dependent variable was the level of critical thinking ability in students as measured by the Classroom Test of Scientific Reasoning (CTSR). The independent variable was the classroom setting students experienced while using science to build their critical thinking skills. This study collected data from five sections of a high school Earth Science course. Three of the sections were part of the treatment group and experienced a blended environment. These students were enrolled in Canvas and were expected to use its features including the online calendar; receiving content electronically; receiving, completing, and submitting assignments electronically; and using collaboration tools such as Google Docs to work on summative projects as well as take assessments and receive feedback. The remaining two sections of Earth Science served as the control group. These students still had access to technology including a Chromebook, the internet for research and online bulletin boards like Padlet but did not have access to Canvas. As a result, their instructional experiences for this course were more traditional. For example, this group depended on the written schedule in the classroom, received printed and presented content, turned assignments into the teacher on paper, took tests and quizzes on paper, and received all feedback on paper.

The same instructor taught all 5 sections and approximately the same pace was followed in both settings. Other than the use of the online tools in Canvas, the same teaching pedagogy was applied to both groups. This was an inquiry-based class that
focused on answering a driving question by completing assignments and activities. The focus was on deep, cross-curricular understanding of a few big ideas rather than skimming the surface of a large number of concepts. Both groups participated in hands-on learning activities, read and applied content, maintained a paper notebook that organized and documented learning, submitted assignments, and created and presented summative projects as well as summative assessments.

Throughout the study, the treatment group made extensive use of technology by using the LMS Canvas to facilitate their learning. Canvas supported a wide array of features. The calendar displayed all events from all of the student’s classes. Events were linked to content, websites, or assignments. Students were notified by email if the instructor added or changed an event. Content was stored as a variety of files and accessed through multiple parts of the system. The teacher chose to hide or show pieces depending on what students needed at the time. Assignments were submitted as file uploads, URL links, text entries, or media recordings. Collaboration between students happened on shared Google Docs and were facilitated through Canvas. Quizzes were made accessible to different groups at different times. Questions were grouped and shuffled, and feedback was turned on and off. Questions were a blend of multiple choice, multiple correct, true/false, fill in the blank, matching and essay. Daily announcements were posted summarizing the lesson.

The control group did not have access to Canvas and experienced a traditional version of the same class. Content was printed and presented. Assignments were collected. Tests
and quizzes were paper and pencil copies of the same test given electronically to the treatment group.

The data were collected using a full time teacher who agreed to administer the test, assign a random 3 digit code to each student, cross-reference the received consent forms (Appendix A) and notify the Primary Investigator of the code numbers that could not be included in the data analysis. This person is referred to in this study as the Conduit. The Classroom Tests of Scientific Reasoning was given during a full length class period of 45 minutes under the supervision of the Conduit with the Primary Investigator out of the room. Each student received a random 3 digit code from the Conduit to use as an anonymous identification so that scores could be compared before and after the study. Paper copies of the test were distributed (Appendix B) and answers were recorded in a Google Form (Appendix C). Birthdate, gender and grade level questions were only included as a way for the Conduit to identify and correct codes that were not entered correctly. The form was sent through Canvas for the treatment sections and via email for the control sections. The tests were collected as students finished. Students then used the same 3 digit code to complete a Survey in Google Forms (Appendix D).

This was the best method for this study because it attempted to reduce bias. Rather than using personal observations or an instrument that has not been researched, this study used the Classroom Test of Scientific Reasoning (CTSR) by Anton Lawson. This test was chosen for its ease of access, simple scoring due to multiple choice questions, the ability to add to a national database, and its successful use in other studies. The CTSR has been reviewed and used in multiple applications because it is statistically valid (Lawson,
O’Donnell (2011) recommended the use of this test to compare reasoning skills to a national average. It was also age appropriate and relevant to science because science requires the skill of critical thinking, and by their freshman year, students had matured to the point that critical thinking could be reasonably expected of them. Comparing scores before and after the experiment clearly illustrated the gains made within the confines of the study and could be easily compared between the treatment and control groups. Comparing the progress of whole sections showed the average gains achieved. Comparing by gender highlighted any inequality between male and female students. Utilizing a survey provided qualitative data to balance and support the quantitative results. By using the same course, the same instructor and comparable groups of students, results are validated. Using a blend of quantitative and qualitative data was the best choice for this experiment, because the results revealed a complete picture of the benefits and potential drawbacks of teaching in a blended-learning environment.

**Study Setting**

This study took place in Waverly-Shell Rock Senior High School. In the building, there were 630 students, with 10% receiving special education services for an Individual Education Plan (IEP), and 19.21% participating in the state’s Free and Reduced Lunch program (Iowa Department of Education, 2014). The graduation rate was 98.18%. On the Iowa Test of Educational Development, the 9th grade cohort scored above the state average in math, science and reading. Every student was issued a Chromebook at the beginning of the year. Chromebooks are slightly smaller than a traditional laptop and use the internet to run Google applications such as Docs. All freshmen were required to take
Earth Science their first semester in high school and it is a graduation requirement. This course used an inquiry-based curriculum and heavily emphasized how we know what we know about the Earth’s history, processes, and place in space.

