THE EFFECTS OF A DIGITAL LEARNING ENVIRONMENT ON THE WORK

FLOW OF STUDENTS AND TEACHER IN A LANGUAGE-BASED

LEARNING DIFFERENCE SCIENCE CLASSROOM

by

Stephen Joseph Cannici

A professional paper submitted in partial fulfillment
of the requirements for the degree

of

Master of Science

in

Science Education

MONTANA STATE UNIVERSITY
Bozeman, MT

July 2016

DEDICATION

Dedicated to my family, who have been an amazing support system and whom I love more each and every day

To the dedicated administration and board of trustees at Middlebridge School who are amongst the most talented and hardest working people I have ever had the privilege to work with and who have made my career possible.

And to the rest of the staff at MBS (my second family) who do incredible and life changing work every single day…GO OWLS!!!

ACKNOWLEDGEMENT

Thanks to my advisor, Walt Woolbaugh, who has been so flexible, understanding, and informative through this process and to my science reader Robyn Klein. Thank you MBS students of the 2015-2016 academic year for being patient through the research process. Keep working hard to achieve great things! Lastly, thanks to all the coffee shops in the south county area of Rhode Island that I frequented during the past three years including Brewed Awakenings, Fuel, Cool Beans, and Empire Tea & Coffee.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Students at Middlebridge High School typically have challenges sorting and organizing their work in binders as well as completing multistep tasks. In other words, their *executive functioning* ability is often impaired. When attempting to complete something like a lab, or even something as simple as a small homework assignment, some of the assignment can easily go missing in the shuffle of the school day. Technology can often be sold as a "silver bullet" to solve many of these issues. But, how well can technology really help these students? Is the current state of technology in education robust enough to handle the day-to-day issues of a pupil who is susceptible to misplacing parts, or the whole of, an assignment?

Students in a chemistry class were cycled through four phases where they alternately used completely digital methods of managing a workflow to complete homework and lab assignments, and analog methods such as traditional paper with a writing implement and a physical binder organization system. As these phases were cycled through, data was collected to see how well they kept track of artifacts (items of school work) and how efficiently they completed their work. Some of the technology solutions employed were Google Drive, Google Classroom, Google Docs, GoodReader, and DocHub. In addition, the effect of these technology solutions were measured for the teacher.

For these students, it turned out that technology hindered more than it helped. Some of the technology was very frustrating to use by the students, since a single bug in the software, or one user-unfriendly feature, could stop a student working in his or her tracks. Students kept track of assignments less efficiently when using digital methods of work management, evidenced by longer times of retrieval to find assignments and a lower completion rate of assignments. However, there were some promising results for the teacher's use of these digital methods. Some of the methods made it easier and faster for the teacher to grade and return work for students. The technology solutions utilized seemed immature and too fragmented for efficient use by students, seemingly turning a workflow into a "workslow."

INTRODUCTION AND BACKGROUND

Background Information

When I first took the position of science teacher at Middlebridge School (MBS) in

Narragansett, Rhode Island, I knew it was going to be a unique placement. Some of the

greatest imaginations in the world would have a difficult time fathoming the scenarios

that develop on a day-to-day basis at MBS. The type of students that find their place at

MBS are very complicated learners with a wide range of needs across the student

population. The student body is about 64% male, 36% female. Ages range from 13-18

and students are primarily boarding students from the New England area, but we have

students from all over the world.

They all have a primary diagnosis of a learning difference (LD) and average to

above average cognitive potential. The students demonstrate a distinct pattern of

strengths and weaknesses in their academic profile. The students' LDs make them highly

complex learners and can include dyslexia, dyscalculia, nonverbal learning disorder

(NLD), Aspergers, executive dysfunction, receptive-expressive language disorder, and

LD written expression disorder. They may experience difficulty in areas of writing,

reading, comprehension, self-expression, critical thinking, organization, processing

speed, working memory, and time management. Middlebridge plays the role of *Executive*

Function Manager for many students as a strategy to accommodate their needs. So, there

are a myriad of perspectives to keep in mind when I design my lessons.

One of the more massive undertakings of my position was navigating an effective

and engaging format for lab activities for the students. Because the breakdown of larger

tasks, i.e., a lab, into smaller chunks can be so difficult for most of them, one of my

primary objectives became clear very quickly; I needed to develop a format for labs that would be friendly, individualized for each student, easy to organize, *and* meet the learning objectives for the lesson.

After three years of trials, failures, and learning experiences, I finally came up with the, "One Page at a Time" method. The method was, as the name states, developed so that each lab could be distributed only one page at a time. I typed out and formatted each lab myself, very thoughtfully and carefully, to get it *just* right. At the completion of a page, students will have completed one or two small tasks that takes them that much closer to the end goal of completing the lab. It can be thought of as completing a series of individual worksheets that, when all are completed and compiled, a lab report is born! I was happy with the format and revisited the checklist of objectives for lab design…

- ☑ Friendly format (distributed one page at a time, avoids information overload, breaks the task down, large/friendly/spaced out type font always used)
- ☑ Individualized for each student (students have ownership of labs, the direction they take the lab is generally up to them, they mostly take creative control)
- ☑ Meet learning objectives for lesson (labs are always aligned with lesson goals, objectives of lesson are always laid out for student on a lab "cover page")
- ☐ Easy to organize

The "One Page at a Time" method received positive feedback from students, parents, and administration on all aspects of the methods design, except one. Labs quickly grew in size to seven, eight, nine pages. For students that have trouble with organization, distributing *more* pages will never be the answer. Students often lost pages in their binder. This, of course, hurt their grade when they did not turn in a crucial page

for scoring (the conclusion sheet, for instance). More importantly, students never had the opportunity to receive the teacher's qualitative feedback if they did not turn in their work, which meant potential for growth was not being increased.

Try as I might, some flipping back and forth was required in just about every lab; it was inevitable. Little bits of information from previous steps always found relevancy for themselves in latter stages of the lab reports. The more the papers moved, the more likely they were to disappear. "Shuffling syndrome", as I liked to call it, needed a cure! The goal was to minimize the shuffling of papers to reduce misplaced assignments.

Many of the pages offered designated lines, or areas, for students to write in. After all, completion of a task often required proof (output) that the teacher could use for assessment. Some students wanted to use the lines, others wanted to type on separate pieces of paper. However, that could have added another two to four pages to the completed lab. More to keep track of, more opportunity for being lost, more paper used.

The mass of papers was not easy to manage for me as their teacher, either. For a nine-page lab, with four classes of six students each, plus two extra copies per class to account for "casualties," that was 288 pages to keep track of. I also used these pages to identify how far along a student was in the lab. When pages went missing they often had to be redone. Printing all the pages out, making copies, printing extra individual pages when they went missing, it all took up time that the teacher could be using for planning, grading, or any other of the mass of tasks that teachers find themselves responsible for on a daily basis.

Formation of Research Questions

As a teacher in a special needs classroom, I do not believe I developed a thought process similar to the way other educators think. I could stand in the front of the room and lecture all I want. I could create engaging and interactive PowerPoint presentations all I want. I could even create individualized, hands-on, inquiry-based labs all I want. However, what good is any of that if my students could barely structure, prioritize, and keep track of all the small tasks that need to be completed before the larger, whole assignment could be completed and turned in?

One of the primary supports I provided for the students in my classroom is helping them organize their work and stepping them through the process of completing an assignment. If they needed help, "seeing the forest through the trees," then I provide them with guidance through the forest. However, I cannot always be there to help guide them. After they leave my classroom and work on their science assignments in study hall, for example, they may not get the specialized support that I can provide. An assignment like a lab, which can have anywhere from eight to ten pages and numerous sequential tasks, could take a turn for the worse as the students try to progress through that lab.

I began to ponder the possibilities of technology as a solution. I went off and did some preliminary research. As I questioned colleagues about how they were using technology for curriculum distribution and organization, they showed a degree of interest that told me I was researching something important to them. They wanted solutions to one of the primary problems for our students; they expressed discontent with the conundrum of, "I can't find it. I don't know where it is." The possibility that a student completed homework the previous night was always a possibility. But, that is of no use

on the teacher's side if the student could not provide the evidence. Teachers would like to have an effective system that they could easily implement to help students keep track of their daily assignments.

Technology became the potential solution for me, the distribution of the entire curriculum via digitization. It could solve all of the problems discussed above. If an entire lab were distributed to students through electronic means, the paper to be kept track of would come to a total of zero (for student *and* teacher!). A digital copy of any assignment would have a home, and there it would stay until ready to be submitted. It could satisfy the last objective of the lab design, easy to organize. I would like to bring my students one step closer to having a streamlined, seamless as possible, digital work flow. The steps in a student's workflow would include:

1) Receiving reference material (a handout or personally recorded notes from class)

2) Storing that reference material in a safe location from which it can eventually be retrieved or accessed

3) Student (within a reasonable amount of time) identifies and retrieves the necessary reference material to complete a given assignment, from wherever the student chose to store the reference material

4) Student completes assignment

5) Assignment is turned in by student, on-time

6) Assignment receives qualitative and/or quantitative feedback from the teacher

7) Teacher returns the assignment with the feedback to the student

This "workflow" (and digital solutions used to create it) will be the treatment that I apply. With all of that said, here are my AR research questions:

Statement/observation - Many of the students I work with have challenges in organization, staying on task, and keeping track of and executing the steps necessary to complete labs and other long-term or multistep assignments.

Primary question - How will a completely digital learning environment affect the workflow of the students in a language based LD classroom?

Secondary questions:
A) What are the pros and cons of the digital solutions in each step of the workflow?
B) How will the treatment affect me as the classroom teacher?

There were two people in my support team that I knew would provide valuable feedback as I moved through the AR process.

Janie Cannici - Middle School Spanish Teacher

Janie, my mom, recently completed the AR process within the past few years to earn her Master's degree in education. Having someone on the team who recently completed the AR process was a valuable asset as she helped steer me in the right direction if it appeared I was falling off the rails or straying too far from what I originally set out to discover with my AR question.

Kristen Killilea - English Teacher, Middlebridge School

This is my most trusted coworker. She and I were hired together in the school's first year (2008) and are the only two remaining employees of the "new hires" that were necessary to round out a complete staff. I felt it was very important to have someone on my team that was familiar with the type of population that was involved in the research. She provided a perspective, and insight, that many others would not be able to see if they had never worked with this type of population. She also has a Master's degree in education.

I established with these individuals that I would be asking them for feedback from time-to-time. I emphasized that they could use whatever method was convenient for

them. Most often, I posted sections of my AR research in the form of a Google Doc to

share with them. This way, they were able to read through and provide feedback when it

was convenient for them, but also in a timely manner.

CONCEPTUAL FRAMEWORK

Introduction & Background

Many questions arose as hurdles blocking the way to the introduction of a

completely digital workflow:

- How will students produce output associated with digital materials (writing on/filling-in pages from a lab)?
- What platforms are available for distributing and working with digital materials?
- How will the teacher provide feedback for submitted digital materials?
- Surely other researchers have attempted similar measurements, what have they found?

The answers to these questions were included in my research. They were directly related

to the development of my treatment and AR research questions. I hoped the answers

would give me the ability to develop a completely digital workflow for teacher and

students to use. The literature that I found gave me a good foundation and general

direction for my research, though not the direction that I thought it would take me.

