Use of technology and its impact on higher order thinking in the science classroom

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USE OF TECHNOLOGY AND ITS IMPACT ON HIGHER ORDER THINKING
IN THE SCIENCE CLASSROOM

An Abstract of a Thesis
Submitted
in Partial Fulfillment
of the Requirements for the Degree
Master of Arts

Mauree Angelina Haage
University of Northern Iowa
May 2022
ABSTRACT

This study focuses on examining the impact of technology on higher order thinking in the science classroom by first examining the impact of a teacher’s knowledge of Bloom’s Revised Taxonomy on the integration of higher order thinking activities and then by examining what levels of higher order thinking exist when technology was utilized. Previous research has found correlations between the levels of Bloom’s Taxonomy exhibited when using technology, particularly probeware, simulations/virtual labs, and special software like LoggerPro. In addition, previous research has shown a trend of teachers inaccurately categorizing their lessons and activities as having a higher order thinking level than what was found by researchers.

For this study, teachers were recruited from the Great Prairie Area Education Agency to submit one to two lessons they determined had students completing tasks at a higher order thinking level as according to Bloom’s Revised Taxonomy. In addition, teachers were asked to complete a knowledge inventory to determine their knowledge of Bloom’s Revised Taxonomy. These pieces of data were then analyzed to determine whether there were any correlations between the knowledge inventory scores and the level of Bloom’s their submitted lesson was as well as determining any correlations between the level of Bloom’s and the use of technology in the activity.

The results of this study found there to be no correlation between a teacher’s knowledge of Bloom’s and the level of Bloom’s their lesson demonstrated. Teachers in this study typically incorrectly identified the higher levels of Bloom’s when completing their knowledge inventory. Additionally, teachers submitted activities that illustrated a
wide variety of higher order thinking when asked to submit ones in which they felt the highest levels were present. There appears to be a correlation between the primary type of technology used and level of higher order thinking occurring in the lesson submitted. Since this was not one of the research questions, future research is needed to validate this result.
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Maureen A. Haage
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This Study by: Mauree A. Haage

Entitled: Use of Technology and its Impact on Higher Order Thinking in the Science Classroom

has been approved as meeting the thesis requirement for the

Degree of Master of Arts

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CHAPTER 1

INTRODUCTION

Every day in classrooms around the country, students not only grab for a pencil and paper but also a computer in order to complete their homework. More and more, in today’s classroom, we see students utilizing some sort of technology whether it be interactive whiteboards, tablets, laptops, or even the latest trend to “bring your own device” (BYOD). While the range of technology integration is vast, this study focuses on one-to-one computer technology. One-to-one technology can be defined as schools issuing an electronic device (iPad, Chromebook, or laptop) for use in the classroom and at home to use as a tool to learn. Over the past two years, COVID-19 expedited the push for schools to become one-to-one, which makes it more important than ever to evaluate and critique the use of technology in the classroom.

Recent studies examined the benefits of technology in the classroom. Some of the research suggests the use of technology in the classroom increases student achievement. One prime example is a study where students who were placed into a laptop immersion program not only scored better on standardized testing, but also had higher GPAs and better grades than those who were not part of the program (Gulek & Demirtas, 2005). However, some research shows a different story. For instance, Muyingi (2014) found having laptops in the classroom led to several distractive behaviors called digital distractions. These digital distractions were negatively associated with several factors including, but not limited to: age of student, un-engaging lecture style environment, and lack of classroom management.
Researchers have also looked at the age-old question of quantity versus quality of technology use in instruction. One study examined this question and found a very definite point where the amount or quantity of the technology use significantly impacts student achievement (Lei & Zhao, 2007). Lei and Zhao (2007) found the majority of computer usage in the classrooms they studied was spent on emailing, playing games, or simply browsing the internet for information. Very rarely were the computers being used for higher order thinking activities such as creating or constructing something or using probeware in science despite these activities showing a higher impact on student achievement as measured with GPA scores (Marcum-Dietrich & Ford, 2002).

One area of classroom technology usage overlooked is the need to research how the levels of higher order thinking are impacted by science lessons that integrate technological tools. With the acceptance of the Next Generation Science Standards (NGSS) as the state of Iowa’s standards for science education, it is important to take higher order thinking into account more than ever. At the core of the NGSS is the importance of students to not only have a deep understanding of the content, and to also be able to take that knowledge and apply it to the real world. This is the purpose of the Science and Engineering Practices (SEP) portion of the standards. Through the SEP, all grade levels utilize engineering design and technology applications to emphasize the core ideas of science (NGSS Lead States, 2013). For this reason, the purpose of this study is to examine the impact of computer technology use on higher order thinking in the classroom and compare to the teacher’s knowledge of higher order thinking. The research done in this study will help science teachers think more critically about curriculum
choices and enhancing critical thinking when incorporating computer technology in the classroom.
CHAPTER 2

LITERATURE REVIEW

History of Computer Technology in the Classroom

The use of technology in the classroom is not a new topic. It is one that has been around for hundreds of years, but it was not until the 1990s that this technology boom drastically accelerated with new computer-related technologies being introduced nearly every month. Now three decades after the technology boom of the 1990s, technology is still a major component in the educational setting. Between 1982-1990, during the rise of Apple II, Macintosh, PC, and other computing technologies, the term “educational technology” began to surface in educational journals (Elia, 2014). Over the course of the next couple decades, computers became more integrated into the classroom through computer labs, the Internet, interactive whiteboards, 1:1 technology, and most recently video conferencing and remote instruction.

Introduction of Computers in Classrooms

One of the major influences of the movement for technology in education came in 1996 when the first National Educational Technology Plan (NETP1996) was developed during the Clinton-Gore administration (Alamin et al., 2015). This plan recognized technology as the “new basic” of education and the Internet as its “blackboard.” NETP1996 set the following goals: 1) all teachers in the nation will have the training and support they need to help students learn using computers and the information superhighway, 2) all teachers and students will have modern multimedia computers in their classrooms, 3) every classroom will be connected to the information superhighway,
and 4) effective software and on-line learning resources will be an integral part of every school's curriculum. The Technology Literacy Challenge Fund was created and provided $2 billion for five years to help fund these goals. Since 1996, there have been three other NETPs with the last one occurring in 2010 and focusing on 21st learning skills and classrooms (Wyzard, 2011).

