Mobile Technology in Science Classrooms: Using iPad-enabled Constructivist Learning to Promote Collaborative Problem Solving and Chemistry Learning

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Abstract

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Most recently, there has been a noticeable rise in the push for use of technology in the classroom. The advancement in digital science has increased greatly the capacity to explore animations, models, and interesting apps. that should substantially enhance science cognition. At the same time, there is a great need to increase collaboration in the science classroom. There is a concern that the collaborative experience will be lost with the use of technology in the classroom. This study seeks to explore the use of iPads in conjunction with a constructivist learning approach to promote student collaboration. The participants in this study included two sections of 11th grade AP Chemistry students. Data was generated from different sources such as teacher observations of classroom interactions patterned after Gilles (2004). In order to gauge student perception of working in groups with the use of the iPad, survey questions adapted from Knezek, Mills and Wakefield (2012) and group interviews were used (Galleta, 2013). Learning outcomes were assessed using methods adapted from a study by Lord and Baviskar (2007). Findings of this study showed high percentages of evidence for increased community, productive student group communication, effective feedback through use of the iPads, and value of the interactive apps., but it also showed that students still preferred face-to-face interactions over virtual interactions for certain learning situations. The study showed good content learning outcomes, as well as favorable opinions among the students for the effectiveness of the use of iPads in collaborative settings in the classroom.
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CHAPTER ONE
INTRODUCTION

The growth of new technology has been so rampant that it has become an integral part of our society today (Mistler-Jackson & Songer, 2000). Despite the emergence of this rise in the use of technology, the capability of new technology to transform classroom education has been minimal. Papert (2003) describes this as a transformation of society by the technological advances, and yet the methods and means of teaching have not changed. The core idea is that the world has progressed and improved to an extent that everything around us evolves around technology. Why is it that the use of technology found in the classrooms has not been transformed? The rapid improvement of technology has put an increasing demand on how it is used in the classroom. Teachers are the key to effective technology use, but the lack of professional development has become a major obstacle to the realization of the full potential of technology in the classroom (Teo, 2009). Edelson (2001) comments on the increasing demands faced by science educators as they are encouraged to balance both acquisition of science content and improved motivation for student engagement, as increasingly emphasized by national standards. The traditional way of teaching would not attain the goals that these standards require, and thus teachers as well as their classrooms need to be transformed to meet these changing views of the field of science teaching and learning. This becomes one of the motivations for exploring this thesis topic on how to use technology more effectively in the classroom, especially drawing information from modern perspectives in learning theory and the philosophy of constructivism, and exploring more fully why teachers need to evolve to adapt to this technologically advancing world today.
Background of the Study

As society changes to accept new norms, such as the transformation of communication with the evolution of writing from regular mail to electronic mail, social media has just expanded to render any traditional form of communication out-of-date and irrelevant. The 2010 executive report from the President’s Council of Advisors on Science and Technology justified the increasing demand for the incorporation of technology in education, to prepare the students for a technologically advanced society (Lander & Gates, 2010). With such an increasing demand for technology and virtual experiences, traditional classroom science can no longer motivate students’ interests as it did in the past, before technology has become increasingly a part of nearly every student’s daily life. Educators, therefore, need to evolve and incorporate the rise of technology into the development of classroom tools (Wilson, Goodman, Bradbury, & Gross, 2013).

The push for the integration of technology in classrooms has also engendered its share of problems. Baser and Yildirim (2012) proposed that the funding invested in the transformation of technology in the classroom has not been utilized to its fullest potential. Teachers rarely used the technology readily available in the classroom and some are unwilling to change what they deem as an existing “working” pedagogy. If the current system “works”, why change it? Teachers lack the motivation to add another professional task on their plate. Another barrier mentioned was the lack of teacher training needed to integrate these tools into the classroom. Rodrigues (2007) shared this same conclusion that teachers only began to integrate technology into the classroom when they themselves have become confident in the available technology. Based on a review of the literature, there is evidence that the advantages of incorporating classroom technology outweigh the problems, when educators view the incorporation of technology as something that
stimulates and motivates the students (Henderson & Yeow, 2012). It can also be said that with the advancement of new innovations in technology leading to readily available tablets and mobile devices, increasingly a part of many people’s daily experience, the science classroom must evolve to follow this rise in technology.

The focus in this study of pursuing a more thorough analysis of mobile technology in classrooms stems from the wide availability of the technology along with lack of information on the role, and proper integration, of technology in the classroom setting. Random applications of technology are not an effective use of the resource. Falloon (2013) suggested that one of the most likely failures is directly related to jumping from one “fad to the next;” and this shortcoming, without greater understanding, will result in failure, disappointment and disillusionment.

Motivation behind the Study

The use of technology in the classroom is inevitable. As the push for integration is increasing, there needs to be ways and means to understand how learning has changed with such integration. Studies on technology applications have been met with both successes and difficulties. This study seeks to address that lack of understanding in the social processes behind technology in the science classroom.