Direction

Clark (1983) explicitly cautioned against media comparison research. Clark

reviewed a set of literature that all pointed towards one general direction; comparing

different types of media based instruction (i.e., lecture vs. media based instruction such as

radio, television, and computer-assisted) to choose a "best" method was not worth a

researchers time. The quality of the instructional strategies was more important.

Some of what Clark reviewed were meta-analyses of research comparing the learning advantage of various media. The result of all these studies, he stated, "seem to be reasonably unambiguous and unanimous. Taken together, they provide strong evidence that media comparison studies that find causal connections between media and achievement are confounded" (p. 447). So, not only did much of the research point to the idea that strategies were more important than delivery methods, he also emphasized that any research that *did* show any significant advantages were confounded in some way.

One example he discussed was a pair of studies that reported a significant savings in time while using computers. Clark suggested that, "Comparisons of computer and conventional instruction often show 30 to 50 percent reductions in time to complete lessons for the computer groups" (p. 449). He hypothesized that there was no true savings in time because computer groups needed to invest time beforehand to learn the new technologies they were using before they could become meaningfully proficient with it. Given Clark's warning, modern researchers have not been dissuaded from studying the effects of media delivery in the classroom.

While reviewing the literature, I did not read about any classrooms that have completed the digital transition. By that, I mean the complete elimination of pencil, paper, and binder from the classroom. For some time, I always thought the classrooms' digital divide had not been fully closed because the technology was not easy enough for students to use. The creation and curation of student work always required multiple steps, with multiple platforms and programs. However, research showed that ease of use may not be the driving factor for the lack of full technology integration (Harvel, 2006). Rather, students will access content related to course curriculum, whether it is digital or

paper based, according to their need for that content as it pertains to performance

assessments. Convenience and ease of user interface did not appear to increase students'

use of primary or secondary curriculum related content. Harvel stated, "The optimistic

view that students will use supportive content if we make it convenient, held by many in

the digital library and content creation communities, is based on a belief that student

behavior is intrinsically motivated" (p. 172).

Theory

Much of the modern research in educational technology focuses on learning

outcomes with its use in the classroom. There was not much literature discussing the use

of technology itself; the assumption was made that the use of technology would lead to

learning (Oliver, 2013). One theme that came up across several articles was the idea of

technological affordances, which Oliver (2013) discussed is one way we can try to

theorize the technology we use in education. He cited Gibson (1979), to define an

environment's affordances to be, "What it offers the animal, what it provides or

furnishes, either for good or ill" (p. 115). In other words, Oliver (2013) states that the

affordances of technology, "do things to us: they constrain what we can do, or at best,

permit us to do particular things; they have a controlling role" (p. 35). Indeed, the

affordance-based approach seems to be popular based on review of the literature. He

contrasted this approach with a social analysis of technology theory, where, "people do

things with technologies, placing people at the centre of the analysis" (p. 35). His paper is

mainly an illustration of these two theories of technology, and he concluded that the

social analysis is more in line with the learner-centered and individualization direction

that current educational technology research is taking. He concluded that, "researchers,

teachers and students alike are not simply 'caused' to act by technologies, but must make

efforts to make sense of them, work them into our social practice and through doing so

remake them" (p. 41).

<u>Data Analysis</u>

Data analysis and collection in an action research project must be carefully

planned. The triangulation of data is what helps to shore up the credibility and validity of

an action research study (Hendricks, 2006). One study looked at the use of a Bring Your

Own Device (BYOD) environment for seamless science inquiry in a primary school

(Song, 2014). The study adopted a method of triangulation. First a summative assessment

was used to gather pre- and post- treatment data. The two assessments were compared to

measure students' advancement towards the learning goals of the unit, "The anatomy of

fish." Next, the development of artifacts was traced through the research. "The artifacts

included concrete objects (e.g., real fish), and conceptual/knowledge artifacts (e.g., text,

pictures, and drawings)" (p. 53). The development of these artifacts were traced so that

Song could, "explore how groups work together to make sense of the problem inquiry

situations" (p. 53), in this case, the collaborative refinement of a diagram of a fish with

all parts labeled. Lastly, students wrote reflections in a field journal that they kept online

using the content curation suite, Evernote. This very much reflects the data collection

strategy I had planned out in my AR research journal. The paper provides validation, and

a very strong blueprint method of ideas that would prove successful. This is confirmed by

Song in her discussion section where she states:

> The results of the study also show that using a trialogical approach
> (Hakkarainen & Paavola, 2009) to trace the students' individual and group
> inquiry in multiple spaces can help make the learning process and outcome

visible (Stahl, 2002). The visible conceptual artifacts in the form of pictures, text, videos and recordings documented the students' learning process and mediated their learning progressively (p. 59).

One article that I found very appealing was on a concept called mobile seamless learning (MSL). Luisa-Hsiang Wong cites Chan et al. and their definition of seamless learning as:

a learning style where a learner can learn in a variety of scenarios and in which they can switch from one scenario or context (such as formal and informal learning, personal and social learning, etc.) to another easily and quickly, with the personal device as a mediator (p. E19).

She also reviews the 10 dimensions to be considered that were put together by Wong and Looi (2011) and offers a critique. Her paper, "departed from [these] two publications by foregrounding individual learners' perspective to reconceptualise MSL" (p. E22). She defined the idea of "a learning hub [that] should be the nucleus of: (1) a suite of affordances to support learning activities, and (2) the learner's learning history (including stored resources and self-created artefacts)" (p. E21). She suggests the idea that a mobile device could act as the hub for each student.

Considering the Middlebridge Student

One aspect that needed to be considered was the executive dysfunction of the students I work with. What were the aspects in the classroom that they could benefit from through the use of technology? Lizarraga, Baquedano, & Villanueva (2012) sum it up nicely in their paper:

They constitute a set of managerial processes involved in programming, implementation, supervision, regulation, generation and adjustment of thoughts, memories, emotions and behaviour to achieve complex goals in dynamic environments, most notably when it comes to situations that require an unfamiliar, novel or ambiguous approach (as cited in Lizarraga et al., 2012, p. 274).

They cite scientific literature that lists seven (three of which were of particular interest to my research) specific executive functions:

> (4) updating, support, review and renewal of the representations of working memory; (5) planning, control and monitoring (action-oriented), proposal of the most appropriate alternatives for action and choice according to the characteristics of the problem at hand; … and (7) task fixing, executive direction based on task demands (as cited in Lizarraga et al., 2012, p. 274).

In the classroom, these are absolutely critical. It can be easy for a student to get "lost" in all the material they need to keep track of for a particular class.

Educational technology is not a homogeneous intervention, but a broad variety of modalities, tools, and strategies for learning. Its effectiveness, therefore, depends on how well each of these many pieces helps teachers and students achieve the desired instructional goals (Ross, Morrison, & Lowther 2010). Ross et al. (2010) discuss technology in the classroom from three different vantage points: technology in the classroom as a tutor, as a teaching aid, and as a learning tool. While they cite that the tutor and teaching aid vantage points are well understood, Ross et al. (2010), go on to discuss that, "there is a much greater need today to obtain scientific knowledge and data regarding student learning *with* computers" (p. 21). They state that, "The first two forms augment and enhance what teachers can do on their own to orchestrate and adapt instruction to individual needs. The latter form is directed to enabling students…to use technology effectively to master and perform 21st century skills" (p. 22). This all seems to have merit, however, I believe that the latter component can be extended even further. For my student population, it's not just about 21st century skills. Some of my students need it broken down even further, to a more basic level. They can use present day technology to enhance their life skills and quality of life outside of the classroom. When

the teacher is no longer present to make the accommodations necessary for them, they

need to know how to work *with* technology to complete simple tasks. For my research,

simple tasks will entail proper management of time and materials to complete a typical

course load of homework, worksheets and labs. One of the final conclusions of Ross et al.

was a bulleted list of technology in education research topics that will be important in the

coming decade. Two of those bullets were:

- Integrating technology as a learning tool in classroom instruction
- Teaching students to become skilled and confident users of technology

My research will be able to address both of these points.

<center>Influence of the Literature on this Research</center>

While the Clark paper strongly cautioned against media comparison, I, along with

many researchers before me, did not heed his warning. A utopian workplace that could be

disinfected of its piles of paper and misplaced student assignments had a siren's song that

was too strong for me to ignore. Despite the dearth of previous studies that waded in a

similar area to mine, I designed a research project that would compare conventional to

digital tools for students to use to complete science lab reports and assignments.

There was plenty of research that discussed learning outcomes, yet that was not

relevant to what my research was trying to measure. My research project focused on

digital tools for successful completion of science labs. Despite searching the literature, I

did not find this kind of study.

When I think of the reports of Harvel and Oliver together, I receive the message

that people will not mold their living (i.e., working, schooling) habits to the technology,

the technology must conform to the user. Oliver emphasized that people must remake the

technology to fit us if it doesn't satisfy our needs, based on his social-analysis theory of educational technology. This was a great mile-marker on the roadmap of my research development. It told me that the technology I planned to implement in my classroom must meet a certain set of criteria. The criteria were that the technology needed to be very flexible and willing to adapt to the user, not the other way around. As Jack Dorsey, stated in an interview with Charlie Rose, "I think the best technologies…disappear. They fade into the background, and they're relevant when you want to use them, and they get out of the way when you don't" (Palis, 2012). I tried to find a suite of technologies that my students could use easily. I prioritized that the technology should not act as a blockade to performing tasks. If a student wanted to perform a particular action, such as annotate a PDF, then the technology should all that to be performed in the most direct way possible and the fewest number of steps. That was a very challenging task.

The mobile seamless learning system discussed by Wong (2012) is the closest example of what I wanted my research to achieve--a seamless system to track students. Quick and easy access to a hub that each student worked through would make for an easy data collection system. Unfortunately, it was a set of affordances that my school does not have access to.

Many of the supports provided for students come in digital forms; computers, iPads, and use of the Internet are the productivity platforms of the future. The flexibility and adaptability of these electronic wonders are capable of offering many possible solutions and supports for students with learning differences. One of the goals of my research was to try to identify best practices for a student's workflow. For now, I

attempted to assemble the most seamless suite of software solutions possible for my

students using Google Classroom and the products associated with it.