Computer-Related Classroom Advancements

The push and financial support from the Clinton-Gore administration was needed to increase the number of computers in schools. Schools around the country began to place computers in every teacher's classroom as well as create computer classrooms for use when each student in a classroom needed access to a computer. This momentum continued into the 2000s. According to the National Center for Education Statistics, by 2015 about 80% of eighth graders reported using a computer for schoolwork during weekdays. Students aged 3-18 also stated that school was one of the main locations where they accessed high speed internet (KewalRamani et al., 2018).

Probeware as an Integral Component of Technology-Enhanced Science Teaching

Another notable advancement was probeware. While the initial technology development for what would eventually become probeware began in the 1970s, it was not until the mid-1980s that the development of a universal lab interface was developed. This was important because up until this point the Apple II had been the dominant computer in the education sector. However, in the mid-1980s, IBM, Macintosh, Commodore and Atari all were equally competitive. This led to Pricilla Laws and David Vernier creating a Universal Lab Interface for different types of probes to be able to work with all
computers. These probes initially became popular with physics teachers through the American Association of Physics Teachers conventions as an easy way for students to record measurements, such as position and speed, during physics labs. As technology and varied probes became available, science teachers across disciplines were incorporating the technology into the classroom. In 1997, probeware took yet another giant step forward due to the development of the first hand held, standalone units (Tinker, 2000). These are the units we still see today in many science classrooms being used to take real time data on anything from temperature and pH to even speed and position.

**One-to-One Computer Movement**

One of the more recent movements in educational technology has been that of one-to-one computers. Iowa has seen a large increase in the use of computers in the state, particularly schools implementing 1:1 initiatives in their districts. According to the Iowa Section of the Computer Science Teachers Association (CSTA) in 2015, 152 out of 333 school districts in the state have implemented 1:1 technology in their school district. This study focuses on school districts within the Great Prairie Area Education Agency (GPAEA) which includes 33 public school districts and 6 accredited private schools in a 14-county area of southeast Iowa. Sally Lindgren, the Director of Technology and Innovation stated that 100% of the school districts within GPAEA have incorporated 1:1 technology, although the methods of incorporation vary. In elementary, the most common devices used are iPads whereas in middle and high school, Chromebooks are steadily replacing other types of laptops as the device of choice for school districts in this AEA (S. Lindgren, personal communication, March 29, 2021). These numbers were largely
impacted by the need of school districts to take classes online in the spring of 2020 due to COVID-19. As a result of the pandemic, Iowa K-12 schools received $71.6 million through the federal CARES Act which allowed the schools to use money to help cover unexpected costs related to the pandemic including technology (CARES Act, 2020).

Technology-Related Teaching Standards

With the push and incentives to bring technology into the classroom, a clear need for standards became apparent. The International Society for Technology in Education (ISTE) helped create standards for not only students but also for teachers. Those standards have been used for more than 20 years in the United States and have been adopted in all 50 states. They were most recently updated in 2008 to focus on supporting learning with technology. For teachers, these standards were created to help deepen their practice, promote collaboration with other teachers, rethink teaching in the context of the digital world, as well as prepare their students to have ownership of their learning. The student standards focus not only on preparing students to be responsible digital citizens, but also emphasize the importance of being innovative, creative, and to be a computational thinker (ISTE, 2000).

Iowa not only adopted the ISTE standards, but also created a portion of the Iowa Core to ensure the incorporation of technology literacy in K-12 classrooms. This portion of the Iowa Core is called 21st Century Skills and was developed to create classrooms where Iowa students were acquiring the knowledge and skills to learn and live in the digital age. These standards stress the importance all classrooms and subject areas incorporate these standards within their content (Iowa Department of Education, 2008). It
is because of these standards the Iowa Code for teacher education states that, “each teacher candidate exhibits competency in all of the following professional core curricula: … k. Technology” (Standards for Practitioner and Administrator Preparation Programs, Iowa Code § 79.15(5), 2021). This section of Iowa Code goes on to state in order to earn a teaching license in the state, the teacher must be able to effectively integrate technology into their teaching to help support student learning.

**Technology Use and Student Learning**

Over the past several decades, researchers conducted a multitude of studies analyzing the effects of technology use in the classroom on student learning. This research studied technology in many different ways, whether as an advantage or as a distraction (e.g. Kulik, 2003). Yet, other studies examined how student achievement is tied to quality and quantity of technology use (e.g. Lei & Zhao, 2007). These studies guided the way technology is used in the classroom.

Several studies conducted on technology in the classroom focused on the quality of computer-based instruction versus the quantity of computer use in the classroom. Lei and Zhao (2007) examined middle school students over the course of one year to see how the quality of computer use and the quantity of computer use affected students’ grade point averages. Quality of technology use (how the technology was used) was measured for its effect on student achievement via GPA scores. Over the course of this study, Lei and Zhao found that lessons where students used computers to create artifacts of their learning (e.g. creating websites, use of desktop publishing or using science probes) had the largest positive impact on student grade point average (Lei & Zhao, 2007). Each of
these examples of what Lei and Zhao deemed quality lessons correspond with higher levels of learning. An interesting finding in this study was that while Lei and Zhao found the quality of technology use could be beneficial to students, lower quality tasks on the computers were done more frequently than higher quality tasks in the classroom. These lower quality tasks included emailing friends, using search engines, and taking notes on the computer.

Lei went on to investigate not only quality of technology use but also how the quantity of technology use impact student achievement. In this study, Lei (2010) once again examined middle school students but looked more closely at the relationship between quality of technology use (based on how technology was used), quantity of technology use (based on the time spent on computers each day), and a student’s grade point average. In this study, Lei concluded that it’s not about how much technology gets used, but rather how that technology is used that makes the greatest impact in student achievement. As a result, it was concluded there needs to be a focus on quality of technology use as well as clear and defined educational goals for technology use (Lei, 2010).

Benefits of Technology Use

The most widely studied areas in educational technology examine the benefits technology have on student achievement. This is a significant area of interest considering between 2010 and 2011 the number of Iowa schools utilizing one-to-one technology doubled, making the number of schools approximately 90 (Sauers, 2012). Now, ten years later it is reasonable to assume this number has increased as the demand for educational
technology has increased thanks to the COVID-19 pandemic. Now, nearly every school in the state of Iowa is considered one-to-one with some sort of technology whether it be laptop, Chromebook, or tablet.