Five sections of Earth Science were used in this study. The starting number of students was 135 but 2 students left part way through the semester leaving the final number of participants at 133. The demographics of all sections were approximately the same but some differences naturally occurred. All sections were almost entirely composed of Freshmen. Earth Science is a graduation requirement, so any students who did not pass the course as a freshman had to retake the course. The upperclassmen totaled 2 sophomores and 6 seniors. Interestingly, all of the upperclassmen were male. There were several students with Individual Education Plans (IEPs) who participated in this course, and consequently, there was a Special Education teacher who was consulted on accommodations and modifications needed for those students. A third demographic that was unpredictable was the ratio of males to females. Finally, each academic class has a unique social composition that can affect their academic performance.

**Data Analysis**

Before this study began, the parents of all participants were asked to sign Institutional Review Board (IRB) consent and assent forms as part of their beginning of the year orientation. Signed consent/assent forms were collected and stored by front office personnel until after the post-test was taken. Only the results from participants with a signed parental assent form were used.
During the first week of class (August, 2015), all five sections took the CTSR as a baseline pre-test. During the last week of the study (December, 2015), all sections took the CTSR as a post-test. The data was then collected, analyzed and compared.

Pre- and post-test scores were evaluated using a paired, two-tailed t-test to determine statistical significance. The overall scores were compared by control versus treatment, gender, and grade level and the t-tests assumed unequal variances because the sample sizes were different. For this study, significance was set at p < .05.

Additionally, a Likert-scale survey was administered concurrently with the CTSR. Students were asked about their knowledge of the subject, their feelings toward technology in general, their feelings toward technology in education, and some environmental questions (collaboration, sense of community, level of engagement etc.). Responses were compared by student from pre- to post-test as well as by section and gender to provide a complete analysis of the functionality and usefulness of a blended learning environment.
CHAPTER 4

RESULTS

Demographics

The 133 total participants were divided into five sections. Two sections became the control group while the remaining three sections formed the treatment group. Some sections were fairly balanced between males and females while in two sections the males outnumbered females nearly 2 to 1. At least one upperclassman was in each section except for Section 7. There were 20 students with an Individual Education Plan.

Some student data was excluded from analysis. Of the original 135 participants, only 103 assent forms were signed and returned to the office. The Conduit matched these forms to the students’ 3 digit codes and notified the Primary Investigator of the codes that could not be included in the analysis. As a result, data from 32 students were removed. In addition, 135 students participated in the pre-test however only 128 students participated in the post-test. By matching the 3 digit code numbers, data from students who did not complete both assessments were removed from the study and not included in any subsequent analysis. The number of participants who returned a signed consent form and completed both assessments totaled 88 with 34 in the control group and 54 in the treatment group. The 88 students included in this study consisted of 45 males and 43 females and only four upperclassmen (Table 1). As a result of these demographics, there was a broad range of ability, interest, and ages in this study. The best effort was given to account for the unique nature of the students in each class.
Table 1: Demographics

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Students</td>
<td>34</td>
<td>54</td>
</tr>
<tr>
<td>Upperclassmen</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Males</td>
<td>19</td>
<td>26</td>
</tr>
<tr>
<td>Females</td>
<td>15</td>
<td>28</td>
</tr>
</tbody>
</table>

Classroom Test of Scientific Reasoning (CTSR)

CTSR Pre-test

Initial scores were low. Mean scores across all sections were 11.91 out of 24. Students were most correct on questions 16 and 1. They were the least correct on questions 7 and 12. Mean scores for the treatment students were higher than the control students by 1.10. An independent-samples t-test yielded no significant difference between the treatment and control groups (p = .25). No significant difference (p = .53) was observed between the males and females. The mean scores between freshmen and upperclassmen were also not significantly different (p = .72). Therefore, at the beginning of the study, the two groups were equivalent.

CTSR Post-test

Final scores were also low. Mean scores across all sections were 13.33 out of 24. Mean scores for the treatment students were 13.50. Mean scores for the control students were 13.05. This is a difference of 0.44 but it is not significant (p = .66). Males scored higher than females. The mean male score was 13.92 while the mean female score was
The p-value ($p = .18$) indicates that this was not significant. The mean scores between freshmen and upperclassmen showed no meaningful difference ($p = .28$). Table 2 summarizes these results.

Table 2: Changes in CTSR Scores

Statistically significant p-values < .05 are in bold.