METHODOLOGY

Description of Treatment

To complete this research, I first needed to perform an analysis of how students

and teacher work together to see how an assignment progressed from its initial

distribution to its final state. I defined the workflow as having seven steps: *Distribute ->*

Store -> Retrieve -> Output -> Submit -> Generate Feedback -> Return Feedback,

which is generally executed linearly, but one segment of steps does not necessarily need
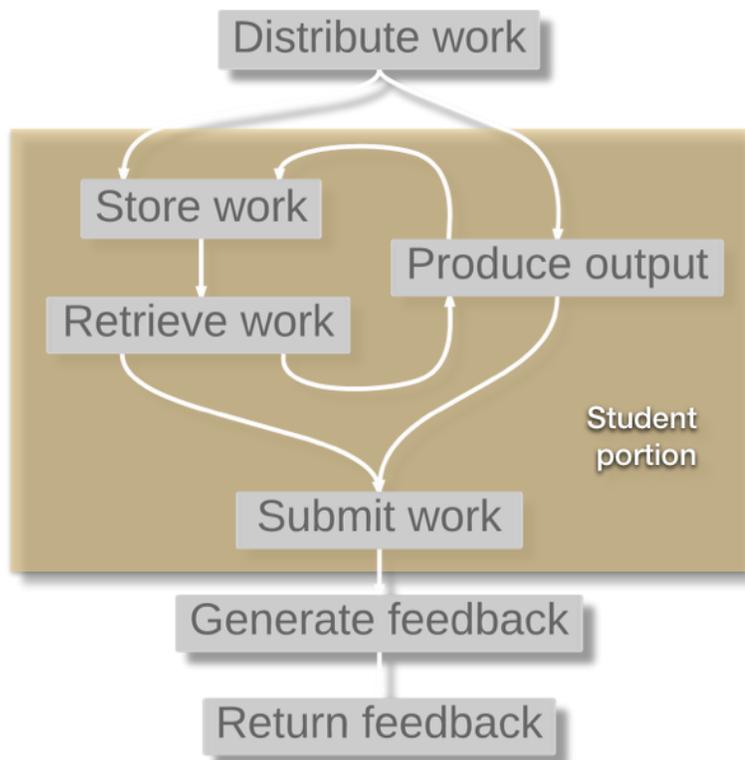

Figure 1. Illustration of student workflow.

to be completed linearly, i.e. the *Store -> Retrieve -> Output* steps could be repeated

multiple times before an assignment is *submitted*. This workflow (See *Figure 1*) can be

thought of as having two sides, a teacher side and a student side. Pages of a lab are *distributed* by the teacher. The students have to *store* those pages somewhere and they typically have to *retrieve* those pages at some point. After retrieval, they have to produce some type of *output* (generally on the page, itself, with a few exceptions), based on the directions on the page. After they produce their work they have to *submit* it back to the teacher. On the teacher side, I review their work and *provide feedback* (qualitative and/or quantitative) and, finally, *return feedback* to be read by the students. Many of these steps can also be applied to any worksheet that is distributed to classroom students or even for one-night homework assignments.

For each step of the workflow, some type of digital solution needed to be employed. Our school recently implemented the use of Google Classroom, which can facilitate the steps of distributing, storing, retrieving, submitting, and both feedback steps. However, the output step proved to be a problem depending on the type of output that needed to be created by the students. If students were working on a lab, that meant they were working within a file type called a Portable Document Format (PDF). To generate output on PDFs, students had to open the PDF in a program called DocHub and annotate the PDF with their output, usually using text boxes that they added to the document themselves. I was also able to pre-add text boxes for students after acquiring the Adobe Acrobat software, which allows users to create and modify the properties of a PDF file.

When the treatment was being applied, there were multiple ways that students participated in the digital workflow process. When students were conducting a lab, they received PDF files in a sequence. Each time they showed me that they had completed a PDF they were working on, I posted the next file to Google Classroom for them to work

on. At that point, it was their responsibility to manage that file via a digital method of storage and retrieval (most often Google Docs) and to generate the output required for that file, via DocHub, and to submit that file with the generated output back to me, via Google Classroom. There was a "submit" button associated with each PDF that I distributed to them that let me know when they were ready to move to the next step of the assignment.

Another way the digital workflow manifested itself throughout the treatment periods was through homework assignments. Since homework assignments were nothing like the arduous planning task of a lab, students were able to complete these with a little less guidance from the teacher. Homework assignments were typically one- to two-page worksheets that asked students to practice a skill that we had gone over in that day's class period. The plan was to distribute these assignments using Google Classroom. Then, students could create a brand new Google doc to complete the assignment. Google Classroom automatically stored this document in each student's Google Drive. When it came time to submit this document, students could easily click the "submit" button to confirm that they felt their work was finished.

Whether they were working on a lab or a quicker homework assignment, the workflow turned to the teacher's side of the equation after their work was submitted. To provide feedback on PDFs, each file was imported into an app called GoodReader on an iPad. GoodReader is an iPad app that allowed me to modify and manage PDF files in various ways. For example, the app allowed me to annotate PDF files with quantitative or qualitative feedback. I was able to mark individual questions on student homework

assignments as correct or incorrect. Then, I could add comments as to how to improve their work or inform them where they had gone wrong on a specific problem.

Finally, I could use GoodReader to quickly email any PDF back to the appropriate students after it had been marked up. GoodReader has an "email" button that can be tapped after selecting a particular document. After tapping that button it asked me for an email address. I typed in the email address of the student, or students, that I wanted to return the rubric to and tapped "send" and it would be sent. A similar procedure was used for returning homework assignments, when appropriate.

<div align="center">Description of Methods</div>

Sample

I selected four class sections of chemistry to collect data. Each section contained six students, for a total of 24 students: 13 boys and 11 girls. All of these students were Caucasian and ranged in age from 16-18. The data was collected during the time period of September 2015 to March 2016.

The four sections of chemistry that I chose included a diverse array of learners. Since MBS groups classes by learning style and ability instead of grade, the four sections generally represented four different groups of learners. However, the important point is that all these students had been diagnosed with a disability that in some way effected their executive functioning abilities. All of the students were familiar with the use of digital and computer technology.

When deciding which classes to include in the research, I also had to factor in who to exclude from the sample. The students at MBS reap benefits when a routine is kept and followed. Some students would fall behind quickly after an abrupt change in the

way classwork was completed. I decided to leave out my second period class, where this change would have too dramatic of an effect on their daily classroom routine. Second period was a group of students with very low processing speeds, were prone to being very inattentive, and had the lowest cognitive ability based on IQ testing. It would have been very difficult to isolate all the variables from this grouping of students, which is why they were not included in the treatment.

The sample of students selected were subjected to a treatment that was applied with a longitudinal approach. This means that four phases were executed over a long period of time that alternated between the application of the treatment followed by a period of no treatment. The longitudinal approach with the same set of students helped provide for some control. In addition, each treatment was not always exclusively digital. That would have been very difficult to achieve given the way classroom plans fluctuate from day-to-day.

<div align="center">Timeline for Capstone Data Collection</div>

Phase One: Treatment Applied - Wednesday, September 16 - Wednesday, October 14

- Lessons and assignments included
  - Science Fair Lab
  - Various homework assignments
- Measurement instruments utilized
  - Observational journaling by teacher
  - Logs kept of time required to grade assignments
  - Technology utilization survey
  - One-on-one student interviews

Phase Two: Treatment not Applied - Tuesday, October 27 - Friday, December 4

- Lessons and assignments included
  - Properties and Transformations of Matter
    - Separating a Mixture lab
  - Various Homework and classwork assignments

- Measurement instruments utilized
  - Observational journaling by the teacher
  - Logs kept of time required to grade assignments
  - Student Homework Completion Survey
  - Artifact Retrieval Timing Sheet
  - Completed and submitted on-time artifacts (pages of lab, homework/classwork assignments)

Phase Three: Treatment Applied - Monday, January 4 - Friday, January 22

- Lessons and assignments included
  - Periodic Table (research project)
  - Types of Bonds Homework assignments
  - Various Homework and classwork assignments
- Measurement instruments utilized
  - Observational journaling by the teacher
  - Artifact Retrieval Timing Sheet
  - One-on-one student interviews

Phase Four: Treatment not Applied - Monday, February 1 - Friday, March 11

- Lessons and assignments included
  - Measurement and Units Unit
  - Various Homework and classwork assignments (Practicing the use of Measurement Tools)
- Measurement instruments utilized
  - Observational journaling by the teacher
  - Artifact Retrieval Timing Sheet
  - Student surveys/interviews

Data Collection Techniques

Observation Journal

A teacher's journal was created to record open-ended observations about where students appeared to be getting frustrated, what appeared to be very easy for them, and to record quotes about their experiences. Though this was a time-consuming way to collect data, it served as a very rich data set to analyze the results. The method used involved a composition notebook where quick notes were taken down throughout observation periods during a class. Following the class period, or at the end of the school day, I

looked over the notes and wrote elaborated comments in a more rigorous, typed journal.

This instrument aligned with my primary question and the secondary question concerning

pros and cons of each step of the workflow.

Table 1
Data Triangulation Matrix

AR Questions	Primary: How will a completely digital learning environment affect the workflow of the students in a language based LD classroom?	Secondary: What are the pros and cons of the digital solutions in each step of the workflow?	Secondary: How will the treatment affect me as the classroom teacher?
Data Source 1 (Observational)	Field notes and checklists	Where are students getting frustrated, having issues (how well are the students interacting with, responding to the technology solutions?)	Logs kept of time required to grade
Data Source 2 (Artifacts)	Completed, submitted, on-time sections of labs or worksheets	Timing of the retrieval of handouts that had previously been distributed to students	Periodic compare/contrast journaling of my experiences
Data Source 3 (Inquiry)	Student surveys (Do you feel you worked more efficiently thanks to the technology?)	Student interviews, Likert, attitude scales (How did you feel about this step or that step?)	Self reflection/journaling

Technology Utilization Survey

Another important instrument was the Technology Utilization Survey (See

APPENDIX A). This survey was distributed to students during Phase One. The survey

asked students if they felt Google Classroom was saving them time, if the DocHub

technology solution was easy to use, what was the hardest and easiest part of using the

computer to complete work, and if they preferred pencil and paper to using the computer

to complete school work. Table 2 - *Alignment of Technology Utilization Survey to AR*

Questions illustrates how the items on this survey aligned with the AR questions.

The question about completing work via pencil and paper versus using the

computer provided a baseline to see how students' opinion of work completion methods

changed throughout treatment and non-treatment phases. The instrument was distributed

using Google Forms, which automatically stored results in a spreadsheet and provided

instant analysis in the form of various charts that were compiled from any quantifiable

data from the survey results.

Table 2
Alignment of Technology Utilization Survey to AR Questions

AR Question Addressed	Survey item
Effect of digital learning environment on student workflow	Google Classroom is saving me time as I work through my science fair project (Likert Scale) DocHub has been easy to use (Likert scale) The hardest part of completing my work while using the computer is…(open-ended) The easiest part of completing my work while using the computer is…(open-ended)
Pros and cons of each step in the workflow	DocHub has been easy to use (Likert scale) The hardest part of completing my work while using the computer is…(open-ended) The easiest part of completing my work while using the computer is…(open-ended)

One-on-One Student Interviews

In addition, I completed follow up, one-on-one interviews, with many of the students that participated in the treatment and recorded their responses. The interview started by asking students to read out loud, four bullet points on an index card (initially five, before recognizing that one was irrelevant). These bullet points read:

- Store work

- Retrieve work

- Produce work

- Submit work

Students were then asked the question, "Keeping in mind only the technology you used, which one of those four steps was most frustrating to complete while working on your project?" Students were also asked, "Which one of those four steps was least frustrating, or easiest, for you to complete?" Lastly, students were asked, "How well did the technology help you work with your partner?" Student responses were reviewed to categorize each issue they brought up as being part of one of the four steps of the workflow they read at the beginning of the interview. The results were then quantified to see how many times each step of the workflow was referenced and any specific themes that may have appeared. This instrument aligns with secondary question A, the pros and cons of each step in the workflow.