My personal experience in dealing with technology in the classroom has always been positive. My personal observation though is that when students use technology, they seem to stop talking to each other as they become focused on just the activity presented. Questions then arise as to how to properly integrate it in the classroom in order to maximize social collaboration as key to science education. The motivation for this study comes from the implementation of a 1:1 iPad program in my school, where this study is situated. As an educator, much of the
problems arise from how to best integrate this technology in the classroom. Although much of the research generated support the use of the iPad, because it is a great tool to encourage cognitive learning, largely due to its capability to stimulate multi-modal forms of learning. These modes are not limited to, but include, virtual, auditory or haptic ways of information processing (Henderson & Yeow, 2012). While acknowledging these strengths; classroom technology can also be limiting; because it admirably supports individualized learning, but not so readily social interaction, at least as frequently used presently in some classrooms. The iPad is built to be a tool with capabilities of interaction, but the apps available have very limited collaboration capabilities and none of them offer real time collaboration capabilities (Murray & Olcese, 2011). It is, therefore, the aim of this study to look into the social aspect of learning that can be achieved with the use of the iPad, especially using a constructivist theoretical context.

**Summary of Key Terms**

This study aims to develop an understanding of the interaction of students with the use of iPads. As is supported by literature, collaborative activities especially in science, is beneficial to learning. To clarify the technical terminology used in this study, some of the key terms are defined.

**Technology:** Technology in science education is usually defined as the application of science knowledge. In a broad context technology can be any tool created from scientific processes that is used for practical applications. In the context of this study, technology will be limited to computer or mobile devices, and the advancements in this particular field.

**Virtual environment:** Virtual environment is defined as a digital space where individuals and groups can interact in a non-physical space. Some examples of this would be when students write comments on blog posts, or communicate with each other in a digital environment.
Social learning: First, in general, learning can be viewed as how individuals assimilate new information based on past experience. This means that social learning can be viewed as how individuals can create and process knowledge based on social interactions. In the classroom this can be seen as students observing and replicating specific tasks and problems while working in a group activity.

Situated cognition: Situated cognition emphasizes learning based on the context in which something is learned. It is the process whereby individuals can construct knowledge with other learners in the context of an activity or process. In the classroom this can be seen as students designing and applying science concepts in experiments and experiencing for themselves the application of specific types of problems covered in class.

Multimedia learning: Multimedia learning encompasses how students interact with different forms of media, such as texts, videos, animations, simulations, and the like. Communication that transpire using multiple media, and the learning that occurs during these communications is the essence of multimedia learning. In the classroom, there are multiple means by which information is delivered. With the use of technology, this can come in the form of PowerPoint, videos, as well as communicating and interacting in both a physical and virtual space.

Collaborative learning: Collaborative learning focuses on the interactions between individuals in either a physical or virtual setting in working towards accomplishing an individual or shared goal.
Research Questions

The main research question for this study is:

*How does the process of blending iPad technology with classroom constructivist learning activities in 11th grade Chemistry classroom influence classroom practice and learning outcomes with respect to the following subquestions:*

1. *What are the dynamics of student interaction in collaborative learning when augmented with the iPad-enabled constructivist learning?*

2. *What are the students’ perceptions of social interaction when the iPad-enabled constructivist learning is used in collaborative group learning in the classroom?*

3. *How do students construct shared understanding of a concept during iPad-enabled constructivist learning, and how does it relate to chemistry learning outcomes?*

This study informs researchers of the greater extent of applicability of iPads in the science classrooms. The grounding on various approaches to, and merits of, iPad use in the classroom has been substantial, but not specific towards encouraging true collaboration in the classroom (Aronin & Floyd, 2013; Henderson & Yeow, 2012; Manuguerra & Petocz, 2011). This study aims to examine the interaction between students and technology, when they are given more autonomy to be collaborative and employ their own ideas in constructing new knowledge, thus to better understand and guide learning as an aid for teachers and curriculum designers. Although much work has been generated around iPads, and their use in the classroom, the literature gap still exists in the role of student collaboration with the use of technology in the classroom (Murray & Olcese, 2011). At least, it is known that there are characteristic ways that students interact with each other when using technology, and there is a need to more fully document and analyze this aspect of education. It is important to explore
individual student’s perceptions in both their interaction individually with technology, as well as in collaborative group settings, and study how the use of collaborative learning with technology affects learning and motivation to participate in the classroom.

**Organization of the Dissertation**

This dissertation is organized into five chapters: 1) Introduction, 2) Review of the Literature, 3) Methodology, 4) Findings and 5) Discussion and Conclusion. The first chapter contains the background of the study, research questions and the motivation behind this study. In the second chapter, the rationale behind the study is followed by a review of pertinent literature which is followed by the purpose of the study. The third chapter contains the methodology used to answer each research question including data collection and analysis. The fourth chapter contains the findings of the study outlined for each research question. Finally, the last chapter contains the discussion for each research question, followed by the conclusion, implications to both science education in general as well as recommendations for further research.
CHAPTER TWO
REVIEW OF THE LITERATURE

The classroom is a unique place where many experiences merge and coexist and is constantly changing. With the introduction of technology, there are many things that compete for the student’s attention (Henderson & Yeow, 2012). In a given class, students interact with the teacher, with their peers, with activities and work set before them; and in addition to this, they interact with technology. Therefore, it is useful to ensure that technology is used in a way that will not distract from student learning but complements the learning that already exists in a regular science classroom. This study involves two central ideas, the cognitive aspect of multimedia learning as well as the social aspect of classroom interactions. Since the iPad is the central focus in this study, previous studies with the use of the iPad will also be addressed in the literature review presented in this chapter.