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean CTSR Scores</th>
<th></th>
<th></th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre-test</td>
<td>Post-test</td>
<td>Difference</td>
<td></td>
</tr>
<tr>
<td>All Students</td>
<td>11.91</td>
<td>13.33</td>
<td>1.42</td>
<td>.045</td>
</tr>
<tr>
<td>Males</td>
<td>12.16</td>
<td>13.92</td>
<td>1.76</td>
<td>.049</td>
</tr>
<tr>
<td>Females</td>
<td>11.59</td>
<td>12.59</td>
<td>1.00</td>
<td>.285</td>
</tr>
<tr>
<td>Control Group</td>
<td>11.24</td>
<td>13.06</td>
<td>1.82</td>
<td>.071</td>
</tr>
<tr>
<td>Section 1</td>
<td>11.83</td>
<td>12.17</td>
<td>0.33</td>
<td>.843</td>
</tr>
<tr>
<td>Section 4</td>
<td>10.91</td>
<td>13.55</td>
<td>2.64</td>
<td>.040</td>
</tr>
<tr>
<td>Treatment Group</td>
<td>12.33</td>
<td>13.5</td>
<td>1.67</td>
<td>.231</td>
</tr>
<tr>
<td>Section 2</td>
<td>12.20</td>
<td>13.40</td>
<td>1.20</td>
<td>.397</td>
</tr>
<tr>
<td>Section 3</td>
<td>12.82</td>
<td>13.18</td>
<td>0.35</td>
<td>.815</td>
</tr>
<tr>
<td>Section 7</td>
<td>12</td>
<td>13.94</td>
<td>1.94</td>
<td>.387</td>
</tr>
<tr>
<td>Freshmen</td>
<td>11.94</td>
<td>13.20</td>
<td>1.26</td>
<td>.090</td>
</tr>
<tr>
<td>Upperclassmen</td>
<td>11.25</td>
<td>16</td>
<td>4.75</td>
<td>.011</td>
</tr>
</tbody>
</table>

Changes in CTSR Scores

Across all sections, scores increased significantly from an average of 11.91 on the pre-test to 13.33 on the post-test ($p = .045$). Scores from the treatment group improved by
1.17 points, yet this gain was not significant (p = .23). Similarly, scores from the control group improved by 1.82 points but this gain was also not significant (p = .07). Males scored higher than females on both the pre-test and the post-test. On average, the males in the study significantly improved their scores from 12.16 to 13.92 (p = .049). By contrast, the females in the study did not significantly improve their scores (p = .28). The highest scoring section on the pre-test was a treatment section, Section 3 with a mean score of 12.82. The highest scoring section on the post-test was also a treatment section, Section 7 with a mean score of 13.94. Section 4, a control section, showed the only statistical improvement (p = .040). Freshmen improved but not enough to be significant (p = .090), however the upperclassmen did yield a significant change (p = .011). Table 3 shows how CTSR scores compare between different groups.

<table>
<thead>
<tr>
<th>Group 1</th>
<th>Group 2</th>
<th>Difference</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male Pre-test</td>
<td>Female Pre-test</td>
<td>0.57</td>
<td>.531</td>
</tr>
<tr>
<td>Male Post-test</td>
<td>Female Post-test</td>
<td>1.32</td>
<td>.179</td>
</tr>
<tr>
<td>Control Pre-test</td>
<td>Treatment Pre-test</td>
<td>1.10</td>
<td>.248</td>
</tr>
<tr>
<td>Control Post-test</td>
<td>Treatment Post-test</td>
<td>0.44</td>
<td>.660</td>
</tr>
<tr>
<td>Freshmen Pre-Test</td>
<td>Upperclassmen Pre-test</td>
<td>0.69</td>
<td>.722</td>
</tr>
<tr>
<td>Freshmen Post-test</td>
<td>Upperclassmen Post-test</td>
<td>2.80</td>
<td>.282</td>
</tr>
</tbody>
</table>
**Survey**

Students used their same assigned 3 digit code on the survey as well so that comparisons could be made between CTSR results and survey responses. The survey was sent and completed as a Google Form (Appendix D) that was sent through Canvas for the treatment sections and via email for the control sections.

**Survey Before**

When asked how well they worked independently, 19% said “extremely well.” For how well they worked in groups, 52% responded 4 out of 5. Engagement in class was ranked as 4 out of 5 by 60%. The most common response to “How connected do you feel to your classmates” was 4 out of 5 by 38%. Interest in Science was limited to “there are a few things that catch my interest” as the most common response (46%). Half prefer to read on paper. To solve technology problems, the most frequent response was “ask a friend for help” (32%). “Technology does not make learning easier or harder” was selected by 59%. Control sections were less confident in their ability to work independently. Figure 1 summarizes the responses to the initial survey for the control sections. Figure 2 summarizes the responses to the initial survey for the treatment sections.

**Survey After**

When asked how well they worked independently, 27% said “extremely well.” For how well they worked in groups, 60% said 4 out of 5. Engagement in class was ranked as 4 out 5 by 62%.
Figure 1: Survey Responses for Control Before

Figure 2: Survey Responses for Treatment Before
The most common response to “How connected do you feel to your classmates” was 4 out of 5 by 46%. Interest in Science was identified as “there are lots of things interesting things about science” by 44.5%. Half still preferred to read on paper. To solve technology problems, the most common response was “solve it myself” (28%). “Technology makes learning easier” for 63%. There were no distinct differences in responses between the treatment and control groups. Figure 3 summarizes the responses to the final survey for the control sections. Figure 4 summarizes the responses to the final survey for the treatment sections.