One study examined the advantages of one-to-one laptop computers in two middle schools and found the addition of students having their own laptop device helped bring current information directly into the classroom. In addition, teachers were able to use the technology to collect formative assessment data (Dunleavy et al., 2007). Their conclusion was the addition of the technology contributed to the effectiveness of the learning environments by making them more student, assessment, and knowledge-centered. The researchers of this study also found the use of one-to-one laptops in the classroom helped teachers differentiate their lessons as well as allowing for a more self-paced classroom. Students were able to complete ongoing research projects as well as utilize different drill and practice exercises to gain mastery in different content objectives.

Kulik (1994) found in a meta-analysis students of all age groups not only score higher on state assessments and have higher GPAs when being exposed to technology in the classroom, but also learn more content in less time. In addition, Kulik found students’ positive attitudes toward learning increased with this exposure. Kulik in 2003 revisited the use of computers in education with another meta-analysis. This time he examined the efficacy, in regards to student learning, of several types of incorporations of computer technology including computer simulations in math and science classes. Kulik found an overall positive efficacy, although he did point out the amount of this efficacy increased
with more recent studies and could be contributed to advances in the simulations studied. This same result is seen over and over again in several research studies (Harris & Al-Bataineh, 2015; Bebell & O’Dwyer, 2010; Chang, 2016). Researchers who conducted these studies concluded content knowledge in both math and science increased when technology is utilized in the classroom. However, this was not the only content area researchers analyzed. Researchers also concluded technology use in the classroom benefits the language arts as well (Lowther et al., 2003).

Apple Classrooms of Tomorrow (ACOT) is a long-term research project funded by Apple Computer, Incorporated to examine the effects of technology in the classroom on both teachers and students. In a study conducted in 1994, ACOT found, again, students perform better and achieve more when in a classroom with technology. In addition, they found the students’ level of learning, per Bloom’s Taxonomy, was much higher than those students who were not exposed to technology in the classroom (Baker et al., 1994).

Higher Order Thinking

Bloom’s Taxonomy

Educators are often asked to create learning targets and objectives for classroom lessons. These objectives are often used to aim toward higher order thinking in student learning, but what is higher order thinking? Defining higher order thinking has been difficult due to the varying examples and non-examples given by psychologists (Cuban, 1984). Through research and compilation of previous definitions, Lewis and Smith (1993) defined higher order thinking as what “occurs when a person takes new
information and information stored in memory and interrelates and/or rearranges and extends this information to achieve a purpose or find possible answers in perplexing situations” (p. 136). They went on to elaborate the implications to teachers by saying teachers who encourage higher order thinking help take lessons beyond learning facts and memorizing and create a learning environment for students to think critically. This is accomplished by allowing students the opportunity to answer questions or solve problems in ways other than rote memory. Lewis and Smith’s goal for teachers aligns with the goals of Benjamin Bloom when he developed his hierarchy known as Bloom’s Taxonomy. In 1956, Benjamin Bloom along with several collaborators published the final draft of a framework the teaching world has used for decades known as Bloom’s Taxonomy (Bloom & Krathwohl, 1956). This framework consists of six major categories and then subcategories ranging from simple (knowledge) to complex (evaluation). The categories use nouns for each category’s title and are arranged in a pyramid shape with higher order thinking at the top (Figure 1). The purpose of the original taxonomy was to create common language for test banks and measuring learning objectives and outcomes among faculty at various universities. Bloom’s vision of this framework was much larger than solely being used as a measurement tool. His belief was that it could serve as a common language amongst educators of all grade levels and subject matters (Krathwohl, 2002).
Revised Bloom’s Taxonomy

In 2001, a collection of educational professionals revised and published an updated version of the taxonomy (Anderson & Krathwohl, 2001). This time, the six main categories were named with action words thinkers would encounter as they experienced deeper understanding of the content. The verbiage used for each level changed from nouns to verbs; for example, the highest order thinking level in the original taxonomy was “knowledge” and with the revision it changed to “remember.” Use of action words
also helps educators create learning objectives to clarify learning for both themselves and their students (Figure 2).

Figure 2
Revised Bloom's Taxonomy

![Bloom's Taxonomy](Image)


**Higher Order Thinking in the Science Classroom**

As stated previously, the introduction of the NGSS called to the forefront the need for students to not only understand content but also apply and use that knowledge in context to real world situations. Many studies have examined higher order thinking in the science classroom. Barak Miri, Ben-Chaim David, and Zoller Uri (2007) looked at the
effect of purposely teaching critical thinking skills as a means of promoting higher order thinking skills. The researchers found when teachers persistently incorporated strategies designed to enhance those skills, like the ability to assess/evaluate information as well as the ability to use information to draw conclusions, it led to the development of critical thinking skills in the students. Another interesting finding in this study was a small number of teachers in their sample were incorporating strategies for the promotion of higher order thinking and these teachers were not aware of the strategies they were using that supported higher-order thinking.

Several other studies focus on the implementation of specific approaches that foster higher order thinking in student learning, such as problem-based approaches. Problem-based (Harland, 2002; Gordon et al., 2001) learning has been found to foster an environment where students are forced to think and challenge themselves in their learning (Bissell & Lemons, 2006; Thomas, 2000) as well as promote critical thinking skills (Bishop et al., 2014; Weimer, 2002). All of these studies recommend similar strategies and teaching approaches as those required by the NGSS.

**Higher Order Thinking and Technology Use**

As soon as technology entered the science classroom, researchers began looking at how technology use could help improve higher order thinking in students. One of the earliest incorporations credited with improving higher order thinking was WebQuests (Polly & Ausband, 2009). WebQuests were developed in 1995 by Bernie Dodge at Sand Diego State University as a way to take information from the Internet and utilize it as an inquiry-based activity. These WebQuests helped students move through a series of tasks
while transitioning toward higher levels of thinking. Polly and Ausband (2009) were critical of the fact that teachers often miscategorized their tasks in WebQuests at higher levels than the researchers believed they should.