Rationale for the Study

DeBoer (2000) presents a good overview of the history of science education and how it has changed over time. Science was integrated into the curriculum in the 19th century with the main argument being the fact that it possessed both inductive and deductive reasoning. As science and technology has progressed over the years, the goals for science education have also changed. Educators, researchers and the business community saw the need to improve teaching and learning and the need to increase public literacy levels in the country. Corcoran, Mosher and Rogat (2009) explained that students are not sufficiently immersed in complex tasks that require argumentation or critical thinking skills. Thus, science was boiled down to memorization of a large quantity of facts, which was emphasized in the state standards at that point in time. These goals of attaining a wide range of scientific knowledge, without a deep understanding, defeat the
purpose of scientific literacy. In order to raise national literacy levels, national standards were created with the goal of increased, and more rigorous, deeper cognitive goals for students (Schweingruber, Duschl, & Shouse 2007).

Technology, with its remarkable capacity to enhance information processing and creativity, has progressed to a point that it has changed the way society is viewed, and in some cases how we view our own individual capacities. The way scientists think and generate ideas have progressed, as well, to an extent that the goals of science education have changed over the years. One goal is to move past the traditional use of knowledge recall as the main objective, toward a more coherent integration of critical thinking skills and problem-solving ability. This implies that a traditional understanding of science needs to encompass a skill set that allows students to draw on multiple ideas and empowers them to relate concepts to each other. In setting forth a review of current literature on this process, this chapter is subdivided into two parts. The first is focused on the cognitive theory of multimedia learning; this is the main learning theory involved in the use of technology in understanding how students learn with technology. The second part will focus on different learning theories involved in social interaction in the classroom. This second part is further subdivided into three subsections: 1) social learning, 2) situated cognitive theory, and 3) computer supported collaborative learning. The final part of this chapter focuses on past research with the use of the iPad in the classroom from the perspective of different grade levels and different subject areas.

**Cognitive Theory of Multimedia Learning**

The central perspective guiding this project is a cognitive theory of multimedia learning as proposed by Harp and Mayer (1997). The theory behind multimedia learning is that people learn more deeply from words and pictures than from words alone. A key distinction, however,
is that not all multimedia outlets are equally effective in learning. A particular definition of multimedia instruction that I find most useful in this research is defined by Moreno and Mayer (2005) and denotes communication delivered in any medium, such as pictures in textbooks, videos, animations, simulations, and the like. Cognitive theory of multimedia learning has three main assumptions based upon three different learning theories. Moreover, it is grounded in the idea that the design of multimedia assumes an underlying conception on how people learn.

**First assumption.** The first assumption is called the dual coding theory, which states that humans process information differently depending on the source of the information, either auditory or visual. The conceptualization of information is different for the two different modes of learning. Clark and Paivio (1991) posited the main components of dual coding theory as structures and processes. Mental representations often associate with distinct words or symbols explicitly founded in two types of communication: verbal and nonverbal. Dual coding theory is a multiple coding theory with an emphasis on the difference between verbal and nonverbal. Based on their study, they pointed out “concreteness, imagery, and verbal associative mechanisms lead to concrete models for specific phenomena in many areas of education and at many levels: comprehension, learning and memory, effective instruction, educational assessment, affect, motor skills, and the science and practice of educational psychology” (p. 198).

Moreover, Paivio (1991) summarizes this theory as derived from the study of the role of imagery in learning. As classrooms move into the technological area, students use substantially more nonverbal forms of communication, and is used to that space. This theory encompasses the structural and functional properties of both language and the nonlinguistic world. Both types of communication however come in different modalities – visual, auditory and haptic. The theory
focuses largely on visual imagery, more than any other modalities, and somehow places very little emphasis on the motor-sensory aspect of cognition. In Chemistry, where much of what is to be learned cannot be seen directly, there is a substantial application of models to help the student comprehend the otherwise unobservable phenomena to be learned. The use of visuals such as models, as well as verbal dialogue of problems, allow for multiple modes of learning, which would hopefully help in their learning process.

**Second assumption.** The second assumption is called the cognitive load theory; it states that humans are limited in the amount of information they can process at a specific given time. Forcing the brain to process both modes visual and auditory impacts a great deal on how much information is encoded in the brain. Chandler and Sweller (1991) suggests that this is an effective pedagogical theory as it facilitates learning by directing cognitive resources toward activities that are relevant to learning. They are more focused on actively thinking about the cognitive resources used and how to better create spaces where the resources are maximized.

Moreno and Mayer (2002) postulated that learning outcomes when generated from multiple modalities allow greater chances for cognitive transfer. Students are able to learn more deeply when the visual working memory is not overloaded in having to process both animation and printed text. The advantage to having a good animation and an auditory aspect to learning is to be able to create a space where neither auditory or visual aspects are overloaded and thus engendering a better atmosphere for learning. Baddeley (1992) calls this area of brain functioning as the “working memory” – the area of the brain where temporary storage of information is mobilized and cognitively processed during the performance of cognitive tasks. Because it is capable of dealing with only a given amount of information, he likened it to a computer with a limited capacity CPU.
**Third assumption.** The third, and last, assumption is called the constructivist learning theory, which is based on the principle of active learning; i.e., humans will always try to create coherent order in mental representations that they construct based on personal experience. Based on the idea that meaning is actively constructed, Schnotz, Boeckheler and Grzondziel, (1999) looked at the use of animated pictures, which can be manipulated for active exploratory learning. The combination of texts with pictures is rationalized as a means to visualize information making verbal description more comprehensible. Schnotz, Picard and Henninger, (1994) looked at the consequences of stimulating constructivist learning by using both text and graphics, and noted that it can present some difficulties in the level of integration of knowledge if the graphics are too superficial or abstract (removed from the students’ prior experiences). In order for a greater level of integration to occur, the students must be able to construct mental representations of both text and graphics based on their own experiences.