Artifact Retrieval Timing Sheet

A key instrument that was used across multiple phases of the research was the Artifact Retrieval Timing Sheet (See APPENDIX B). This instrument was designed to give me the ability to easily record data about what took place as students retrieved

artifacts such as homework or a worksheet no matter which phase of the treatment we were in. It was designed to record if students had actually done the assignment, where they were storing the artifact and in what form, i.e., digital or paper, how long it took them to retrieve the artifact, and if they were even able to retrieve it at all. This instrument aligned with my primary question and the secondary question concerning pros and cons for each step of the workflow.

Student Homework Completion Survey

Lastly, a key instrument was the Student Homework Completion Survey (See APPENDIX C). The purpose of this survey was to gather data on student opinions regarding completing homework, specifically while using digital or pencil and paper methods, in science class. This survey asked students how they felt about two important statements. The first statement was, "When I receive homework in science class, I prefer to type it up over writing it out by hand." The response option was a Likert scale consisting of four possible choices, "Strongly Agree," "Agree," "Disagree," and "Strongly Disagree." Students were asked to fill in the bubble accordingly. They were then asked to describe why they answered the way that they did.

The second key item on the survey asked students how they felt about the statement, "When it is time to hand in my homework for science class, it is easier to find my homework assignment if I wrote it out on paper compared to if it was typed." Again, the response option was the same Likert scale as described for the first item on the survey and students were asked to describe why they answered the way that they did. Finally, students were asked to make a choice, "Which would you rather use to complete your work?" The options provided to them were "pencil/pen and paper" or "computer."

<u>Validity and Reliability</u>

For the results to be valid, a triangulation approach was necessary. The various data collection methods listed above employed various types of measurements that would allow one observation to be made from at least three different perspectives, or measurement tools. A slight degree of redundancy was necessary to make sure that any one observation was not just an improbable occurrence.

The reliability of some of the instruments was a little more difficult to assess, given that they were created for the sole purpose of taking measurements for this research. The Artifact Retrieval Timing Sheet was used many times throughout the research and each time I was the one recording the times. If students had a way to time themselves and report the data on their own then the reliability of that instrument could have been increased. Several of the surveys were used only once and some students seemed to just want to, "get it done with" instead of taking their time. Allowing students more time to complete these surveys would have benefitted their reliability.

The most reliable instrument was the One-on-One Student Interviews. These were always 5-10 minute sessions where I could ask all of the questions I needed. This is why these interviews played such a key role. Students had no opportunity to hide their opinions, since I could take my time asking probing questions to get more details about any statement a student may have had. In addition, I was able to follow up with students on any survey questions they may have answered. That helped bring more validity to the Technology Utilization Survey and the Student Homework Completion Survey.

The research methodology for this project received an exemption by Montana State University's Institutional Review Board (See APPENDIX D), and compliance for working with human subjects was maintained.

DATA AND ANALYSIS

The data collected pointed to a number of themes, some of which did not truly develop until the completion of Phase Four. One observation that I made in my AR journal was how consistently and frequently some students stated that they needed the computer to get their work done. Some students do have accommodations that state they need a computer, and that was a factor as the data collection process played out. As the data will show, however, the reliance that some students had on the computer may have actually hindered their work, as well as negatively affected the efficiency of the classroom experience we all shared.

Phase One: Treatment Applied

Phase One kicked off the research by having students work through their science fair projects in a completely digital manner. This was an attempt to get some data on all stages of the workflow. As this phase progressed however, it became apparent that attempting to measure all stages of the workflow with just this one research project was a little too ambitious. The instruments applied in this phase, however, provided some great preliminary data that helped guide the design of future phases. In fact, each phase helped to add some structure and solidify what needed to be measured in each subsequent phase.

The Technology Utilization Survey returned some great quantitative feedback (N=24). The first question asked students, "Google Classroom is saving me time as I work through my science fair project" and 42% of students said they agreed with this

statement (See *Figure 2*, APPENDIX E). This question aligned with the storing, retrieving, and submitting of student work. Zero percent of students disagreed that Google Classroom was saving them time in the workflow process. In total, 83% viewed Google Classroom in a favorable manner.

The second big question on the Technology Utilization Survey asked specifically about DocHub: "DocHub has been easy to use" (See *Figure 3*). Again, on a scale of one through five, where one represented "Agree" and five represented "Disagree," the "Neutral" choice was the most common response at 42%. A closer look at the "Agree" side of the scale reveals that 33% chose "Somewhat agree" and 8% chose "Agree." So, when adding the students that chose any form of agreement with the students that were neutral, there was an overwhelming majority of students (83%) that seemed to either favor the use of DocHub or felt neutral about it. This seemed counter to what most of my observations had been. One of the comments from my observational journal stated, "…students are definitely frustrated with the functionality of placing, resizing, and editing of text boxes." I suspect that most students were still making up their mind about how they really felt about the use of this piece of technology. The One-on-One Interview Analysis came two weeks later and it helped clear up any ambiguous opinions that students had.
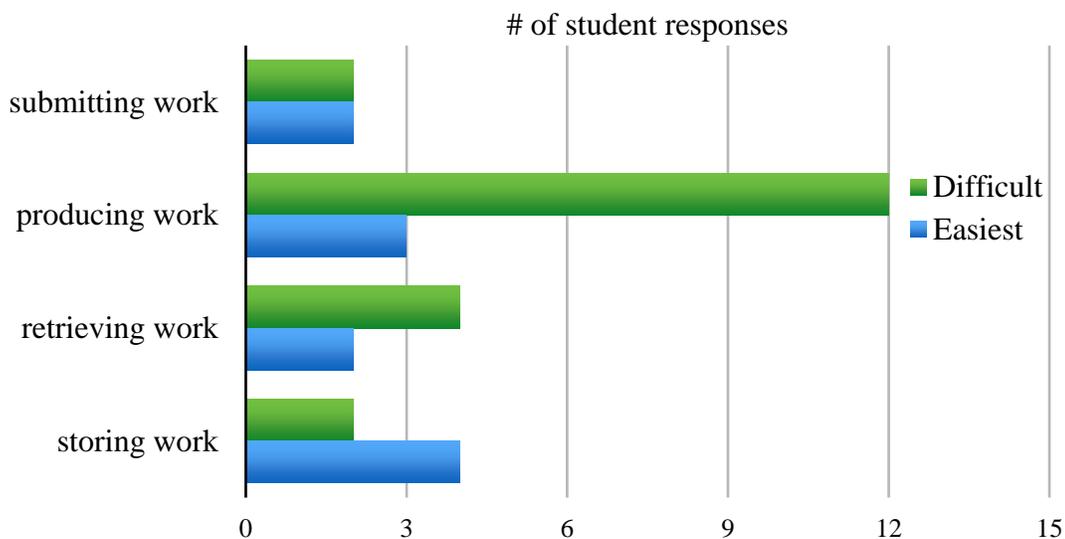
In Figure 4, we see the One-on-One Interview Analysis (*N*=15). As I asked students what step of the workflow they found most frustrating and which they found the easiest, a clear trend emerged. In terms of most difficult step of the workflow, 80% of students cited *producing work*, compared to the 27% that cited *retrieving work*, and the 13% each that cited *storing work* and *submitting work*. If DocHub was the main digital

solution associated with *producing work*, which is what students used it for, then this data

does not agree with the data from Figure 3 or the observational journal. When discussing

student frustrations, 60% of students interviewed specifically cited, "DocHub" as being

the most frustrating. In addition, one particular task was cited as being frustrating; of the

students that cited, "DocHub" as being most frustrating, 56% stated that, "placing or

adjusting a text box" on the PDFs they were working with in DocHub was the main

source of their frustrations. One student said, "You had to place the text box just right, or

else it would look weird. That really annoyed me." Another student stated, "Typing on

the PDFs was difficult sometimes, because some of the text boxes…would get

frustrating." This aligned with the observations mentioned above from my observational

journal.

As I watched students try to complete the task of placing a text box, I was able to

gain a first-hand account of what was happening. DocHub was a separate platform from

Google Docs. Hence, a new web browser window was opened each time students

attempted to access DocHub. That action created a "seam" or a spot in the workflow

where one technological solution had to stop being used and another had to be

introduced. Each time, a student's thought process had to be interrupted by a seam, they

were at a greater risk of losing their train of thought. Similarly, the placing of a text box

in DocHub was not a smooth and simple process due to the ambiguous user interface that

was implemented for that function of the software. Though this opinion is somewhat out

of line with the conclusions of Harvel (2006), I do not think that the frustrations here

came from any one person's low technological aptitude because of the large percentage

of students that cited DocHub as being the most frustrating

Phase Two: Treatment not Applied

The main assignment that was scheduled during Phase Two was a lab. The

Separation of a Mixture Lab (SMLAB) challenged students to come up with a procedure

to separate a mixture of salt, sand, and water into its constituent parts. The end result

should be that students captured the sand and the salt in some way. Students were not

instructed that they needed to capture the water, though many made an attempt using a

Figure 4. One-on-One interview analysis, (*N*=15).
Note. Throughout this survey, students were allowed to list
multiple steps as being difficult or easy.

makeshift distillation apparatus.

Students were assigned to complete, "The Separation of a Mixture Lab: Procedure

Worksheet" (See APPENDIX F) for homework. The assignment provided them with a

logical first few steps of the procedure for the SMLAB and asked them to write out five

more steps that could progress them towards the final goal of separating the mixture.

They were also provided with a list of materials they would be able to use during the lab.

Initially, Phase Two was supposed to be completely non-digital. However, some students approached me with a concern that they needed an accommodation to be able to use the computer for an assignment of this type. I did accommodate them, which turned out to be a great decision because it gave me some preliminary data that I was able to use to guide the experimental design in the next few phases. As will be discussed, the Phase Two data from the Artifact Retrieval Timing Sheet revealed some interesting themes as the two methods of completing work were contrasted.

Students' Preferred Method of Completion

The Student Homework Completion Survey (*N*=24) was a very telling instrument that was implemented during Phase Two. Students were asked their opinion of the statement, "It is easier to find my homework assignment if I wrote it out on paper,

Figure 5. Easier to Find My HW if I Hand Wrote It, Compared to Typing It (*N*=24).

compared to typing it" and returned a "disagree" response of 54% (See *Figure 5*). In addition, 13% responded "strongly disagree." Taken together, 67% of students felt some type of disagreement with that statement; a full two-thirds. A common explanation
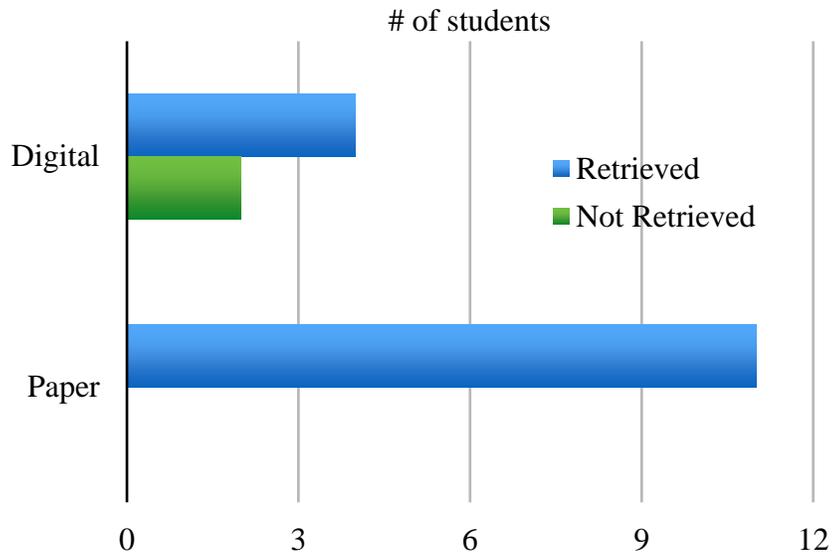
students cited for answering this way was that the digital copy could not be misplaced.