Virtual labs, simulations, and probeware have also been the focus of numerous research studies pertaining to higher order thinking. Several of these studies (Millar, 2005; Hopson, 1998; Aksela, 2005; McMahon, 2009; Gokhale, 1996) found the incorporation of these forms of technology led to significantly higher levels of thinking than students who experienced a lecture-lab format of teaching where labs utilize standard lab equipment and tools of measurement instead of technology. This was thought to be due to several factors including the technology allowing students to collaborate easily with other groups even in other classes, the allowance for student explorations based on the near immediate feedback provided, and the attitudes of students to apply knowledge to real world applications.

Theoretical Framework

Strategies for Developing Higher Order Thinking

The term “higher order thinking” is a staple in the education community. However, finding a clear and concise definition is somewhat of a challenge. Lewis and Smith (1993) examined several components of higher order thinking: 1) the psychology and philosophy lineage, 2) the difference between what is considered lower order thinking and higher order thinking, and 3) how higher order thinking differs from other skills like critical thinking and problem solving. Based on their analysis, the following definition was offered: “Higher order thinking occurs when a person takes new
information and information stored in memory and interrelates and/or rearranges and extends this information to achieve a purpose or find possible answers in perplexing situations” (p. 136). It was the hope of Lewis and Smith that educational researchers would build upon this definition to develop strategies for teaching the skill of higher order thinking and that is precisely what occurred. Miri et al. (2007) came up with three main categories of such strategies. These were: dealing in class with real world cases, encouraging open ended discussions, and fostering inquiry-oriented experiments. These three strategies all fulfill the teaching of higher order thinking by having students refrain from answering questions that have only one answer or make them remember information and rather has students look at problems and use their knowledge base to solve those problems.

Collins (2014) took these strategies and expanded upon them. She wrote on the importance of specifically teaching the terms and process of each higher order thinking level. This included modeling the process and explaining to students why higher order thinking was needed to solve particular problems. This was done by not only incorporating the strategies written about by Miri et al. (2007), but also to incorporate metacognition and scaffolding. This scaffolding of classroom activities could be accomplished through not only teaching specific skills based on content area, but also utilizing Bloom’s Taxonomy as the building blocks of higher order thinking. This is one of the reasons Bloom’s Revised Taxonomy will be used as the guiding framework in answering the research questions of this study. Another reason is due to the prevalent usage of Bloom’s Revised Taxonomy in classrooms around the world. This framework
will guide the methodology and data analysis of this qualitative study. Utilizing Lewis and Smith’s definition of higher order thinking along with Bloom’s Revised Taxonomy, the categories of analyze, evaluate and create will be considered higher order thinking for the purposes of this research.

**Research Questions**

1. How do teachers’ understanding of Bloom’s Revised Taxonomy relate to the integration of higher order thinking activities in their classrooms?
2. What levels of higher order thinking exist in classroom activities of science teachers utilizing computer technology in their classrooms?
Participants

Participants in this study consisted of middle school and high school science teachers who volunteered to participate in the study. These research participants were recruited through an email sent via the GPAEA (Appendix A) to all 6-12 science teachers in that area. All teachers involved worked as a science teacher for at least five years in classrooms that incorporate one-to-one technology for at least the past three years. Teachers who participated in this study did so as volunteers and were not compensated in any manner; however, they were able to learn more about their technology implementation through the results of this study. All study procedures were approved by the University of Northern Iowa Institutional Review Board (Appendix A).

Materials and Procedures

Data collection consisted of the completion of an electronic questionnaire on Bloom’s taxonomy and the collection of instructional artifacts from participants. All middle school and high school science teachers in the GPAEA region were sent an email with the questionnaire link. From there, the questionnaire was divided into three sections. The first section was comprised of questions validating the participants’ eligibility to be a part of the research. If the participant was not eligible, then the questionnaire would end. However, if they were eligible the questionnaire would continue to the second section.
The second section of the questionnaire contained a series of questions designed to measure the participants’ knowledge of higher order thinking as defined by Bloom’s Revised Taxonomy. These questions were developed by the researcher and will be referred to as the Bloom’s Revised Taxonomy Knowledge Inventory (Appendix B). The inventory consisted of ten scenarios classroom teachers would find familiar. They were then asked to choose which level of Bloom’s Revised Taxonomy fit each scenario. Participants were given the list of verbs used in the hierarchy but not the order in which they occur. To ensure the accuracy of this tool, the scenarios and corresponding Bloom’s levels were vetted by a professional colleague who is well versed in the recognition of Bloom’s Revised Taxonomy due to their experience as both a science teacher and college education methods instructor.

The final section of the questionnaire asked participants to upload one to two activities or projects they believed best exemplified the use of higher order thinking in technology rich situations. These activities could include but were not limited to the use of animations, simulations, probeware, or even data analysis software. Activities submitted included lesson plans, student handouts and questions, as well as links or files to any digital materials utilized. Each submitted lesson and accompanying materials were analyzed by the researcher and the same colleague previously mentioned using Bloom’s Revised Taxonomy Dichotomous Key adapted from Semsar and Casagrand (2017) to evaluate the cognitive difficulty of assessments (Appendix C). In their version of the dichotomous key, the original Bloom’s Taxonomy was used, so for this study the Dichotomous Key was updated to use the corresponding verbs found in the revised
taxonomy. Additionally, the original dichotomous key was created with the purpose of helping teachers examine individual questions within an assessment. Since an entire activity would be examined for this study, the tool was edited by changing the wording to reflect that. For example, instead of asking if students could memorize the answer, the wording was changed to “could students memorize all of the answers involved in this activity.” Much of the wording was left unchanged as most of it worked for not only the original intent of the tool but also for this research. The overall goal of this tool was to examine and score an activity based on the opportunity it gives for higher order thinking.
CHAPTER 4

RESULTS

Data Collection

A total of 15 teachers opted to take the survey sent out by GPAEA. Of those 15 teachers, only 10 met the participant criteria and completed all requirements. Seven of the 10 teachers responded they had been teaching for a least 10 years and six of the 10 teachers had been utilizing 1:1 technology in their schools for at least six years. The data collected from these 10 teachers were then analyzed for the purpose of answering the research questions.