**Further extensions of the theoretical perspectives.** Based on these theories, Edelson (1997) addresses how technology is successfully integrated into the classroom meeting these requirements through the following: scientific visualization, communication tools and collaboration tools. Moreover, in order for learning to occur using multimedia as a medium there are five relevant processes to be considered. The first is to select relevant words that can be highlighted when presented in the multimedia message. The learner must be able to select which words are relevant to the study as a way to overcome their limited capacity to conceptualize in the auditory process (assumption three). Similar to the first step, and following the same rationale, the learner must be able to select relevant images as well. The third step is to organize the information gathered in which the learner assembles connections among pieces of verbal knowledge. Similar to the third step, this should also be followed by organization of visual
images based on pictorial knowledge. The final and most important step involves making connections between the auditory and visual model. Mayer (2005) presents the idea that once the visual and auditory models of learning have been integrated with prior knowledge, then it is stored in long term memory.

Social Interactions in the Classroom

Social Learning. There are two main proponents in the development of social learning theory, Robert Sears (1951) and Albert Bandura (1969, 1971, 1977, 1989). Sears and Bandura both utilized this theory to understand human behavior. Sears focused mostly on personality and social development. Bandura, on the other hand focused more on the cognitive aspects of social behavior and would be the focus of this study (Grusec, 1992). Bandura’s theory has two different stages, abstraction and integration that occur during social interaction. Abstraction can come in three different forms: models, verbal discussions, and symbols. Models are any representation of the desired behavior; verbal discussions detail any verbal instruction pertaining to the desired behavior; and finally, symbolic, which includes any form of media such as movies, television, or Internet that can stimulate modeling (Grusec, 1992).

According to Bandura (1977), social learning is not driven by inner or external stimulation but continuous social interaction. Learning occurs through observation and reinforcements in these social situations. Observation allows for a large input of complex patterns, which can be processed through the use of modeling (Bandura, 1969). There are four key components that are required for modeling, and each of these components play a role in either the abstraction or integration of the information gained from social interaction (Grusec, 1992). These components are: Attention, Retention, Reproduction, and Motivation as addressed more fully below.
Attention. In order for modeling to occur, the attractiveness of the model plays a role in compelling imitation. In order to learn, there has to be an interpersonal attraction to the actual model (Bandura, 1971). In Chemistry, much of the subject is created using models, the nature of the science deals with things that cannot be seen, and the more the models use apprehensible components familiar to, or previously encountered by, the students, the more likely they will be successful. Unlike other sciences, the main difficulty in Chemistry lies in the fact that concepts often involve microscopic interactions. In order to capture the attention of students, information has to be presented in a way that can enhance their attraction, particularly to allow students to be involved in interaction.

Retention. If an observation is not retained, there would be no relevance to learning if it is not stored in memory. Modeling has two representations, visual and verbal. Most cognitive processes rely on verbal representations and show a greater retention if visual images are accompanied by verbal representations that clearly relate to the visual material (Bandura, 1971). When productive technology is used in the classroom, it allows for both verbal and visual interaction. A particular example is the combination of using visual images and the social interaction that coherently follows it as a way of improving the chances for retention, in accordance with this theory.

Reproduction. The physical reproduction of symbolic representations is dependent on the skills acquired to reproduce the action. Therefore, complex actions are less likely to be successful compared to simple actions (Bandura, 1977).

Motivation. Incentives make a difference. Learning is rarely activated if it is not favorably received. Motivation not only influences the actual performance but the level of integration of what was learned (Bandura, 1977).
Although social cognitive learning was originally designed for behavior, the cognitive aspects of this theory can clearly be applied in learning Chemistry. The key component in this theory is observation and modeling. In Chemistry, many concepts are abstract and are not readily experienced which makes learning very difficult. In order to understand abstract concepts, the use of images and verbal descriptions are very essential. Therefore, social interaction with teachers and peers are very important for the learner in forming their own understanding of concepts. In addition to that, the ability to observe and imitate will play an important part in initiating the learning process. Although the study is limited to the cognitive aspects of Chemistry learning, the sociocultural and developmental affects are also very important, especially in teaching adolescents (e.g. Budwig, Turiel & Zelazo, 2017). While this aspect is not formally expanded in the rationale for this study, the modern perspectives on cognition and learning utilized here are fully consistent with some of the current published findings on the role of affect in classroom learning.