Changes in Survey Responses

Effectiveness and quality of work created independently increased, but p-values showed no statistical significance between control and treatment groups. Ability to work in groups increased, but p-values showed no statistical significance between control and treatment groups. Engagement did not show significant change. Interest in science went from the majority choosing “a few things in science are interesting” to “lots of things in science are interesting.” Solving technology problems shifted from asking a friend to fixing it myself. Technology went from being neither helpful nor harmful to learning to being generally helpful. Comparing the treatment and control groups did not show any significant difference in how their responses changed.
Figure 3: Survey Responses for Control After

Figure 4: Survey Responses for Treatment After
CHAPTER 5
DISCUSSION

Classroom Test of Scientific Reasoning (CTSR)

The CTSR has been used and validated for PreK-12 to measure critical thinking and scientific reasoning. Literature searches did not reveal any studies correlating critical thinking and blended learning in science using the CTSR. This study did not show any statistical difference in CTSR scores between students experiencing a blended learning environment or a traditional learning environment. Statistically supported differences were limited to males and upperclassmen. Males who both showed significant improvement regardless of their experience. Upperclassmen also showed improvement. This is consistent with data collected by de Armendi (2014) who found that male medical and nursing students had higher mean raw CTSR scores than females in the same programs.

The lack of a significant difference in scores between the control and treatment sections suggests that there is not a connection between a blended environment and critical thinking. This opposes the hypothesis that there would be a difference between groups. The significant growth overall shows that critical thinking developed during this study, regardless of the level of technology used. This supports the hypothesis that critical thinking would improve in both groups. The slight male advantage does not correlate with being in the treatment or control group and did not remain throughout the study. Only one control section showed statistical improvement while no treatment groups did.
This data reveals that while technology gets a lot of attention, it does not necessarily correlate to critical thinking. This implies that an increase in technology is not required to achieve gains in critical thinking. Therefore, teachers willing to embrace technology do not have to sacrifice critical thinking skills just as teachers who do not have access to technology are not limited in their ability to improve critical thinking skills. It is the pedagogy in the classroom that affects critical thinking, not the level or use of technology. The same inquiry-based pedagogy was applied to both groups and both groups improved their critical thinking.

Survey

Survey responses did not reveal any distinct differences between control and treatment groups. Overall, there were some changes worth discussing. Interest in science improved from the beginning of the study to the end regardless of how much technology was used. This indicates that technology did not affect the participant's perception of science. Rather it shows that exposure to science increased their interest. This supports the hypothesis that perceptions of science would improve regardless of which group students were in. The ability to fix a technology problem independently improved over the course of the study. Technology went from being viewed as neither helpful nor harmful to learning to something that makes learning easier in both groups. These changes can be attributed to using technology either in Earth Science or in other courses as well. By becoming familiar with the Chromebooks and learning how to solve problems, students had to become more independent. This opposes the hypothesis that students would prefer technology in the treatment group more than in the control group.
This survey data supports the CTSR data in that there was not a significant
difference in responses between the treatment and control groups. Overall, there was an
improvement but this was not due to the amount of technology used. This implies that not
all classes need to use technology systemically for students to gain proficiency in using it
and solving problems with it.

**Reservations**

Not all student data could be included due to not receiving their consent to use
data and some students only took one measure. Out of the 133 participants, only 88 data
sets could be used. Additionally, technology was still used in the control group just to a
lesser extent. Students still conducted research, created electronic flyers and used an
electronic corkboard to explore other student’s work. Also, because the entire is 1 to 1
with technology, students also used technology in other classes and outside of school.
The selection of control groups being the co-taught sections may have resulted in
inaccuracies. A higher percentage of students with an IEP and the presence of a co-
teacher may have had unmeasured effects on the data and experiment. The difference in
sample size between freshmen and upperclassmen might make the upperclassmen data
invalid. Additionally, the situations of those upperclassmen were markedly different from
the freshmen. The upperclassmen were either retaking the course because they had
previously failed it or were taking it as an easier alternative to Chemistry. This could
have affected the data due to their attitude at being stuck in a freshmen class.

Throughout the study, there were a few differences between the treatment and
control sections in terms of logistics. The control sections took less time to grade daily
work but more time to grade assessments. The control section participants asked more content related questions on a regular basis while the treatment sections asked primarily procedural questions. These differences may have had an effect on how questions were answered and the quality of feedback given.

If this study were to be repeated, there are a few suggested changes. For the consent/assent forms, there may have been a higher rate of return if the study could have been explained in person rather sending it home. Treatment sections should have a completely electronic “notebook” that would be submitted and graded through Canvas. This will make the notebook a single resource for the students which would be more comparable to the control sections. This would also reduce the grading burden on the teacher by creating one platform to assess instead of two. The survey questions should be reworded to be easier to evaluate. There were some questions that did not reveal much information because of how they were worded. The use of technology questions were not presented in the results because they were not in the same Likert-scale form and could not be compared like the rest of the questions. Other questions were very difficult to analyze because responses were non-numerical. Since there was an average increase in scores, measuring critical thinking in blended and traditional classrooms after a full year science course might yield a greater difference in scores.