One student stated, "For some reason, I always misplace the homework I write out. But if

I misplace a typed assignment, I can just reprint it." So, it seemed students

overwhelmingly thought that using the computer was better for the storage and retrieval

of their work. The Artifact Retrieval Timing Sheet, however, provided data that told a

different story.

Success Rate of Student Assignment Retrieval vs. Preferred Method of Completion

The data from the Student Homework Completion Survey really stood out to me

after analyzing the data from the Artifact Retrieval Timing Sheet (N=17). The data from

this instrument showed that the method of homework completion the students chose to

use agreed with the data from the Student Homework Completion Survey. Students that

chose to complete the assignment using a pencil and paper method made up 65% of the

sample, while the remaining 35% used a digital method (See *Figure 6*).

Of the entire sample, 88% were able to retrieve the assignment, while 12% never

found it (two students that each completed the assignment digitally). I was able to

confirm that the assignment had been completed using the teacher side of the Google

Classroom platform. When this data was broken down even further, it revealed that of the

65% of students that used an analog method to complete and store the assignment, there

was a 100% retrieval rate. Of the 35% of students that used some sort of digital method,

only 66% were able to retrieve their assignment (See *Figure 7*).

This was in stark contrast to students' preferred method of completing their

homework based on the data from the Student Homework Completion Survey, in which

students overwhelmingly stated it was easier to find and organize homework using a

# of students

Figure 7. Retrieval Rate of SMLAB: Procedure
Sheet When Asked for It Based on Storage Method
($N = 17$).

digital method (See Figure 5). Despite the earlier results where students stated they

preferred to use the computer, the data from Figure 7 showed they actually perform better

when using a paper method. Meanwhile, Figure 5 showed students wanted to use the

computer for their work. They said that they preferred it and provided multiple reasons as

to why this was the case, based on the data from the Artifact Retrieval Timing Sheet.

Duration of Assignment Retrieval by Students

The most interesting data point, in my opinion, came from timing how long it

took students to retrieve their assignment using the two methods. The average retrieval

time of students who used a paper method was approximately 17 seconds. The average

retrieval time of students who used a digital method was approximately 90 seconds. That translated to students taking 5.3 times longer to retrieve their homework.

Students who were having trouble finding the assignment were cut-off after four minutes. This cut-off time was achieved in multiple instances by several students, and it was always a student that chose the digital method. Those four-minute search times translated to 10% of the 40-minute class periods that were implemented at MBS. In contrast, the longest paper search time was 30 seconds. There was a stark contrast in the fastest retrieval times as well. Digitally, the fastest retrieval was 29 seconds. Using a paper method, the fastest retrieval time was five seconds. For perspective, the fastest digital retriever was one second slower than the slowest paper retriever.

The difference in retrieval results, both in their success rate and in their duration, intrigued me, but I felt the sample sizes from these two instruments were too small and too inconclusive. The results from this phase were responsible for influencing my decision of how to direct Phases Three and Four. These two remaining phases took a focus on the *storage* and *retrieval* stages on the student side of the workflow.

<u>Phase Three: Treatment Applied</u>

Phase Three focused on a digital means of homework storage and retrieval. Data was specifically collected on two separate occasions. On each occasion, students were assigned the Polyatomic Ion Practice Worksheet (See APPENDIX G) or the Polyatomic Ion Transition Metals Practice Worksheet (See APPENDIX H) through the use of Google Classroom and asked to complete it digitally. The first round of data collection began when students were asked to retrieve a homework assignment from the previous night. They started the process by acquiring a computer (either a school-owned computer or

their own personal device) and navigating to the document's location, wherever they had

left it on the Internet. As they moved through the process, I was timing how long it took

each student to reach the final destination of having their homework assignment appear

on screen and making observations on what was going well or not so well, for all the

students as they attempted to bring up their assignment.

For the second instance of data collection, timing and observations did not begin

until after all students had a device sitting in front of them. This was an attempt to

simulate a BYOD environment so that a small analysis could be done to see if the act of

having to go retrieve a computer changed the outcome of the search for students'

homework assignments.

Retrieval of Homework in Non-BYOD Simulation

In this round of data collection, all students (*N*=20) used Google Docs to store

their homework. Data was gathered using the Artifact Retrieval Timing Sheet. Of the

students, 70% were able to retrieve the assignment, 15% were unable to retrieve the

assignment, and 15% did not complete the assignment. As was the case with students

who digitally completed the Separation of a Mixtures Lab procedure homework in Phase

Two, I was always able to confirm whether any student had actually completed the

assignment and was not able to find it, or was just stating they had completed it and

"couldn't find it," using the teacher's side of the Google Classroom platform.

Students cited various reasons as to why they had issues accessing the

assignment. One student stated, "I just kept clicking the spot on Google Classroom where

the assignment is and it was just blank." I had the opportunity to observe this experience

as the student was performing the stated action. The observation that I made was that his

description of what was taking place was accurate. When I accessed the assignment on my side of Google Classroom, I could see that he had completed the assignment. He had come up with and marked the worksheet with several of his own procedural steps So, the question became, where was the actual work that he had produced been stored? Why could I access a completed version of the assignment and he could only access the blank, unfinished version? How would he edit it if he wanted to? What if I was unable to access it on my end? Would his only option be to redo the assignment? We searched together through his Google Drive account (Google's cloud storage service that is used to store student work via Google Classroom) and we could not find it after four minutes.

The two other students that were unable to retrieve their assignment had technical difficulties with the computers they used. One of them had a computer that was not turned on, so was forced to wait for it to do so. The other student's web browser crashed every time she attempted to open Google Docs. She had to swap the computer for a different one. Overall, the retrieval rate of 70% was pretty close to the data collected in Phase Two.

Students were also timed to see how long it took for each of them to access the homework assignment. The average time it took for them to retrieve the assignment was approximately 2 minutes and 11 seconds, with a median time of 1 minute and 47 seconds. This average was about 1.5 times longer compared to the result from Phase Two. When students attempted to access assignments via a digital medium, it appeared as if there were more ways for the assignment retrieval to be sidetracked, i.e., the computer crashing, not being on, and an unreliable cloud service, compared to paper retrievals.

Retrieval of Homework in BYOD Simulation

This round of data collection controlled for the fact that some students accessed computers by walking to the room next door and bringing one back with them to their seat. The reasoning behind this round of data collection was to try to eliminate any confounding variables involved with the walk that students needed to take to acquire one of the computers provided by the school. So, students (*N*=11) were all asked to acquire a device and have one on the desk in front of them before the data collection began.

Of the students in this round of data collection, 73% of them were able to retrieve their assignment and 27% were not. These numbers are fairly similar to the retrieval rate of the non-BYOD round of data. Students' reasoning for not being able to retrieve the assignment were similar to the non-BYOD data. One student ended up with a computer that crashed Google Docs every time an attempt was made to access it. Another student could not find the assignment on Google Drive. The laptop of another student was having difficulties accessing the Internet.

In terms of how long it took students to access the assignment, students averaged 1 minute and 58 seconds, which was 12 seconds faster than the BYOD simulation data of 2 minutes and 10 seconds. The time it took students to walk from the classroom to the area where the computers were kept was not measured; however, the walking distance there and back was 18 meters, so a 12-second difference is reasonable. The fastest retrieval time was 24 seconds and the longest hit the cutoff time of 4 minutes with a median time of 1 minute and 46 seconds. The BYOD median time was only one second faster than the non-BYOD time. After accounting for any extra time that may have introduced error into the data due to students' retrieval of devices, there did not seem to

be any major changes in the overall pattern of retrieving digital assignments. The digital

method proved to be more time consuming and not as effective as a paper method.

All of the metrics measured in this phase had results that were similar to the

digital retrieval data that was collected in Phase Two. This helped reinforce the validity

of those results. In Phase Four, the treatment was not applied. So it was used to help

confirm the pencil and paper results from Phase Two.

<div align="center">Phase Four: Treatment not Applied</div>

In the last phase of research, many of the same metrics were measured as in

Phases Two and Three. In this phase, only non-digital methods of homework storage,

retrieval, and completion were used by students. At the conclusion of class, a paper copy

of a simple Measurements Practice Worksheet (See APPENDIX I) was distributed to all

students (N=21). Students then stored the worksheet via whatever method they typically

used to keep track of worksheets and homework assignments. The following day, data

was collected, using the Artifact Retrieval Timing Sheet for how many students

completed the worksheet, where they were storing it, how many were able to retrieve it,
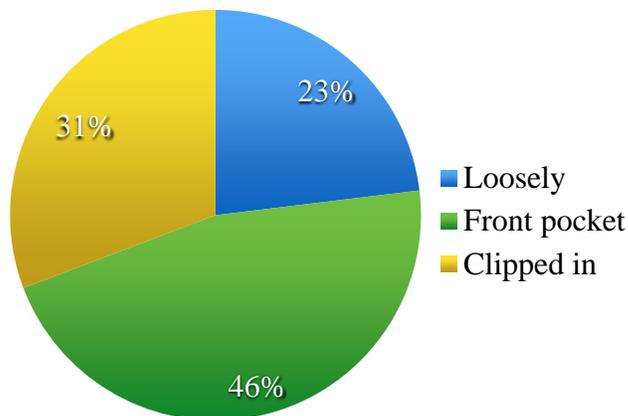
and how long it took them to retrieve it.

Storage

Students chose various methods of storage for the homework assignment.

Twenty-four percent of the students chose to store the assignment loosely in their

backpack, while 10% stored it in their science binder, which stayed in the classroom. The

10% of students that stored the worksheet in their science binders had study hall in the

room next door to the science room. That was a good strategy for them to use to keep

track of the worksheet since that meant the sheet never left the classroom. The less the

sheet moved around campus, the less likely students are to misplace it while searching through a binder for another sheet or artifact at various other times during the school day.

The "assignment binder" system that the school set up for students at the beginning of the school year was the most popular method used (62% of students). The assignment binder system supplied each student with a one-and-a-half-inch binder that was stocked with a typical assignment pad and dividers. Each divider was labeled with one of the primary subjects such as English, math, science, etc. Students then carried this binder with them throughout the day. Since the school set them up with this system, it is what most students defaulted to. Each student may make minor tweaks to help suit his or her own needs.