**Constructivist Theory.** The second learning theory is constructivist Theory. Constructivist theory is a philosophical theory focusing on how people learn through active construction of knowledge and its applications; and is usually a representation of teaching strategies that promote student autonomy and active construction of knowledge. This theory is grounded in the assumption that students come to the classroom with their unique experiences and preconceived ideas about science, and the constructivist theory believes in promoting student mobilization of those prior experiences and helping students shape these prior acquired ideas to align with those held by the scientific community. In the classroom, students are encouraged to recall and share their ideas with each other. Simply, the task of talking about or explaining more fully one’s viewpoint encourages students to question their own ideas. Challenging questions
provide for a space for students to understand the flaws in their own ideas, especially when questions are coming from their peers (Colburn, 2000).

The major cognitive theories at that time were social learning theory and the constructivist theory, where learning occurs by doing. This framework, espoused in different ways by Piaget and Bruner, proposed that learning occurred by constructing new knowledge based on prior knowledge. This differs from situated cognition in that it is not limited to learning by action, but can be generated in mental functions and problem-solving (Hill-Jackson, 2007). It is still important, however, to consider problems that are recognized by the learner as authentic and relevant in their lives.

There are four key aspects that need to be considered when looking into contextualization of problems in the classroom: 1) role of context, 2) role of content, 3) role of facilitation, and 4) the role of assessment; and all need to be addressed for an effective use of this theory in education. First is the role of context. Lave (1988) noted that the difference between formal learning and situated learning is the role of context. When a teacher informs a class in a professionally stated or authoritarian way, it is perceived by students, all too often, as truth; it creates a uniform understanding but not a personal understanding. This is the reason why most students cannot transfer what is learned to a non-formal context. If learning is situated in authentic practice, it creates a greater likelihood for transfer of knowledge to real life problem-solving (Choi & Hannafin, 1995).

The second aspect is the role of content. Although context may define the framework, content describes the authenticity. Content should be applied in various ways to promote both general reasoning and specific situated skills. For this to occur there are two methods included within the concept of situated learning. The first method is cognitive apprenticeship as written
by Brown, Collins and Duguid (1989). They emphasized the relationship between content and thought process utilized by experts to perform specific tasks, and further highlight experiential learning. Cognitive apprenticeship offers a method for students to internalize learning and develop self-regulating skills. The second method is anchored instruction. The Cognition and Technology Group at Vanderbilt (1992) emphasizes the importance of authenticity in problem-solving. That is, problems that relate to real-life experiences, or are viewed by the student as relevant to success in life, are more likely to be motivating and engaging, than more abstruse problems.

The third aspect is the role of facilitation. Facilitation provides an environment for students to internalize information. This can assume different forms: modeling, scaffolding, coaching, guiding, collaboration, fading and the use of cognitive tools (Choi & Hannafin, 1995).

Finally, the fourth aspect is the role of assessment. Romer (2002) writes about the role of assessment, and recognizes that how we conceive of assessment practices should be based on how we conceptualize how students learn and retain information. The current methods of assessment are counterproductive in fostering excellent problem-solving skills. Assessments need to reflect multiple perspectives, diversity, and authenticity that can promote higher level thinking skills.

Learning and its role in education play an important role in how students can be motivated to learn. Most often learning is decontextualized, creating limited access to knowledge learned outside of the classroom. In order to aid in the contextualization of problems, situations from the outside world need to be incorporated into the classroom by discussing concepts or phenomena typically observed in real-life situations, as well as link what is learned in the classroom to outside experiences. It creates a personal understanding of what is learned
and allows for internalization of knowledge. In order to create authentic experiences in the 21st century, technology needs to be incorporated, because it is clearly already a part of most students every-day experiences. In this particular study, the focus is largely in iPad technology, so it is important to understand the cognitive theory of multimedia learning as it applies to iPads in the classroom. This should include some perspectives on collaborative learning as presented below, before literature on iPad uses in the classroom are addressed more directly.

**Computer Supported Collaborative Learning.** Strijbos (2016) defines collaborative learning as: “a learning phenomenon where individuals in a social constellation within a physical and/or virtual environment, interact on the same or different aspects of a shared task to accomplish implicit or explicit shared and individual learning goals” (p.302). Cen, Ruta, Powell, Hirsch and Ng (2016) define it as a model that is created by an active population of members who interact by sharing their own experiences and taking on asymmetrical roles. Since the introduction of computers, collaborative learning has been studied to determine how group processes affect individual and group cognition. The main two foci in this form of research is first the understanding of practice and the second as the determination of conditions to create good collaborative learning. In order to take this further, computer-supported collaborative learning, adds on the technology component in the interaction within a group. Technology is the main means of communication or common resource in their view of collaboration.

Popov (2013) described computer supported collaborative learning as an environment that enhances collaboration between students to improve learning processes. Zhan, Fong, Mei and Liang (2015) describe this as a means for students to interact in such a way as to increase problem-solving, decision-making and collaboration skills through the means of co-creating knowledge using collaborative activities. Arama, Macedo, Bendella and Santos (2015) have
taken this a step further and added on mobility in the context of collaboration. Using the means of mobile technology instead of computers allow for construction of knowledge collaboratively anywhere, any time and in any context.