To determine the longevity of the gains in critical thinking, the CTSR will be reassessed in the spring of 2017 to the same students.
Conclusions

This study aimed to determine a correlation between the level of technology used in the classroom and performance on a critical thinking assessment. Due to the absence of statistically supported differences, this study shows that there is not a connection between critical thinking as measured by the CTSR and the implementation of technology in the classroom experience. Qualitative survey results support this conclusion by showing no distinct difference between treatment and control groups and their perception of the classroom climate, interest in science or use of technology. These results indicate that it is not technology that impacts critical thinking rather the pedagogy used in the classroom.
REFERENCES


de Armendi, A. (2014). Medical and nursing students' cognitive levels measured by the Classroom Test of Scientific Reasoning and correlation to knowledge gained from lecture, simulation or lecture with simulation. (Doctoral dissertation). Retrieved from shareok.org


APPENDIX A

IRB CONSENT FORM

UNIVERSITY OF NORTHERN IOWA

HUMAN PARTICIPANTS REVIEW

INFORMED ASSENT

Project Title: How Does Blended Learning Affect Critical Thinking Skills?

Name of Principal Investigator(s): Renee Borglum

This is your first homework assignment: Take this home, ask your parents to read it and decide whether to sign it or not and turn it in to MRS. STOVER in the office by FRIDAY.

I, _________________, have been told that one of my parents/guardians has given his/her permission to use my earth science scores on my survey and critical thinking test as part of a research project.

I understand that my participation is voluntary. I will have to do the survey and tests as part of normal class activities, but I can choose whether I want to have my scores included in the study. I agree to allow my responses to be used in Mrs. Borglum's study.

________________________  __________
Signature     Date
UNIVERSITY OF NORTHERN IOWA

HUMAN PARTICIPANTS REVIEW

PARENTAL PERMISSION

Purpose: I am a Master’s student at the University of Northern Iowa. I am conducting research about the ways in which technology impacts critical thinking in Science. To see whether technology affects critical thinking, I will be teaching my sections of Earth Science a little differently this year. In some sections, technology such as Canvas and Google Docs will be used to communicate, assign, complete and grade assignments and to collaborate on group work. In other sections, technology will be used as little as possible. All students will receive the same content, complete the same assignments and get the same amount of work time. I am asking for permission to use your student’s data. The following information is provided to help you make an informed decision whether or not to allow me to use the results of critical thinking tests and surveys in my research.

Procedure: This study will run for the entire Fall semester. All classes will be taught by Mrs. Borglum. The same curriculum will be taught through the same assignments and assessments and all students will have the same expectations. The differences between the classes will generally be in the scope of technology used:

- Daily announcements posted on Canvas vs written on the whiteboard
- Assignments will be assigned, submitted and graded on Canvas vs on paper, completed by hand and graded by hand
- Group work will be conducted through shared Google Docs vs on paper
At the beginning and at the end of the semester, all students will be required to complete a survey and a critical thinking test. This is similar to what I do every year. The results of this study could help educators to purposefully decide when and how to most effectively use technology.

Risks and Benefits: There are no foreseeable risks in participation, nor are there anticipated benefits to participants. The data may help teachers decide the best way to teach science in the future.

Confidentiality: Information obtained during this study which could identify your child will be kept strictly confidential. The summarized findings with no identifying information may be submitted to the national database for this test, published in an academic journal and/or presented at a scholarly conference. Confidentiality will be maintained to the degree permitted by the technology used. Specifically, no guarantees can be made regarding the interception of data sent via the Internet by any third parties.

Signing this consent form gives me permission to use the data from your child. If you do not wish for me to use your child’s data, do not sign. These forms will be kept sealed by the school secretary until after grades are posted and your child’s participation will have no bearing on their grade or treatment. I will not know which parents give permission until after the fall semester is complete.

I am fully aware of the nature and extent of my child’s participation in this project as stated above. I hereby agree to give my permission to use the data from my student. If you would like a copy of this form, initial here: ________
(Signature of parent/legal guardian)  (Date)

(Printed name of parent/legal guardian)

Renee Borglum - Primary Investigator
319-352-2087
renee.borglum@wsr.k12.ia.us

Dr. Kyle Gray - Faculty Advisor, Earth Science Department University of Northern Iowa
319-273-2809
Kyle.Gray@uni.edu

If you have questions about research participant’s rights, contact Anita Gordon the UNI IRB Administrator at 319-273-6148 or anita.gordon@uni.edu
APPENDIX B

CLASSROOM TEST OF SCIENTIFIC REASONING

CLASSROOM TEST OF
SCIENTIFIC REASONING

Multiple Choice Version

Directions to Students:

This is a test of your ability to apply aspects of scientific and mathematical reasoning to analyze a situation to make a prediction or solve a problem. Make a dark mark on the answer sheet for the best answer for each item. If you do not fully understand what is being asked in an item, please ask the test administrator for clarification.