The first data analyzed were the teacher responses to the Bloom’s Revised Taxonomy Knowledge Inventory which was designed to measure each teacher’s overall knowledge of Bloom’s Revised Taxonomy. Each correct answer was scored a point for a maximum score of ten points. The raw data results from the knowledge inventory can be found in Appendix D. Each lesson plan submitted by the teachers was then analyzed by the researcher and the professional colleague mentioned in the methodology. The Bloom’s Revised Taxonomy Dichotomous Key was used to evaluate each lesson plan for the overall level reached. The level was then recorded as a numerical score where a score of 1 was given for the lowest level (remember) and a 6 was given for the highest level (create). These scores were then averaged and used for further analysis. The compilation of the scores is found in Appendix E.
Understanding of Bloom’s Revised Taxonomy Versus Higher Order Thinking Integration in Activities

In order to answer the first research question, how do teachers’ understanding of Bloom’s Revised Taxonomy relate to the integration of higher order thinking activities in their classrooms, the teacher responses from the knowledge inventory needed to first be analyzed. The number of correct responses for each scenario was tallied and those results were then grouped based on the level of Bloom’s Revised Taxonomy for each scenario. The data indicate teachers had a better recognition of the lower half of the taxonomy (Remember, Understand, and Apply) than the higher tiers (Analyze, Evaluate, and Create) (Table 1). Correct identification of the lowest three tiers of Bloom’s Revised Taxonomy occurred 70% or more of the time, whereas the percent correct quickly declined in the highest three tiers.

Table 1
Bloom’s Revised Taxonomy Knowledge Inventory

<table>
<thead>
<tr>
<th>Bloom’s Level</th>
<th>Remember</th>
<th>Understand</th>
<th>Apply</th>
<th>Analyze</th>
<th>Evaluate</th>
<th>Create</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scenario</td>
<td>2</td>
<td>5</td>
<td>3</td>
<td>9</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>Number Correct (n=10)</td>
<td>8</td>
<td>10</td>
<td>4</td>
<td>10</td>
<td>7</td>
<td>4</td>
</tr>
<tr>
<td>Percent Correct</td>
<td>90</td>
<td>70</td>
<td>70</td>
<td>35</td>
<td>0</td>
<td>10</td>
</tr>
</tbody>
</table>

Responses were generally not far from the correct level of Bloom’s and varied only one to two levels even in the highest three tiers of the taxonomy (Figure 3). This
possibly demonstrates a basic knowledge of a general divide between the higher and lower tiers of higher order thinking although the results showed a lack of accuracy for recognizing specific levels within Bloom’s Revised Taxonomy. It should also be noted while most levels of Bloom’s were represented by two different scenarios, the levels of Create and Apply only had one scenario each and may have affected the results.

Figure 3

Difference in Responses by Bloom’s Level

The next analysis compared the scores on the Knowledge Inventory and the Dichotomous Key scores for the lessons submitted (Table 2).
Table 2

Participant Knowledge Inventory Scores and Dichotomous Key

<table>
<thead>
<tr>
<th>Participant #</th>
<th>Knowledge Inventory Score</th>
<th>Ave Dichotomous Key Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5</td>
<td>4.0</td>
</tr>
<tr>
<td>2</td>
<td>5</td>
<td>5.0</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>3.0</td>
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<tr>
<td>4</td>
<td>6</td>
<td>2.5</td>
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<td>5</td>
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<td>6</td>
<td>6</td>
<td>5.2</td>
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<td>7</td>
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<td>3.0</td>
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<td>8</td>
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<tr>
<td>9</td>
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<td>3.8</td>
</tr>
<tr>
<td>10</td>
<td>5</td>
<td>2.8</td>
</tr>
</tbody>
</table>

This was done to provide a clearer insight into whether a correlation between knowledge of Bloom’s Revised Taxonomy and incorporation of higher order thinking in activities in the classroom existed. To truly determine the presence of a correlation, the dichotomous key scores were plotted against the knowledge inventory scores and a linear trend line was added to the graph. When analyzing this data, it was perplexing to find there was no correlation ($R^2=0.0001$) between teachers’ knowledge of Bloom’s
Taxonomy and the average level of higher order thinking contained within the lessons they submitted (Figure 4).

Figure 4
Correlation between Bloom’s Level of Submitted Lessons and Teacher Knowledge of Bloom’s

Levels of Higher Order Thinking in Lessons Utilizing Computer Technology

The purpose of the second research question was to determine what levels of higher order thinking exist in classroom activities of science teachers utilizing technology in their classrooms. This research question was analyzed a few ways. First, the overall Bloom’s Revised Taxonomy Dichotomous Key Scores (Appendix E) were examined. There was a wide variance in those scores considering teachers were asked to submit lessons that exhibited higher order thinking. So, the researcher then examined the lessons
more thoroughly to determine if certain types of technology lent themselves to higher order thinking. To do this, the researcher went back through the responses and compiled the different types of technology used in the lessons submitted (Appendix F) as well as compiling data comparing the type of technology used in the lesson submitted versus the average dichotomous key score (Table 3).

Table 3
Type of Technology Compared to Average Dichotomous Key Score

<table>
<thead>
<tr>
<th>Type of Technology</th>
<th>Average Dichotomous Key Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Special Software</td>
<td>5.50</td>
</tr>
<tr>
<td>Probeware</td>
<td>5.38</td>
</tr>
<tr>
<td>Simulation</td>
<td>4.00</td>
</tr>
<tr>
<td>Computer</td>
<td>3.25</td>
</tr>
<tr>
<td>Other smart</td>
<td>2.50</td>
</tr>
</tbody>
</table>

The categories of technology used were: computer, probeware, simulation, special software, and other smart device. Since it is presumed a computer is necessary for all of the other categories of technology, the lesson was only counted as having a computer as it’s means of technology if that was the only type of technology present. Probeware was used as a category to encompass lessons that utilized any type of probe that could provide instantaneous feedback/data collection that was stored on a device. Special software in contrast was used as a category for lessons utilizing specialized software such as logger pro or graphing calculator software that did not require any types of probeware for use.
The simulations category was used to include lessons where students used web based or app-based simulations of scientific concepts and the other smart device category was used for the use of smart projectors, tablets and other handheld devices. These categories along with examples are provided in Table 4. This data was then used to help examine any relationships between the level of Bloom’s and the type of primary technology used. To calculate this, an average of the dichotomous key scores was taken for each type of technology.