Their paper suggests that one of the key factors in the success or failure of a collaborative learning experience is the learning groups. Central to this key factor in collaborative learning are the types of learners that are paired within the group, including the ability of each learner, as well as the contribution that each learner brings to the group as a whole. The grouping process should include personal characteristics of the learner, such as age, gender, skill, cultures, etc. as well as preferences related to the learning context. Slotta, Tissenbaum and Lui (2013) present relevant information for this study about the use of a pedagogical model known as Knowledge Community and Inquiry, where technology is used in collaborative knowledge construction in the science classroom. Each of the above research papers suggests improvement in the skills of individual students through the use of technology in collaboration.

iPad Technology

Nykvist (2012) describes the emergence and enthusiastic adoption of handheld devices in education, yet very little research on how to effectively use these devices. The iPads were released in March 2010 and have been advertised as tools that can transform education. Miller (2012) describes the iPad as a multipurpose computing device. It has the ability to display readable texts, which can decrease the cost of textbooks. It has the capability of web browsing and visual interfaces that include multimedia and collaborative elements. Apple Inc. (2015) advertises the iPad as a tool to create “hands-on, customizable learning experiences.” It is a technology with the ability of making learning personalized as it can create a variety of methods to access the same material.
Pilgrim, Bledsoe and Reily (2012) describe the iPad as a device that serves as a personal computer with access to the Internet. Its mobility allows for greater engagement in activities during times that might otherwise be wasted. It is customizable with the different apps that are downloaded and has the capability to access digital resources that would otherwise be difficult with a physical textbook. Clark and Luckin (2013) describes this technology as something that can support seamless learning, motivate and engage students to be interested in content for longer periods of time, and allows for interaction by making communication easier. Finally, Hargis, Cavanaugh, Kamali and Soto (2013) describe the iPad as a technology that is “personal, extensible, and a cognitive toolbox for authentic, active learning centered on interaction among students, faculty members, and community experts” (p. 46). Although interaction was a key phrase used by Hargis et al., there was no mention of how collaboration was achieved apart from ease of access to course page, and ability to communicate with teachers.

The potential of this technology is not being put to full use. Harp and Mayer (2005) stress the importance of creating multiple modes of learning to allow greater chances of cognitive transfer. Culen and Gasparini (2011) describe the potential for iPads in situated learning, and postulating that the iPads create a shorter path to learning with an easy to use interface. One of the interesting things about the Culen and Gasparini paper was that although they would not support the integration of the iPads for the undergraduate studies of geology, they saw great success with the implementation in primary school.

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iPad Technology in Education. Manuguerra and Petocz (2011) write about the use of iPads in tertiary education and their main use of the iPad is as a higher-level presentation and communication tool. Communication is facilitated through a message board where students can leave comments and requests. The greatest use is the videos where students can watch lectures.
at home without having to come to school to attend class. Hofstein et al. (2013) have proposed the idea of creating a paperless classroom. There was not a lot of emphasis on the ability of the iPad to do things that was they could not otherwise do in a classroom. Several apps were used to account for the fact that one app cannot have all the functionalities needed in the course. They did praise the iPad for its ability to replace the notebook as they can zoom in, annotate documents, and create handouts that would normally be impossible with traditional note taking.

The more important role fit for an undergraduate Chemistry class is the use of reference databases. The iPad can provide access to American Chemical Society (ACS) and Royal Society of Chemistry (RSC) mobile for access to scientific papers or journals as well as presentation tools that would allow for real time file transfers and data sharing. These functionalities are important for colleges, but not necessarily for secondary and primary education. The focus of this study is on secondary education, so some examples of this kind of research is reviewed in the next paragraph. Henderson and Yeow (2012) discussed the multi-touch capabilities as the most important feature in the primary classroom as it allows more than one student to engage with one iPad at the same time. Aronin and Floyd (2013) review the use of the iPad in a preschool classroom and noted that motivation and durability are the most important aspects of the iPads in their classrooms.

As the focus of this study is on secondary education, an example on the use of the iPads in secondary school is the work of Berson, Berson and Manfra (2012) where the use of the iPad was used in social studies class. Their main use of the iPad is to generate authentic learning for students, making use of visual stimulations and online resources to create a clearer picture of topics covered in class. It is clear that the needs of different grade levels vary greatly and the
functionalities preferred in one age group could not be transferred to another age group. It is the appropriation and application of the iPads that make a great difference in how it is used.

**Applications (Apps) for Learning.** The device hardware is what makes it a powerful tool, but what can differentiate its functionalities are the apps. Murray and Olcese (2011) propose four categories for the use of apps: 1) tutor; 2) explore; 3) tool; and 4) communicate. The choice of apps is very important as they dictate the role of its use in the classroom. The apps have the ability to take a powerful hardware and its capabilities and focus it on one particular function. Apps create a specific, targeted functions utilizing all the features that are available in the iPad such as: multitouch interface, multi-touch display (more than one user can touch the display), gestures such as pinch, flick or stretch and screen rotation. The power of apps is that they are able to take abstract concepts as is very common in Chemistry, and break it down into graphics, visual stimulation, videos, animations, all incorporated in one button on the iPad screen.