DO NOT OPEN THIS BOOKLET UNTIL YOU ARE TOLD TO DO SO

1. Suppose you are given two clay balls of equal size and shape. The two clay balls also weigh the same. One ball is flattened into a pancake-shaped piece. Which of these statements is correct?

   a. The pancake-shaped piece weighs more than the ball
   b. The two pieces still weigh the same
   c. The ball weighs more than the pancake-shaped piece

2. *because*
   a. the flattened piece covers a larger area.
   b. the ball pushes down more on one spot.
   c. when something is flattened it loses weight.
   d. clay has not been added or taken away.
   e. when something is flattened it gains weight.

3. To the right are drawings of two cylinders filled to the same level with water. The cylinders are identical in size and shape.

   Also shown at the right are two marbles, one glass and one steel. The marbles are the same size but the steel one is much heavier than the glass one.

   When the glass marble is put into Cylinder 1 it sinks to the bottom and the water level rises to the 6th mark. *If we put the steel marble into Cylinder 2, the water will rise*

   a. to the same level as it did in Cylinder 1
   b. to a higher level than it did in Cylinder 1
   c. to a lower level than it did in Cylinder 1

4. *because*
   a. the steel marble will sink faster.
   b. the marbles are made of different materials.
   c. the steel marble is heavier than the glass marble.
   d. the glass marble creates less pressure.
   e. the marbles are the same size.
5. To the right are drawings of a wide and a narrow cylinder. The cylinders have equally spaced marks on them. Water is poured into the wide cylinder up to the 4th mark (see A). This water rises to the 6th mark when poured into the narrow cylinder (see B).

Both cylinders are emptied (not shown) and water is poured into the wide cylinder up to the 6th mark. How high would this water rise if it were poured into the empty narrow cylinder?

a. to about 8
b. to about 9
c. to about 10
d. to about 12
e. none of these answers is correct

6. because
a. the answer can not be determined with the information given.
b. it went up 2 more before, so it will go up 2 more again.
c. it goes up 3 in the narrow for every 2 in the wide.
d. the second cylinder is narrower.
e. one must actually pour the water and observe to find out.

7. Water is now poured into the narrow cylinder (described in Item 5 above) up to the 11th mark. How high would this water rise if it were poured into the empty wide cylinder?

a. to 7 1/2
b. to 9
c. to 8
d. to 7 1/3
e. none of these answers is correct

8. because
a. the ratios must stay the same.
b. one must actually pour the water and observe to find out.
c. the answer can not be determined with the information given.
d. it was 2 less before so it will be 2 less again.
e. you subtract 2 from the wide for every 3 from the narrow.
9. At the right are drawings of three strings hanging from a bar. The three strings have metal weights attached to their ends. String 1 and String 3 are the same length. String 2 is shorter. A 10 unit weight is attached to the end of String 1. A 10 unit weight is also attached to the end of String 2. A 5 unit weight is attached to the end of String 3. The strings (and attached weights) can be swung back and forth and the time it takes to make a swing can be timed.

Suppose you want to find out whether the length of the string has an effect on the time it takes to swing back and forth. Which strings would you use to find out?

a. only one string  
b. all three strings  
c. 2 and 3  
d. 1 and 3  
e. 1 and 2

10. because
    a. you must use the longest strings.  
b. you must compare strings with both light and heavy weights.  
c. only the lengths differ.  
d. to make all possible comparisons.  
e. the weights differ.
11. Twenty fruit flies are placed in each of four glass tubes. The tubes are sealed. Tubes I and II are partially covered with black paper; Tubes III and IV are not covered. The tubes are placed as shown. Then they are exposed to red light for five minutes. The number of flies in the uncovered part of each tube is shown in the drawing.

This experiment shows that flies respond to (respond means move to or away from):

a. red light but not gravity
b. gravity but not red light
c. both red light and gravity
d. neither red light nor gravity

12. because

a. most flies are in the upper end of Tube III but spread about evenly in Tube II.
b. most flies did not go to the bottom of Tubes I and III.
c. the flies need light to see and must fly against gravity.
d. the majority of flies are in the upper ends and in the lighted ends of the tubes.
e. some flies are in both ends of each tube.
13. In a second experiment, a different kind of fly and blue light was used. The results are shown in the drawing.

These data show that these flies respond to (respond means move to or away from):

a. blue light but not gravity  
b. gravity but not blue light  
c. both blue light and gravity  
d. neither blue light nor gravity

14. because

a. some flies are in both ends of each tube.  
b. the flies need light to see and must fly against gravity.  
c. the flies are spread about evenly in Tube IV and in the upper end of Tube III.  
d. most flies are in the lighted end of Tube II but do not go down in Tubes I and III.  
e. most flies are in the upper end of Tube I and the lighted end of Tube II.

15. Six square pieces of wood are put into a cloth bag and mixed about. The six pieces are identical in size and shape; however, three pieces are red and three are yellow. Suppose someone reaches into the bag (without looking) and pulls out one piece. What are the chances that the piece is red?

a. 1 chance out of 6  
b. 1 chance out of 3  
c. 1 chance out of 2  
d. 1 chance out of 1  
e. cannot be determined
16. *because*
   a. 3 out of 6 pieces are red.
   b. there is no way to tell which piece will be picked.
   c. only 1 piece of the 6 in the bag is picked.
   d. all 6 pieces are identical in size and shape.
   e. only 1 red piece can be picked out of the 3 red pieces.