Table 4
Examples of Technology Categories

<table>
<thead>
<tr>
<th>Technology Category</th>
<th>Examples</th>
</tr>
</thead>
</table>
| Computer            | • Laptop or desktop PC  
                       | • Only type of technology used |
| Simulation          | • Web or app based  
                       | • Provides a virtual context to scientific concepts |
| Probeware           | • Logger Pro probes or similar probes  
                       | • Must provide real time data  
                       | • Data can be stored in device |
| Special Software    | • Graphing calculator or Logger Pro software without the probes  
                       | • Microsoft/Google suites  
                       | • Design software (Adobe or AutoCAD) |
| Other Smart Device  | • Any non-iPad device |
Through this data analysis, it appears higher dichotomous key scores are associated with the use of special software and probeware. This suggests the use of these types of technology lend themselves to higher order thinking, although to accurately conclude this would require further investigation.
CHAPTER 5

DISCUSSION

Research Question 1

Both Miri et al. (2007) and Collins (2014) stressed the importance of teaching higher order thinking skills to students, so one would hope there would have to be a solid knowledge base by the teacher in order for this teaching to occur. The results of this research found there was an overall lack in ability of the teacher participants to recognize activities involving the higher tiers of Bloom’s Revised Taxonomy. The data also showed no correlation between the teacher’s knowledge of Bloom’s Revised Taxonomy and the integration of higher order thinking activities in their science classroom.

This is an interesting result when one considers the importance of teaching higher order thinking skills to students. This finding brings up the additional question of how successful students can be with higher order thinking tasks when they are assigned by a teacher lacking the knowledge of Bloom’s Revised Taxonomy needed to correctly identify when these skills are used. In addition, one has to recall the importance of incorporating higher order thinking in the classroom as described by Miri et al. (2007) and its connection to critical thinking. This framework is one that has been used as a foundation to science education best practices and is even incorporated in the NGSS. If teachers have a difficult time recognizing higher order thinking, then how successful are they at consistently providing opportunities for their students to utilize that skill set?

One implication from this study is the necessity to examine why teachers struggle with correctly identifying higher order thinking skills, the highest three tiers of the
hierarchy. This was not a surprise since Polly and Ausband (2009) reported similar findings in their research on WebQuests. While they did not examine teachers’ knowledge of higher order thinking, they did find teachers consistently miscategorized questions and tasks as higher levels of thinking than what these tasks were categorized.

This study did not find any correlation between the ability to categorize Bloom’s levels during the knowledge inventory and the Bloom’s levels demonstrated in the lessons submitted, although teachers were asked to submit lessons involving both higher order thinking and technology. Even with this finding, we cannot argue with the research of Bandura (1986) showing modeling as one of the most efficient modes of learning. One might conclude in order to best model higher orders of thinking one has to have a mastery in order to recognize those levels of Bloom’s Revised Taxonomy within different scenarios.

Research Question 2

From this research, it was determined teacher knowledge of Bloom’s Revised Taxonomy did not impact the higher order thinking skills involved in their submitted lessons. Although, there was evidence certain types of technology may naturally lend themselves to higher order thinking. With technology being in nearly every classroom in the state and technology funds limited in school districts, it is imperative to evaluate the importance of many types of technology. This study can help prioritize spending on items such as special software and probeware sometimes overlooked or deemed non-essential. The relationship between probeware and special software such as LoggerPro achieving higher levels of Bloom’s mirrors the studies mentioned previously by Millar (2005),
Hopson (1998), and several other researchers. These studies all suggested virtual labs, simulations, and probeware promote higher order thinking and this was further supported in this study.

Finding this relationship between the types of technology and higher order thinking reiterates the findings of Lei (2010) where it was found the quality of technology, more specifically how and what technology, had an impact on a student’s achievement/grade point average. Lei further stressed the importance of the need for teachers to focus on the quality of technology use and having clear educational goals for technology use. While this latter part was not studied in this research, it does provide insight of how to continue this research.

**Limitations/Future Research**

This research serves the purpose of being an initial study into the impacts teacher knowledge and technology can have on encouraging students to engage in higher order thinking in the science classroom. While this study began to chip away at the research questions, the data collected created more questions. A larger sample size is needed to better examine the correlations between background knowledge of higher order thinking and its presence in the submitted lessons. With such a small sample (10 participants), correlations and trends are harder to identify and not statistically valid. In addition, providing additional scenarios in the Bloom’s Revised Taxonomy Knowledge Inventory, would help generate a better measure of each teacher’s ability to identify the different levels within the taxonomy. As stated previously, two levels of Bloom’s Revised Taxonomy only had one scenario each whereas the other levels had two scenarios each.
Similarly, the knowledge inventory is a new instrument that with the small sample size cannot be tested for validity and reliability.

Further, it would be beneficial to have each teacher submit a specific number of lessons (perhaps three) so all teacher submissions had the same quantity of lessons. This would help with the accuracy of the data analysis since during this research, some participants submitted one lesson and others submitted three. This meant one participant was scored on one lesson, others who submitted multiple lessons had their lesson scores averaged. This inconsistency could have played a role in the lack of correlation between teacher knowledge of Bloom’s and level of Bloom’s within their submissions. Similarly, another limitation of this study was the assumption that the teachers who participated had access to technology enriched lessons that also were providing opportunities to learn at higher orders of thinking. Participants may have simply submitted lessons that represented the “highest” order thinking they had, rather than lessons that required students to create, evaluate, or analyze or opted out of the study entirely they realized they did not have such lessons.

Another recommendation is to film the lesson implementation in the classroom to examine whether students are engaging at the level of higher order thinking to which the lesson lends itself. This would help provide a better measure of the impact on higher order thinking as this study made the assumption that students would be performing at the intended level, which is not always the case. In a similar regard, it would be interesting to provide teachers a way to comment on the level of Bloom’s Revised Taxonomy they
intend for the activity to reach and then compare this intent with the actual level achieved.

**Conclusions**

Overall, this study found there to be no correlation between the teacher’s understanding of Bloom’s Revised Taxonomy and their integration of higher order thinking activities in their classrooms. In addition, a wide variety of levels according to Bloom’s Revised Taxonomy occurred in lessons submitted by teachers despite them being asked to submit lessons and activities where the highest levels of thinking (top three tiers) were occurring. This shows just because there is technology involved in the lesson, higher order thinking is not necessarily involved; although, data seemed to indicate that particular types of technology (probeware, simulations, et cetera) lent themselves to those higher levels of thinking. As this was not a question being researched, this conclusion would need further investigation in order to validate.