Schnotz, Picard, and Henninger, (1994) cautioned the random use of superficial graphics. If graphics and text do not blend successfully, it can present some difficulties in the level of integration of knowledge. In order for a greater level of integration to occur, the students must be able to construct mental representations of both text and graphics based on their own experiences, which shows the importance of situated learning. Their own experiences and shared experiences can aid in the construction of mental representations thus proving the value of collaboration. In this study of the 315 applications considered, only 15 fall under the category of collaboration, and none of these applications allow for real time collaboration. These limitations for the use of the apps are precisely tied to the research questions in this study.
An interesting study on different apps by Falloon (2013) concluded that the thoughtful engagement of the iPad can produce productive learning. The apps were able to:

- communicate learning objectives in ways students can understand
- provide smooth and distraction free pathways towards achieving goals
- include accessible and understandable instructions and teaching elements
- incorporate formative, and corrective feedback
- combine an appropriate blend of game, practice and learning components
- provide interaction parameters matched to the learning characteristics of the target student group

**Limitations in the use of iPads and Apps in Learning**

There is no technology that can in itself influence learning; it is dependent on the use of the technology. The iPads are a great tool but they also present limitations and problems with use, which have been echoed in other research papers as well (Peluso, 2012). The challenge faced in the lack of technical support when apps break down or interruptions to Internet connectivity, cause frustration for both teachers and students. One of the most common frustrations is that no two apps can be opened at the same time so multitasking on the iPad is not possible. Loading PowerPoint slides takes time and downloading files would also take time.

There is also a lack of Flash support that can create problems when viewing different forms of multimedia, which is said to be one of the iPad’s strengths. There are instances when the device stops working or apps will crash and students lose all the work they have saved with no means of retrieval. Technical difficulties will impede the work that they do in the classroom. In addition to this is the durability of the devices, that if used in every single class, they may not last until they graduate high school. iPads with cracked screens or that have slowed down may
decrease the motivation and engagement factor and can be an excuse for students to stop participating in class.

There are also many different types of learners that for some, the visual stimulation or the wide capabilities available can be too distracting, thus impeding rather than engaging students in learning. As this study hopes to expand on how social aspects of learning affects student learning with the use of the iPad, it is only limited to the actual participation of the students. Each school year will bring a different set of learners and would require different ways to engage students. The iPads are not meant to be a perfect tool to guarantee student participation but would hopefully be a tool that can encourage social interaction.

**Purpose of the Study**

Social learning theory relates to the theory of constructivism through its observational nature; whereas, it differs from constructivism because constructivism has an interaction piece with the surrounding environment. Constructivism is largely based on creating meaning with experiences through action. Social constructivism takes this one step further and creates this collaborative process in learning. Situated cognition shares the theory of interacting with the environment as well but is specific toward the context of interaction. Each person can interact with the same environment but the learning is situated in his or her own personal experiences.

iPads can support seamless learning allowing students to learn things from formal settings to informal settings bringing together personal and social experiences. It is designed to motivate and engage students and enhances learning in ways that was previously impossible. The mobility of the iPads presents a wider range of activities and can promote independent learning.
In a broader scope of science education, questions always arise about how to integrate technology and how to keep up with the technologically advancing world to ensure that education is not left too far behind. More importantly as science educators, what is our role in this rising trend of technology reform? The role of the educator in light of these theories is to create an environment for transfer of knowledge to occur. In social constructivism, creating a shared understanding of particular phenomena helps to transfer knowledge. In terms of situated cognition, knowledge is transferred through the linking of activity to prior understanding. The role of technology therefore is to assist the educator in creating such an environment that motivates students to participate in collaborative learning.
CHAPTER 3
METHODOLOGY

Research Approach

This chapter presents the methods used in the study. This research study used mixed methods. Mixed methods was chosen because it allowed for an integration of both quantitative and qualitative research data in a research study. In this particular approach, qualitative approaches can be used to explain quantitative database and thus provide a more complete understanding to the research problem than one approach alone. (Creswell, 2014).

Quantitative Methods. The quantitative portion of the study involved a momentary time-sampling protocol, where specific behaviors were observed for each student as a function of time (Appendix A). The observation was coded from 1 to 4 (1 = Cooperative behavior; 2 = Noncooperative behavior; 3 = Individual task-oriented behavior; and 4 = Individual non-task behavior and confusion). There was a total of four in-class observations for both Class 1 and Class 2.

The quantitative data included a five-point Likert scale survey (1 = strongly disagree to 5 = strongly agree) and consisted of 15 questions. The survey looked at student perceptions on the use of the iPad in classroom activities. Data generated also included assessments which were coded according to six levels of Bloom’s Taxonomy from (1 = Knowledge; 2 = Comprehension; 3 = Application; 4 = Analysis; 5 = Synthesis and 6 = Evaluation). There were a total of two quizzes and one test in the duration of the study that was coded according to the labels listed above.

Qualitative Methods. The qualitative portion of the study involved interview of the two teachers who came in to observe the classroom. Questions for the interview is located in
Appendix B. Other qualitative data included the open-ended Students’ Perception Survey Post-
Questions (Appendix D) where students were given a space to answer questions based on the
Likert-scale survey. Group focus interviews (Appendix H) was also used to generate a better
understanding of how the students felt about the use of iPads in a collaborative setting in the
science classroom.

Research Context and Participants

This study was conducted in an independent school in Manhattan. It is a college
preparatory school founded in 1888 catered to all boys from Pre-K to 12th grade. The school is
predominantly white, with Asians, African Americans, and Hispanics/Latinos in the minority.
The school promotes a traditional curriculum with flexibility in teaching content as well as rigor
in academic standards.