17. Three red square pieces of wood, four yellow square pieces, and five blue square pieces are put into a cloth bag. Four red round pieces, two yellow round pieces, and three blue round pieces are also put into the bag. All the pieces are then mixed about. Suppose someone reaches into the bag (without looking and without feeling for a particular shape piece) and pulls out one piece.

```
R R R |
Y Y Y Y
B B B B B
```

What are the chances that the piece is a red round or blue round piece?
   a. cannot be determined
   b. 1 chance out of 3
   c. 1 chance out of 21
   d. 15 chances out of 21
   e. 1 chance out of 2

18. *because*
   a. 1 of the 2 shapes is round.
   b. 15 of the 21 pieces are red or blue.
   c. there is no way to tell which piece will be picked.
   d. only 1 of the 21 pieces is picked out of the bag.
   e. 1 of every 3 pieces is a red or blue round piece.
19. Farmer Brown was observing the mice that live in his field. He discovered that all of them were either fat or thin. Also, all of them had either black tails or white tails. This made him wonder if there might be a link between the size of the mice and the color of their tails. So he captured all of the mice in one part of his field and observed them. Below are the mice that he captured.

![Mice illustration]

Do you think there is a link between the size of the mice and the color of their tails?

a. appears to be a link
b. appears not to be a link
c. cannot make a reasonable guess

20. *because*

a. there are some of each kind of mouse.
b. there may be a genetic link between mouse size and tail color.
c. there were not enough mice captured.
d. most of the fat mice have black tails while most of the thin mice have white tails.
e. as the mice grew fatter, their tails became darker.
21. The figure below at the left shows a drinking glass and a burning birthday candle stuck in a small piece of clay standing in a pan of water. When the glass is turned upside down, put over the candle, and placed in the water, the candle quickly goes out and water rushes up into the glass (as shown at the right).

![Diagram of experiment]

This observation raises an interesting question: Why does the water rush up into the glass?

Here is a possible explanation. The flame converts oxygen into carbon dioxide. Because oxygen does not dissolve rapidly into water but carbon dioxide does, the newly formed carbon dioxide dissolves rapidly into the water, lowering the air pressure inside the glass.

Suppose you have the materials mentioned above plus some matches and some dry ice (dry ice is frozen carbon dioxide). Using some or all of the materials, how could you test this possible explanation?

a. Saturate the water with carbon dioxide and redo the experiment, noting the amount of water rise.

b. The water rises because oxygen is consumed, so redo the experiment in exactly the same way to show water rise due to oxygen loss.

c. Conduct a controlled experiment, varying only the number of candles to see if that makes a difference.

d. Suction is responsible for the water rise, so put a balloon over the top of an open-ended cylinder and place the cylinder over the burning candle.

e. Redo the experiment, but make sure it is controlled by holding all independent variables constant; then measure the amount of water rise.

22. What result of your test (mentioned in #21 above) would show that your explanation is probably wrong?

a. The water rises the same as it did before.

b. The water rises less than it did before.

c. The balloon expands out.

d. The balloon is sucked in.
23. A student put a drop of blood on a microscope slide and then looked at the blood under a microscope. As you can see in the diagram below, the magnified red blood cells look like little round balls. After adding a few drops of salt water to the drop of blood, the student noticed that the cells appeared to become smaller.

![Diagram of red blood cells before and after adding salt water]

Magnified Red Blood Cells  After Adding Salt Water

This observation raises an interesting question: Why do the red blood cells appear smaller?

Here are two possible explanations: 1. Salt ions (Na+ and Cl-) push on the cell membranes and make the cells appear smaller. II. Water molecules are attracted to the salt ions so the water molecules move out of the cells and leave the cells smaller.

To test these explanations, the student used some salt water, a very accurate weighing device, and some water-filled plastic bags, and assumed the plastic behaves just like red-blood-cell membranes. The experiment involved carefully weighing a water-filled bag, placing it in a salt solution for ten minutes and then reweighing the bag.

What result of the experiment would best show that explanation I is probably wrong?

a. the bag loses weight
b. the bag weighs the same
c. the bag appears smaller

24. What result of the experiment would best show that explanation II is probably wrong?

a. the bag loses weight
b. the bag weighs the same
c. the bag appears smaller
APPENDIX C

CTSR FORM

Classroom Test of Scientific Reasoning

Enter your responses to the CTSR here, DO NOT mark on the paper copy of the test

* Required

Enter the code that Mrs. Wadding assigns you *

Your answer

Enter your birthdate *

Month/Day/Year (i.e. 06/13/1985)

Your answer

Your gender *

○ Male
○ Female

Student grade level *

○ 9
○ 10
○ 11
○ 12

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Question 1 *
○ A
○ B
○ C
○ D
○ E

Question 2 *
○ A
○ B
○ C
○ D
○ E

Question 3 *
○ A
○ B
○ C
○ D
○ E

Question 4 *
○ A
○ R

https://docs.google.com/forms/d/1Uc9ZrNt9Gk8yvza9nHyXe86C4mLJxZ-wpU2rZyED1k/viewform
Question 5 *
○ A
○ B
○ C
○ D
○ E