The students that chose the assignment binder method had the worksheet stored in

Figure 8. Assignment binder storage method (*N*=13).

various ways within the binder (See *Figure 8*). Of the students that chose the assignment binder system, 31% chose to clip the worksheet into the binder rings somewhere within the binder; 23% chose to clip the worksheet behind the science section divider of the binder; while 8% had it clipped to the very front of the binder. Twenty-three percent of

students had the worksheet placed loosely within the binder: three students, two of which

placed it loosely in the very front, while one student placed it loosely behind the divider

section labeled "science." Lastly, six students chose to place the sheet in the front pocket

of the binder. The "front pocket" position was the most common location for the

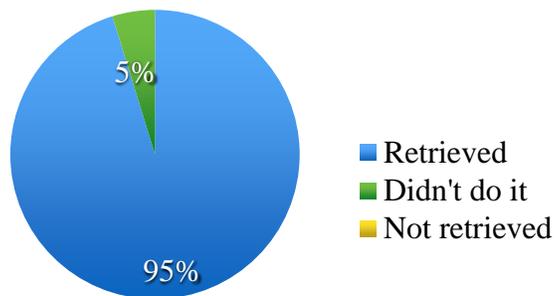worksheet of students who used the assignment binder method.

Students clearly used a very diverse set of methods to store their worksheet.

Unsurprisingly, the most popular method choice also happened to be the fastest. Figure 8

showed that most students, 46%, may actually be choosing to compromise between the

method that is fastest and least organized (loosely shoving the paper in the binder) and

the method that is the most organized, yet took the longest amount of time (clipped in).

The front pocket method was fast and also somewhat securely stored the artifact. Be it

clipped into their binder or loosely somewhere on their person, the most interesting result

of the research came when I analyzed how well they retrieved this assignment from

whatever storage location they chose.

Success Rate of Assignment Retrieval by Students

Of the 21 students that participated in this portion of the research, there was a

95% assignment completion rate, with all but 1 student completing it. Of the 20 that

completed the assignment, 100% were able to retrieve it (See *Figure 9*).

There are several facts that are very impressive about that number. The first fact is that it matches the retrieval rate that was observed in Phase Two by students who chose to complete their SMLAB procedure homework using pencil and paper. The second fact is that the number is 100%, meaning everybody. When contrasted with the retrieval rate of digital methods, that number is 1.5 times better than the rate from Phase Two, and about 1.4 times better than both retrieval rates observed in Phase Three. This means that students were finding and keeping track of their assignments more effectively when compared with a digital method.

This result added validity to the measurement from Phase Two. In addition, it helped bring light to the misconception of "computers help me with my work," based on the Student Homework Completion Survey. No one paper method seemed better than any
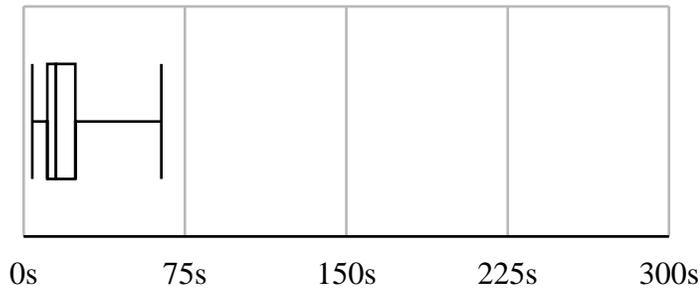

Figure 9. Retrieval rate of
Measurements Practice Worksheet
(*N*=21).

other. In fact, ANY paper method was better than trying to use a computer. The same held true when I analyzed how long it took student to retrieve their assignments.

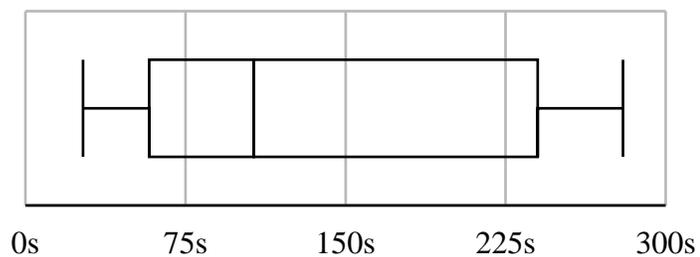Duration of Assignment Retrieval by Students

        The average retrieval time in this phase was 19 seconds with the shortest time

being 4 seconds and the longest time being 1 minute and 4 seconds (See *Figure 10*).

Some interesting patterns emerged when this data was contrasted with the Phase Three

data (See *Figures 11 and 12*). With the exception of the two fastest retrieval times in the

0s   75s   150s   225s   300s

Figure 10. Phase 4 - Paper Retrieval times
(*N*=20).

non-BYOD data of Phase Three and the two longest times in the Phase Four data, all of

the Phase Four times were faster than the non-BYOD times. In other words, the slowest

paper retrievals were faster than the fastest digital retrievals, except for six outliers. When

0s   75s   150s   225s   300s

Figure 11. Phase 3 - Non-BYOD Digital
Retrieval Times (*N*=16).

contrasting the times with the BYOD simulation data, all of the paper retrieval times

were faster than all of the digital retrieval times with the exception of the slowest paper

retrieval and the fastest digital retrieval.

After contrasting the averages, the differences were barely comparable. The

average paper retrieval time was 6.2% and 6.8% faster than the average retrieval times of

the non-BYOD and BYOD simulation, respectively. Nineteen seconds was a mere 0.8%

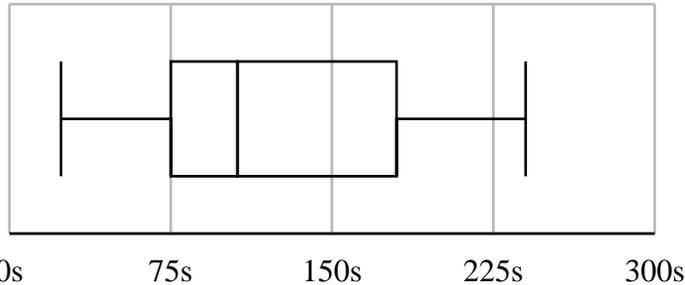of the total class period, compared to some of the 10% of class time that was sometimes

| 0s | 75s | 150s | 225s | 300s |

Figure 12. Phase 3 - BYOD Retrieval
Times (*N*=11).

being observed with the digital methods.

There could be a multitude of reasons for some of these results. Computers were

sometimes finicky and did not work exactly the way they were expected to. Some

students did not exhibit the patience that is sometimes necessary when dealing with

things like the Internet. One of the most common observations I made was that using

pencil and paper was just simpler. The analog method involved less steps and it worked

every time. The biggest hurdle the student's faced was when their pencil tip needed to be

sharpened or when they just didn't have a pencil or a pen. All of the above data across all

four phases seem to be sending the same message; technology can be complicated and

simpler is better.

<u>Data Concerning Me as the Classroom Teacher</u>

How all of this affected me as the teacher is that it gave me some unique insights

into the stages of the workflow I was responsible for, specifically *generating feedback*

and *returning feedback*. Providing feedback while grading student labs in Phase One did not go smoothly. As recorded in my journal, 14 minutes were spent reading and providing feedback for one group's conclusion via the commenting feature on Google Docs. When it was opened the following day to continue work on it, all of the previous day's work had disappeared. In addition, all of the other logs that were being kept in Apple's iCloud of how long it was taking me to grade their conclusions had also disappeared. It left me with the single data point of 14 minutes to grade one lab. These two different services were being used on the same computer at the same time. Both lost the data when I attempted to retrieve it on the following day. That led me to conclude that the issue was probably not with either service, but instead with the computer that was being used or the Internet connection at the time.

Another comment in my journal really stood out. I had to shuffle PDFs around just as much as the students did when trying to manage them. Specifically, this had to do with any of the PDFs that students used to progress through their science fair projects. On November 18th, while grading labs, I recorded, "Downloading the PDFs from Google classroom, into GoodReader, moving them around...this will not be worth the effort." It was very time consuming to get files from where they were to where they needed to be. Once PDFs finally made it to GoodReader, the annotating and returning of PDFs with feedback on them went smoothly. My journal stated, "I am loving this ability to just write on student's work as if it were a physical worksheet! I'm doing all the feedback with just the iPad and Apple Pencil!" The GoodReader software allowed me to email the PDF with generated feedback with the tap of the "manage file" button, and then selecting the

documents, I tapped the "email" button. So, the *generating feedback* and *returning feedback* went pretty smoothly during periods where the treatment was applied.

INTERPRETATION AND CONCLUSION

Primary Question: Completely Digital Workflow's Effect on My Students

Based on a large amount of the data collected, there were many negative impacts on my students that were rooted in the digital workflow. A good portion of that data came from Phase One, where a complete digital workflow was utilized and measurements were attempted at multiple stages within the workflow. There was a mix of results, not always definitive, but there were some clues leading to potential conclusions.

Students were less organized while trying to keep track of digital materials (See *Figure 7*). Or, at the very least, the systems they were trying to use to keep their materials organized did not work well for most of them. Throughout the entire research project, the slowest paper retrieval times consistently beat the fastest digital retrieval times (See *Figures 10, 11* and *12*). There was something difficult to describe about the process. It was just easier for students to be able to visually process an entire document in full, real-world resolution as opposed to trying to search for a document using a file name or a low resolution thumbnail of a document. The visual cue of the paper itself worked well. Less cognitive processing was being used by students when using paper, pencil, and binder methods of organization and accessing their work.

Students had to work harder to produce output (See *Figure 4*). One of the homework assignments students had to work on digitally, asked them to write chemical formulas after being given the name of a compound. Chemical formulas often contain subscripts that many people don't know how to properly type out on the computer. If they

do know how, it can be repeatedly torturous and time consuming. When working with PDFs, students did not have the ability to simply type right on the document. They had to deal with all of the complications that the text boxes were giving them, especially when trying to place the text boxes. These digital challenges caused students to work less efficiently.

After all of this, it should be no surprise that students' frustrations were building pretty quickly. Fortunately, many worked pretty well together to help each other out with the technology issues that arose. Each class usually had at least one student that was technologically adept. For some of the students with writing issues, a computer was simply not the answer.

There are several potential solutions to the challenges that this project resulted in that can be employed next year. One idea would be to educate students on how to execute some of these specific tasks. Highly structured worksheets could help guide and scaffold students as they learn when to use things like subscripts. In addition, text boxes are not necessary on the flexible canvas that is a blank piece of paper. Along with modeling from the teacher, students could learn how to use the digital workflow tools. However, that would be time consuming. The more likely solution is to just have students use paper and pencil.

Secondary Question: The Pros and Cons of the Digital Solutions in the Workflow

The use of Google services clearly did not help these students with the *retrieve work* step of the workflow (See *Figures 7, 11* and *12*). I felt this was the most definitive result of the research. The use of Google Classroom and Google Drive did not help

students organize their work. Students were not able to find their homework as frequently as paper methods and, if they could find it, they took longer to do so.

DocHub proved to be a tool that functioned poorly for students while in any of the *produce output*, *retrieve work*, and *submit work* phases of the workflow (See *Figure 3*). Students became frustrated while trying to create and work within the text boxes that they needed to create. The work was often messy and incomplete. In addition, the work they tried to complete while using this tool was sometimes never submitted. Only the most tech-savvy students were able to navigate this tool. It was just another fragmented piece of a system that was not made to work with its other various pieces.