The implications of this research on the average science classroom are twofold. First, this study begins to show trends similar to previous research where the importance of quality technology is stressed. This concept is one that classroom teachers should keep in mind when planning and implementing curriculum with the intent of increasing the amounts of higher order thinking. As stated previously, this should be a talking point among administrators, technology coordinators, and school boards who take on the decision making of what technology will be purchased. The other impact to the science classroom is bringing up the question of how does the teacher’s knowledge of Bloom’s impact the modeling and performing of higher order thinking in the classroom. With
higher order thinking being an essential component to classroom best practices, identification of higher order thinking must be an area of continuing education for teachers. The more teachers are able to identify and model higher order thinking, the better their students will be able to apply those skills to the classroom and beyond.
REFERENCES


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APPENDIX A

IRB APPROVAL AND RECRUITMENT LETTER

3/13/22, 4:39 PM

Study approval: IRB 22-0067

1 message

Disa Cornish <disa.comish@uni.edu> Thu, Dec 2, 2021 at 1:32 PM
To: Maureen Haage <maureen@uni.edu>; Dawn Del Carlo <Dawn.DelCarlo@uni.edu>
Co: Sean Parrish <sean.parrish@uni.edu>, Rebecca Rinehart <rebecca.rinehart@uni.edu>, Todd Evans <todd.evans@uni.edu>

Dear Investigator(s):

Your study, The use of technology and its impact on higher order thinking in the classroom, has been approved by the UNI IRB through the review procedures authorized by 45 CFR 46.104, Exempt Category 2, effective December 2, 2021. You may begin recruitment, data collection, and/or analysis for your project. You are required to adhere to the procedures and study materials approved during this review, as well as to follow IRB policies and procedures for human subject research posted on the IRB website.

If you need to make changes to your study design, samples, procedures, or study materials, please email rebecca.rinehart@uni.edu request approval of the changes before they are implemented, and attach any revised study materials with edits highlighted. You may expect a response within a couple of days.

Your study will not require annual review and approval by the IRB. However, you will receive an annual study update request, which will ask if the study is still active and if any problems have arisen. Advisors: If your student has graduated, please reply to the annual update request on the student’s behalf.

Problems or adverse events related to your research that were not anticipated must be reported promptly after being discovered, either within 7 or 14 days, depending on the seriousness of the event, as outlined on the Reporting Problems and Adverse Events page. Examples include unexpected injury or emotional stress for study participants, missteps in the consent process, or breaches of confidentiality. The IRB will advise on any next steps that might be necessary.

If you need a signed approval letter, contact the IRB office and one will be provided for your records.

Best wishes for your project success.

Disa Cornish

Disa Cornish, PhD, CHES (she/her)
Associate Professor
University of Northern Iowa
Department of Health, Recreation and Community Services
Public Health Program
319/273-2684
WRC 221 / Cedar Falls, IA 50614-0241

https://mail.google.com/mail/u/5/?ui=2&ik=0bf655f0&view=pt&search=all&permthid=thread-FRAA178064971083030259&simplesrch=1#msg%3A178064971083030259
Dear Tracy Jarrett,

I am a Master’s of Education – Science Education student at the University of Northern Iowa and am currently working on my thesis research project. My topic is about the impact of technology on higher order learning in the science classroom. I am wanting to find participants for this study who are science teachers in the GPAEA region and was wondering if you could send the below text/information out via your mailing list to all the 6-12th grade science teachers in that region.

I am conducting a survey of people who teach science in 1:1 schools and incorporate technology into their lessons and activities. The survey takes about 10 minutes and it can be done online. In addition, at the end of the survey, you will be asked to provide 1-2 lessons/activities with supporting documents (student handouts, notes, etc.). Participation in this survey is voluntary, but greatly appreciated. Click on the link if interested: https://forms.gle/ag1Bbro1FBH8Hrst5

Thank you,

Mauree A. Haage
APPENDIX B

BLOOM'S REVISED TAXONOMY KNOWLEDGE INVENTORY

UNIVERSITY OF NORTHERN IOWA HUMAN PARTICIPANTS REVIEW

Project Title: The Use of Technology and it's Impact On Higher Order Thinking in the Science Classroom

Name of Investigator: Mauree Haage

Invitation to Participate: You are invited to participate in a research project conducted through the University of Northern Iowa. The following information is provided to help you make an informed decision about whether or not to participate.

Nature and Purpose: The purpose of this research is to determine the impact of technology integration on higher order thinking. It will also help determine the impact of a teacher's knowledge of Bloom's Revised Taxonomy on the occurrence of higher order thinking in their classroom activities.

Explanation of Procedures: As a participant in this study, you will be asked to complete one online survey. The survey will be broken into three parts. In the first part, you will complete a series of questions to determine your eligibility in this research and your consent. The second part will consist of scenarios to which you will assign levels of Bloom's Revised Taxonomy. This will provide your existing knowledge of Bloom's Revised Taxonomy. In the last part, you will be asked to attach two lessons/activities and supporting documents that you have determined demonstrate students learning at higher levels of thinking AND involve technology integration which could include (but not limited to): probes/ware, simulations, virtual labs, etc.

Privacy and Confidentiality: This study is meant to be anonymous, but any information obtained during this study which could identify you will be kept confidential. The summarized findings with no identifying information may be published in an academic journal or presented at a scholarly conference. No guarantees can be made regarding the interception of data transmitted electronically.

Discomforts, Risks, and Costs: Risks to participation are minimal. Risks to participation are similar to those experienced in day-to-day life.

Benefits and Compensation: No direct benefits to participants are expected. Participation in this research is purely voluntary.

Right to Refuse or Withdraw: Your participation is completely voluntary. You are free to withdraw from participation at any time, and by doing so, you will not be penalized.

Questions: If you have questions regarding your participation in this study or about the study generally, please contact Mauree Haage at 402-902-8037. For answers to questions about the rights of research participants and the research review process at UNI, you may contact the office of the IRB Administrator at 319-273-6148.

* Required

https://docs.google.com/forms/d/1XsHJqmxwYk3Wqj5sY5WvZUBH_Dy7YQNQcXZ5kJn4/edit
1. Agreement: I am fully aware of the nature and extent of my participation in this project as stated above and the possible risks arising from it. I hereby agree to participate in this project by answering the following survey questions and sharing my lesson plans and materials with the researcher. I acknowledge that I have received a copy of this consent statement. I am 18 years of age or older. *

   Mark only one oval.
   