Question 6 *
○ A
○ B
○ C
○ D
○ E

Question 7 *
○ A
○ B
○ C
○ D

https://docs.google.com/forms/d/1UXWZ2rlK6k9vazmRYtllyXe86cYT4mLxZmpJUZYED9k/viewform
Question 8 *
○ A
○ B
○ C
○ D
○ E

Question 9 *
○ A
○ B
○ C
○ D
○ E

Question 10 *
○ A
○ B
○ C
○ D
○ E

Question 11 *
https://docs.google.com/forms/d/1KzWZrm8B8klyvapvHtyXe8WcY74mLUZrmpUYyEDI9/viewform
Question 12 *
- A
- B
- C
- D
- E

Question 13 *
- A
- B
- C
- D
- E

Question 14 *
- A
- B
- C
Question 15 *

- A
- B
- C
- D
- E

Question 16 *

- A
- B
- C
- D
- E

Question 17 *

- A
- B
- C
- D
- E
Question 18 *
○ A
○ B
○ C
○ D
○ E

Question 19 *
○ A
○ B
○ C
○ D
○ E

Question 20 *
○ A
○ B
○ C
○ D
○ E

Question 21 *
○ A
○ R

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Question 22 *
- A
- B
- C
- D
- E

Question 23 *
- A
- B
- C
- D
- E

Question 24 *
- A
- B
- C
- D

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APPENDIX D
SURVEY

Survey

This tool is to measure your content knowledge, feelings toward technology and your sense of community

* Required

Enter the three digit code that Mrs. Wadding gives you *

Your answer

Climate

Rate how well you work independently *
Do you use your time effectively? Do you create high quality work?

1  2  3  4  5
poorly   ○   ○   ○   ○   ○   extremely well

Rate how well you work in groups *
Do you use your time effectively? Do you create high quality work?

1  2  3  4  5
poorly   ○   ○   ○   ○   ○   extremely well

If you had to work on a week long project that involved research and creating a presentation, would you rather work independently or in a group? *

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○ independently
○ with a partner
○ in a group of three
○ in a group of four

How engaged are you in class on a daily basis? *
Paying attention, learning, completing assignments, staying on task

1 2 3 4 5

not at all engaged ○ ○ ○ ○ ○ always actively engaged

How connected do you feel to your classmates? *
Do you know all of their names? Do you know something about them? Do you respect them? Do they respect you?

1 2 3 4 5

not at all to anyone ○ ○ ○ ○ ○ very well to most everyone

Content

How would you rate your skill at science *
○ Terrible
○ OK
○ Pretty good
○ I rock at science!

How do you rate your interest in science? *

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3/4/2016

Survey

☐ Everything about science is boring
☐ There are a few things that catch my interest
☐ There are lots of interesting things about science
☐ Everything about science is fascinating

Of the units we studied this semester, which did you enjoy the most? *
☐ Earth History: Rocks, Glaciers and Fossils
☐ Earth Processes: Soil, Plate Tectonics and Cycles
☐ Earth in Space: Big Bang, Stars and Elements, and the Solar System

Technology

How do you use technology? *
Check all that apply
☐ to listen to music
☐ to complete school work
☐ to keep track of tasks (calendar/reminder feature)
☐ to research
☐ to play games
☐ to socialize (facebook/twitter)
☐ to create (presentations)

How much time do you spend using technology during SCHOOL? *
https://docs.google.com/forms/d/fJY-wrkkpQvaAzsnKZ7KsghcRivNQcC3K9c4g5h6vNMv8qo6Q/viewform
Survey

- less than 1 hour
- 1-2 hours
- 2-3 hours
- 4-5 hours
- 5-6 hours
- 6-7 hours
- 7-8 hours
- Other:

*How much time do you spend using technology at HOME?*

- less than 1 hour
- 1-2 hours
- 2-3 hours
- 4-5 hours
- 5-6 hours
- 6-7 hours
- 7-8 hours
- Other:

*How would you rate your ability to use technology?*

- How do you turn it on?
- Barely can do what I need

https://docs.google.com/forms/d/1JjY-wiekpQaAsrM279g6h2FwN5HqC3K3is4cg5HvAbqyeQd/gview?form
Can usually do what I need
Can easily do what I need and some things I want
Can use technology for anything I want

If a technology problem comes up, what do you usually do? *
solve it myself
ask/research on how to solve it myself
ask a friend for help
ask a teacher/tech person for help
don't solve the problem

If you have to read a 2 page article, how would you prefer to read it? *
printed on paper
on chromebook screen
read aloud
Other :

If you have to write a 2 page paper, how would you prefer to write it? *
by hand on paper
type on a Google Doc
type on Word Doc
type in Pages
3/4/2016

Survey

☐ Speak out loud into Notability

How do you feel technology impacts your learning? *

☐ Technology makes learning harder
☐ Technology does not make learning harder or easier
☐ Technology makes learning easier

SUBMIT

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Google Forms

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