<u>Secondary Question: How this Affected Me as the Classroom Teacher</u>

Generating feedback and *returning feedback* did not get as much love as some of the other stages of the workflow throughout the research; however, it did provide some of the bright spots for the digital workflow. The AR journal I was keeping contained some wonderful comments describing some of the positive experiences I had as the teacher, which I enjoyed reviewing given the dearth of benefits on the student side. I did not include a deep data analysis on these two stages of the workflow, however, because I feel I did not collect enough data on these stages given the focus that was eventually placed on the student side of the workflow.

My homework inbox remained completely empty throughout Phases One and Three. I felt more organized each time I noted to myself that my desk was not cluttered with extra paper. I also found myself at the copy machine much less frequently than in Phases Two and Four. On the morning of September 22nd, 2015, I wrote, "As I sit at my desk ready for the school day, I can hear somebody in the other room running off copies

as they prepare for theirs...that's a sound I haven't heard much this year…" The clacking

and whirring sounds of that unreliable hunk of plastic and electronic bits were not

missed.

Though the first phase was difficult for students, the workflow on the teacher's

side had some benefits. Towards the end of Phase One, I acquired an iPad Pro with an

Apple Pencil and the two worked together extremely well. All the PDFs that students

struggled to place text boxes on and sometimes did not submit were easily annotated with

qualitative and quantitative feedback. During Phase Three, students created PowerPoint

presentations on element families. I was able to use the iPad Pro, Apple Pencil, and

GoodReader to annotate PDF rubrics while each student was presenting. At the end of the

day, a few simple taps sent the rubric with all of the feedback right to students' email

inbox. These two devices, along with the proper software, worked very well together.

Despite the fact that there were a few "seams" on the teacher's side, I still believe there is

a promising outlook for the future of a digital workflow…for teachers, at least.

VALUE

The value taken away from this research was unquestionably high to me.

Throughout the whole process, little interesting tidbits revealed themselves in the data.

The research helped me start the process of altering the way I think as I consider many of

the approaches I take in the classroom with respect to the use of technology. Technology

can be a useful tool when it is designed with the user in mind and when invisible as

possible. Technology in the 2016 classroom is still a very young and developing field,

especially when considering that the mobile revolution has just barely moved out of

infancy and into adolescence.

I learned there is a lot to consider when thinking about what technological solutions will work for Middlebridge students. As was always suggested to me from other teachers in my school when I first started working with them, keeping it simple is best for these students. This research supported that statement. The use of Google's services and DocHub introduced many extra steps that did nothing but complicate things for the LD students that participated.

I was always a technology-focused person. I liked to think that technology in the classroom could cure what ails many students. But, a lot of the data from this research said otherwise. In physics, power is the ratio of work output over time. Thinking about this equation as an analogy to the work that students and teacher need to complete in the classroom is a helpful way to analyze what works well.

Paper methods simply required far fewer steps to sufficiently organize work and produce output. The majority of students toiled while trying to complete either of those tasks on the computer. For a population of students with executive functioning issues, the digital solutions employed were just not simple and streamlined enough. Once again, the simplest solutions prevailed as the history of problem solving has illustrated time-and-time again. Until a more seamless and simple solution comes along for digitally managing all the steps associated in a classroom workflow, paper has to be the way to go.

As much as paper methods were more successful than digital methods, there were still pockets of data that presented of themselves that suggested there are ways to improve current paper methods. Many students stored paper homework assignments in their binder, but not in the way that the binder was designed to store paper. The Artifact Retrieval Timing Sheet in Phase Four showed that of students that used their assignment

binder for homework storage (See *Figure 8*, *N*=13), 69% of students did not use the rings to clip the assignment in. This could be associated with all sorts of reasons; students could be in a rush and not want to take the time to three-hole punch a piece of paper, students could be lazy, or their executive functioning just does not tell them to do it. In fact, most students, 46%, used the front pocket in their binder, where assignments from all classes got to mingle together. An improvement that could be made to the assignment binder system would be to get rid of the dividers that are placed in there at the beginning of the year and replace them with folders that are clipped into the rings and labeled appropriately with the subject classes they visit throughout the day. This hybrid "clipped in pocket" system would probably be used by many more students since it eliminates the need for three-hole punching while still securing loose sheets within the binder.

Some people just work well with technology and others do not. The same students repeatedly had the least problems with the digital solutions. If some students had more instruction about how to operate the different tasks that computers are programmed to perform, the process of working with a computer would be more successful. For example, one student used her own personal computer to save documents, but had no system for organizing them. If she had been educated on how to use the universal search function of her computer, then maybe it would not have taken her more than two minutes to find her homework. To her credit, however, even people who work well with technology, myself included, can find it to be frustrating. I found the Google ecosystem of apps for classroom to be very fractured and Google Drive, specifically, to be not very easy to navigate. Work completion through digital methods had its advantages on the teacher

side, but will never truly take off until all the little tasks that need to be done have more automation built in.

Improvements and New Directions

The longitudinal nature of this research across several months of the school year was a useful way to control for the amazing diversity of learners at MBS, or any school for that matter. But, there were still opportunities for error. The very first improvement I would make would be to administer a pretest to assess how well all the students work with technology. This improvement would have allowed me to control for students who may not be very proficient with computers.

The varying difficulty of curriculum that was taught across the research period complicated the research. In Phase Three, the treatment was applied and students were working on a unit that included polyatomic ions and ionic compounds. That is some of the most challenging content of the entire school year. In Phase Four, students were practicing measurements and learning about the metric system, an easier unit. It made sense that the homework completion rate decreased during Phase Three because of the more challenging content. A way to control for this in the future would be to attempt to assess difficulty of the worksheets that are being used and try to keep the level of unit complexity more equal across the whole study.

I wondered how results would have been different if students were working in a less or more challenging content area. In science class, students are often practicing very specific skills on a highly structured worksheet, similar to a math worksheet with practice problems. In an English class, students are more frequently presented with a mostly blank

slate with a simple writing prompt. How might results change if all students had to do was respond to a reading from the day's class with a brief paragraph?

I started out on this path of research because I had dreams of eliminating the pile of papers that teachers have to deal with, lug around, and organize, as they review student work. I have received a tiny glimpse of this panacea through the use of Google Classroom and new technologies like iPad Pro paired with an Apple Pencil. But, at what cost does this cause the students? Phase One showed it was difficult for students to produce the types of output that were necessary for me to realize a productive *and* efficient paperless classroom. Phases Three and Four showed that they actually kept track of their work better, and that a classroom will run more smoothly when they do not use the computer.

One way that this research has influenced my teaching style is that I plan to utilize paper as often as possible. All the worksheets, labs, and homework that I distribute will use the paper method. The results from the treatment Phases One and Three showed very few improvements in the efficiency of the way students and teacher work together. But, I still feel in my gut that the reason for this is that the correct solution just does not exist.

One thing I would like to add to my workflow are Automator actions. An Automator action is a computer program that can be written that will automatically execute a set of steps for you. I would like to learn this skill so that one day, I can hopefully implement software solutions that will eliminate the seams. Software solutions are still too fragmented for students to work with efficiently, I would like to start taking steps to move technology in a direction that will work for my students and their teachers.

REFERENCES CITED

Clark, R. (1983). Reconsidering Research on Learning from Media. *Review of Educational Research, 53*(4), 445-459.

Harvel, L. (2006). Convenience Is Not Enough. *Innovative Higher Education, 31*(3), 161-174.

Hendricks, C. (2013). Improving Schools Through Action Research: A Reflective Approach (3rd ed.). New York, NY: Pearson.

Lizarraga, M., Baquedano, M., & Villanueva, O. (2012). Critical Thinking, Executive Functions and Their Potential Relationship. *Thinking Skills And Creativity, 7*(3), 271-279.

Oliver, M. (2013). Learning Technology: Theorising the Tools we Study. *British Journal of Educational Technology, 44*(1), 31-43.

Palis, C. (2012, April 27). Jack Dorsey on 'Charlie Rose': the best tech disappears. *The Huffington Post*. Retrieved from http://www.huffingtonpost.com/2012/04/27/jack-dorsey-charlie-rose_n_1459400.html

Ross, S., Morrison, G., & Lowther, D. (2010). Educational Technology Research Past and Present: Balancing Rigor and Relevance to Impact School Learning. *Contemporary Educational Technology, 1*(1), 17-35.

Song, Y. (2014). "Bring Your Own Device (BYOD)" for seamless science inquiry in a primary school. *Computers & Education, 74*, 50-60.

Wong, L. (2012). A learner-centric view of mobile seamless learning. *British Journal Of Educational Technology*, *43*(1), E19-E23.

APPENDICES

APPENDIX A

TECHNOLOGY UTILIZATION SURVEY

56

Technology Utilization Survey

PARTICIPATION IN THIS RESEARCH IS VOLUNTARY AND PARTICIPATION OR NON-
PARTICIPATION WILL NOT AFFECT A STUDENT'S GRADES OR CLASS STANDING IN ANY WAY

Just be honest about how you think it's going...

* Required

1. **Google Classroom is saving me time as I work through my science fair project** *
   Mark only one oval.

	1	2	3	4	5	
agree	◯	◯	◯	◯	◯	disagree

2. **DocHub has been easy to use** *
   Mark only one oval.

	1	2	3	4	5	
agree	◯	◯	◯	◯	◯	disagree

3. **The hardest part of completing my work while using the computer is...**

   ....

   ....

   ....

   ....

4. **The easiest part of completing my work while using the computer is...**

   ....

   ....

   ....

   ....

5. **Which would you rather use to complete your work?** *
   Mark only one oval.

   ⬭ pencil/pen and paper

   ⬭ computer

Powered by
Google Forms

APPENDIX B

ARTIFACT RETRIEVAL TIMING WORKSHEET

ARTIFACT RETRIEVAL TIMING WORKSHEET

Date	
Time of Day	

Requested Worksheet Title: _____

Worksheet storage method (circle one):   digital   or   paper

Please provide brief student explanations
if assignment not found:

Student	Time	Retrieved?	Storage location

APPENDIX C

STUDENT HOMEWORK COMPLETION SURVEY

Name: _____ Date: _____

PARTICIPATION IN THIS RESEARCH IS VOLUNTARY AND PARTICIPATION OR NON-PARTICIPATION WILL NOT AFFECT A STUDENT'S GRADES OR CLASS STANDING IN ANY WAY

Please answer the below questions as truthfully as possible.

please mark only one oval for each

1) When I receive homework in science class, I prefer to type it up over writing it out by hand

☺	Strongly Agree	Agree	Disagree	Strongly Disagree	☹
	◯	◯	◯	◯	

2) Why did you answer the way you did on question 1?

3) When it is time to hand in my homework for science class, **IT IS EASIER TO FIND MY HOMEWORK** assignment if I wrote it out on paper compared to if it was typed.

☺	Strongly Agree	Agree	Disagree	Strongly Disagree	☹
	◯	◯	◯	◯	

4) Why did you answer the way you did on question 3?

5) Which would you rather use to complete your work?