   - Yes   Skip to question 2
   - No

Participant Screener Questions

2. How long have you been a science teacher? *

   Mark only one oval.
   
   - 0-4 years
   - 5-9 years
   - 10+ years

3. How long has your school district been 1:1 with devices? *

   Mark only one oval.
   
   - 0-2 years
   - 3-5 years
   - 6+ years
4. What types of technology do you use in your classroom? This could include computer, probe ware, or anything else you would consider technology integration.

5. Students can use logical deduction to figure out how a piece of equipment works, or finding fallacies in the reasoning of an argument.

6. You ask students to recite something you’ve taught them, quoting information from memory based on previous lectures, reading material, and notes.

7. You provide students an assignment to paraphrase a story or definition, explain a concept in their own words, tell a story that relates to it, or provide analogies.
8. You ask students to revise a lab procedure to improve the results. *

9. A student memorizes facts and recalls them, but you have no evidence to suggest that the student understands the material. *

10. You have students use a math formula they’ve learned to calculate the speed of a football player. *

11. You have your students network with others to discuss the merits of a new scientific study. *

12. Your students work on comparing and contrasting the arguments on global warming. *

13. Your students are able to tell you about photosynthesis using their own words. *

14. You give your students a problem to solve and they can generate hypotheses and design experiments to solve the problem while being able to justify their reasoning. *
Technology Enhanced Lesson

Please upload 1-2 lesson plans you feel exhibit higher orders of thinking and are technology enriched. Provide any supporting materials such as student handouts, teacher guides, etc.

15. Upload here: https://www.dropbox.com/request/ARNJ8RIq4RMVvJxqDYZZ

Check all that apply.

☐ Completed

This content is neither created nor endorsed by Google.
APPENDIX C

BLOOM’S REVISED TAXONOMY DICHOTOMOUS KEY

FOR ACTIVITY ANALYSIS

Activity Title:

NGSS standards met with this activity:

Performance expectations:

Directions: Examine your activity or lab and determine a portion of the activity that exhibits the highest level of Bloom’s Revised Taxonomy. Using this portion of the activity, go through this dichotomous key to determine the level of higher order thinking the activity achieves. While your activity may hit on a variety of levels, it is asked that you focus on only the portion that you believe is the highest level of thinking. Once you have determined the level according to this tool, use the spot indicated to provide specific evidence from the activity. This tool needs to be completed on a total of two activities that incorporate high order thinking and technology.

Question 1. Could students memorize the answers to all of this activity’s questions?

Yes: go to question 2.

No: go to question 4.
Question 2. To answer the questions, are students repeating nearly exactly what they have heard or seen in class materials (including lecture, textbook, laboratory, homework, clicker, etc.)?

Yes: See “Remember”

Provide evidence:

No: go to question 3.

Question 3. Are students demonstrating a conceptual understanding by putting the answers in their own words, matching examples to concepts, representing a concept in a new form (words to graph, etc.), etc.?

Yes: See “Understand”

Provide evidence:

No: Go back to question 1.

Question 4. Is there potentially more than one valid solution (even if a “better” one exists or if there is a limit to what solutions can be chosen)?

Yes: go to question 5.

No: go to question 8.
Question 5. Are students making a judgment and/or justifying their answers?

Yes: See “Evaluate”

Provide evidence:

No: go to question 6.

Question 6. Are students synthesizing information into a bigger picture (coherent whole) or creating something they haven’t seen before (a novel hypothesis, novel model, etc.)?

Yes: See “Create”

Provide evidence:

No: go to question 7.

Question 7. Are students being asked to compare/contrast information?

Yes: See “Analyze”

Provide evidence:

No: go to question 16.
Question 8. To answer the questions, do students have to interpret data (graph, table, figure, story problem, etc.)?

Yes: go to question 9.

No: go to question 14.

Question 9. Are students determining whether the data are consistent with a given scenario or whether conclusions are consistent with the data? Are students critiquing validity, quality, or experimental data/methods?

Yes: see “Evaluate”

Provide evidence:

No: go to question 10.

Question 10. Are students building up a model or novel hypothesis from the data?

Yes: See “Create”

Provide evidence:

No: go to question 11.
Question 11. Are students coming to a conclusion about what the data mean (they may or may not be required to explain the conclusion) and/or having to decide what data are important to solve the problem (i.e., picking out relevant from irrelevant information)?

Yes: See “Analyze”

Provide evidence:

No: go to question 12.

Question 12. Are students using the data to calculate the value of a variable?

Yes: See “Apply”

Provide evidence:

No: go to question 13.

Question 13. Are students redescribing the data to demonstrate they understand what the data represent?

Yes: See “Understand”

Provide evidence:
No: go back to questions 4 and 8.

Question 14. Are students putting information from several areas together to create a new pattern/structure/model/etc.?

Yes: See “Create”

Provide evidence:

No: go back to question 15.

Question 15. Are students predicting the outcome or trend of a fairly simple change to a scenario?

Yes: See “Apply”

Provide evidence:

No: go back to question 16.

Question 16. Are students demonstrating that they understand a concept by putting it into a different form (new example, analogy, comparison, etc.) than they have seen in class?

Yes: See “Understand”

Provide evidence:
No: go back through each category or refer to category descriptions to see which fits best.
## APPENDIX D

**KNOWLEDGE INVENTORY SCORES**

<table>
<thead>
<tr>
<th>Participant</th>
<th>1</th>
<th>2</th>
<th>3</th>
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<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
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<td>Score /10</td>
<td>5</td>
<td>5</td>
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<td>4</td>
<td>5</td>
<td>7</td>
<td>4</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>
APPENDIX E

BLOOM’S REVISED TAXONOMY DICHOTOMOUS KEY (DK) SCORES

This data table shows each teacher participant’s lesson submission and how it was scored by the researcher and professional colleague. Some teachers submitted more than one lesson and those are represented by a letter after the participant number.

<table>
<thead>
<tr>
<th>Participant #</th>
<th>Score 1</th>
<th>Score 2</th>
<th>Average</th>
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<tr>
<td>1</td>
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</tr>
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APPENDIX F

PRIMARY TYPE OF TECHNOLOGY FOR SUBMITTED LESSONS

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