- ( ) pencil/pen and paper
- ( ) computer

APPENDIX D

IRB EXEMPTION LETTER

INSTITUTIONAL REVIEW BOARD
For the Protection of Human Subjects
FWA 00000165

MONTANA STATE UNIVERSITY

960 Technology Blvd. Room 127
c/o Immunology & Infectious Diseases
Montana State University
Bozeman, MT 59718
Telephone: 406-994-6783
FAX: 406-994-4303
E-mail: cherylj@montana.edu

Chair: Mark Quinn
406-994-5721
mquinn@montana.edu
Administrator:
Cheryl Johnson
406-994-6783
cherylj@montana.edu
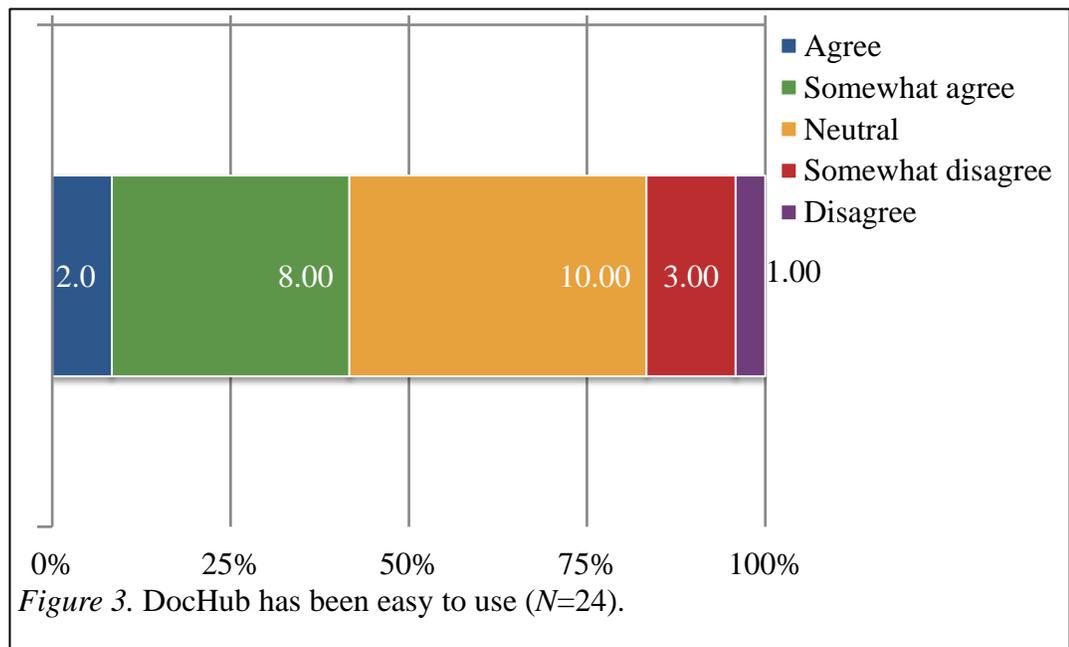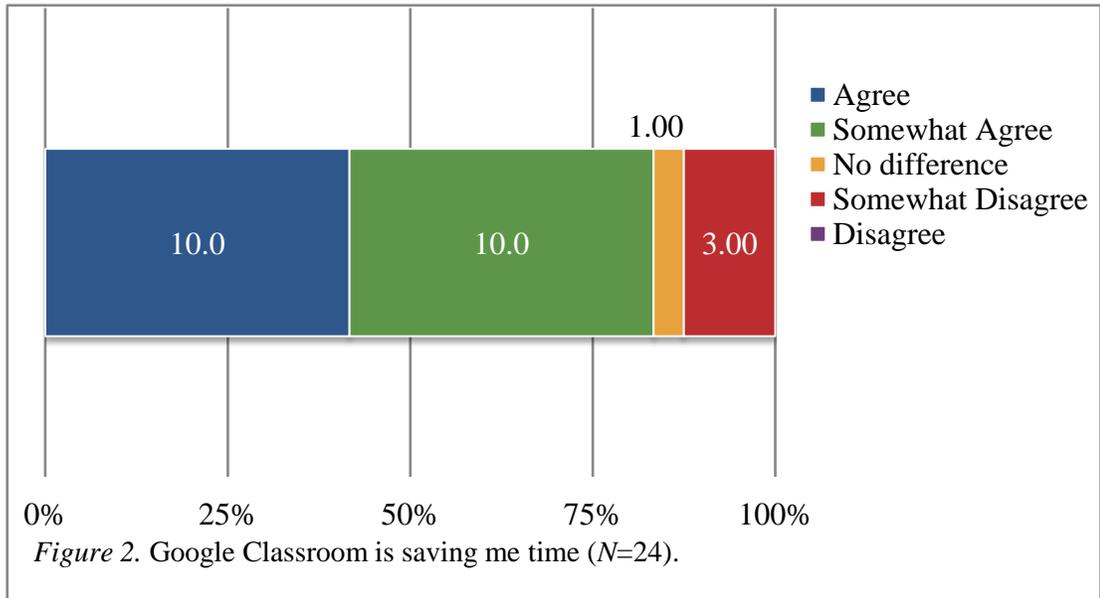
MEMORANDUM
....

TO: Steve Cannici and Walt Woolbaugh

FROM: Mark Quinn *Mark Quinn EJ*

DATE: November 3, 2015

RE: "*The Effects of a Digital learning Environment on the Workflow of Students and Teacher in a Language-based Learning Difference Classroom*" [SC110315-EX]
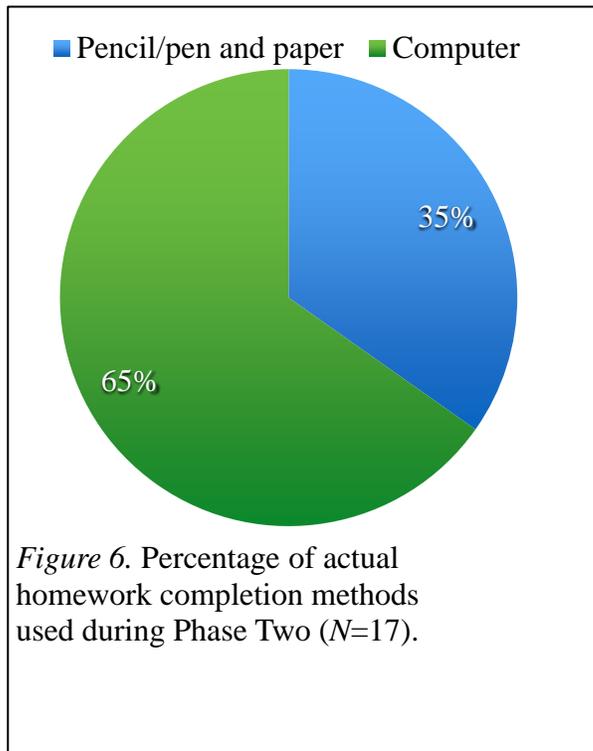
The above research, described in your submission of **November 3, 2015**, is exempt from the requirement of review by the Institutional Review Board in accordance with the Code of Federal regulations, Part 46, section 101. The specific paragraph which applies to your research is:

__X__ (b) (1) Research conducted in established or commonly accepted educational settings, involving normal educational practices such as (i) research on regular and special education instructional strategies, or (ii) research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.

__X__ (b) (2) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior, unless: (i) information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects; and (ii) any disclosure of the human subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability, or be damaging to the subjects' financial standing, employability, or reputation.

_____ (b) (3) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior that is not exempt under paragraph (b)(2) of this section, if: (i) the human subjects are elected or appointed public officials or candidates for public office; or (ii) federal statute(s) without exception that the confidentiality of the personally identifiable information will be maintained throughout the research and thereafter.

_____ (b) (4) Research involving the collection or study of existing data, documents, records, pathological specimens, or diagnostic specimens, if these sources are publicly available, or if the information is recorded by the investigator in such a manner that the subjects cannot be identified, directly or through identifiers linked to the subjects.

_____ (b) (5) Research and demonstration projects, which are conducted by or subject to the approval of department or agency heads, and which are designed to study, evaluate, or otherwise examine: (i) public benefit or service programs; (ii) procedures for obtaining benefits or services under those programs; (iii) possible changes in or alternatives to those programs or procedures; or (iv) possible changes in methods or levels of payment for benefits or services under those programs.

_____ (b) (6) Taste and food quality evaluation and consumer acceptance studies, (i) if wholesome foods without additives are consumed, or (ii) if a food is consumed that contains a food ingredient at or below the level and for a use found to be safe, or agricultural chemical or environmental contaminant at or below the level found to be safe, by the FDA, or approved by the EPA, or the Food Safety and Inspection Service of the USDA.

Although review by the Institutional Review Board is not required for the above research, the Committee will be glad to review it. If you wish a review and committee approval, please submit 3 copies of the usual application form and it will be processed by expedited review.

APPENDIX E

TABLES AND FIGURES

Figure 2. Google Classroom is saving me time (*N*=24).

Figure 3. DocHub has been easy to use (*N*=24).

Figure 6. Percentage of actual homework completion methods used during Phase Two (*N*=17).

APPENDIX F

SEPARATION OF A MIXTURE LAB: PROCEDURE WORKSHEET

Name: _____   Date: _____

Directions: Add 5 steps to the procedure on the right. REMEMBER***The ultimate goal is to separate a mixture of water, salt, and sand. The materials list has been provided on the left as a reminder.

Materials list:

a) sample of mixture
b) funnel
c) filter paper
d) ring stand
e) boiling tube
f) 2 x ring stand clamps
g) 250 ml beaker
h) 500 ml beaker
i) bunsen burner and tubing
j) plastic stirrer

1) Gather all materials
2) Attach a clamp to the ring stand about three fists from the bottom
3) Snugly tighten the clamp so it grasps the boiling tube

4)

5)

6)

7)

8)

APPENDIX G

POLYATOMIC ION PRACTICE WORKSHEET

Directions: Please write the formula for each ionic compound below

1) sodium acetate

2) lithium iodate

3) calcium carbonate

4) potassium permanganate

5) ammonium bromide

6) hydrogen peroxide

7) aluminum phosphate

8) hydrogen hydroxide

9)   aluminum sulfite

10) lithium perchlorate

11) magnesium phosphate

12) sodium hypochlorite

13) ammonium carbonate

14) potassium bisulfate

15) calcium phosphite

16) sodium bicarbonate

APPENDIX H

POLYATOMIC ION TRANSITION METALS PRACTICE WORKSHEET

Directions: Please write the formula for each ionic compound below:

1) iron (II) oxide

2) copper (II) oxide

3) copper (II) chloride

4) iron (III) chloride

5) iron (III) oxide

6) copper (I) oxide

7) lead (II) chlorate

8) lead (IV) nitrate

Name: _____ Date: _____

9) copper (I) sulfide

13) gold (I) bromide

10) iron (II) sulfide

14) tin (IV) bicarbonate

11) tin (II) fluoride

15) mercury (II) phosphate

12) manganese (IV) oxide

16) antimony (III) carbonate

APPENDIX I

MEASUREMENTS PRACTICE WORKSHEET

Directions: Please measure the following lines in <u>centimeters</u>. The place value you measure to will depend on the ruler you use

1.

2.

3.

4.

5.

6.

7.