This study focused on two units in the chemistry curriculum in the 11th grade classroom.
The group, similar to the race distribution in the school is also predominantly white with Asians
and Latinos in the minority. There were no African Americans in this particular group as there
was only one African American in that particular grade and he was in the Physics track instead
of the Chemistry track. This group was chosen due to the distribution of the two sections.
Sectioning in the school is usually tracked by ability where one section can be labeled an A
section and the other the B section. This group had a unique sectioning where it was not tracked
by skill so two equal sections were created. There was a total of 22 students in the class,
distributed in two sections, divided according to how the class can fit into their schedule. There
were ten 11th grade students in each section, with an addition of two 12th graders in one section.
The course taught in 11th grade is Advanced Chemistry. A prerequisite for entering this course is
a grade of at least a B in the Introductory Chemistry course taken in 10th grade. These students
started using iPads in 9th grade when the 1:1 iPad program started at this school.

The classroom was set-up with four large lab tables where four groups would naturally form during class discussion. The composition of the groups was fairly constant, because students naturally gravitate toward a table with people they feel comfortable working with. The class was divided into four main groups. Groupings were generated based on the understanding of each individual student as well as their personalities in group work. Groups were made paying attention to both social interaction as well as a good distribution of abilities.

In this particular class, students were prepping for the AP Chemistry exam. The types of problems and questions they were asked were multi-step problems, which required a solid foundation in conceptual understanding as well as ability to break down data and analyze real chemistry problems. Much of the questions they encountered would relate to lab experiments or scientific-based scenarios that they had to analyze in order to generate a solution.

**Role of Researcher**

I have been teaching at this particular school for five years. I have taught some of these students beginning in 8th grade. For all of the students, I have taught them at least once before and for the majority of them, this would be the third time I would have had them in the classroom. The students I have taught in 8th grade learned the basic concepts of Physics and Chemistry, an introductory course to high school science. I have taught all of them Introductory Chemistry the previous year and thus this class would be my third encounter with these students. A great majority of these students are also part of clubs and activities that I proctor, including Science Bowl or Science Olympiad. My well-established pattern of interactions with these students could contribute to their ease in responding and participation in the classroom.
**Data Collection**

The primary data source for this study were classroom observations, surveys, interviews and student artifacts. Each student had their individual iPad in 9th grade and is kept by the student in the duration of his time at school and is maintained by the technology department in the school. As each student had their own iPad, there was a method of recording everything that happened on their screen for the duration of the study. Much of the interactions with technology in the classroom were apps that have been downloaded into the students’ iPads at the start of the school year by the technology department. In order to justify each type of data source and how it would be used, the particular apps used in this study are described below.

**App selection.** The apps chosen for this study were apps that can give students a way of documenting their thoughts and problem-solving processes as well as interactive ways of generating formative assessments of their current understanding of what had been learned. There were three apps that were used for this particular purpose: Notability, SeeSaw and Kahoot!

Notability functions like a blank canvass – it is a means in which students could take notes and have it save directly to Google Drive. They used it to answer handouts as well as write down solutions to problems. Since problem-solving was heavily emphasized in this course, the ability to be able to write solutions to problems at the same time record their solutions to particular problems makes this app very useful. This app was used in conjunction with AirPlay. AirPlay is a function available in all iPads that allow the students to be able to cast their screen onto another Apple device such as a board or a laptop. Students were able to write their solutions to problems on their iPads and at the same time project it onto the board.
SeeSaw is a digital portfolio used to generate new ideas about a particular unit. Some past examples of blog posts were “Design a titration equipment to allow for more precision control in analyzing unknowns to fix over titration.” Students posted designs of different types of devices they could add to a common buret to increase the precision of the experiment. Each unit had a centralized question that they could choose to explore. These posts were not graded, neither were they required. Their only motivation was to generate participation points, which did not count towards their final grade.

Kahoot! is an online interactive multiple-choice quiz. It was mostly used in class to practice multiple-choice questions. Since the AP is composed of a two-part assessment: multiple-choice and free response, students were able to practice free response assessments with the use of Notability, and Kahoot! allowed them to practice multiple-choice problems. This was a game with a time limit per question, but allowed the teacher to control the pace at which questions are asked and the possibility of stopping the game at any point in class. It also gave the teacher an option of discussing each question in between rounds. After the end of each question, a screen showed the distribution of answers (how many people selected choice 1 vs 2, 3 or 4) in a bar graph format. This data provided instant feedback on a particular concept that may need more work.
Figure 3.3. Kahoot! app

**Data Recording.** The study spanned one month, and included three units of Chemistry. Classes met four times a week, with three lab periods in a two-week cycle. Lab periods are 72 minutes long, whereas regular class periods are 45 minutes long. The school’s schedule works on a four-day two-week cycle. The data was recorded during the Spring Semester; therefore, the content of the study was limited to the topics covered during the duration of the study in that semester. The topics covered in this study were: (1) Equilibrium, (2) Acids and Bases, and (3) Buffers and Salt Equilibria.

**Teacher Observations of Group Activity.** The protocol for group observation was patterned after Gillies’ (2004) junior high school study of small-group, cooperative learning. An observation schedule developed in the Gillies paper, based on Gillies and Ashman (1996), was used in this study as a guide for observations in group settings. Gillies and Ashman created a Four Behavior State categorical system to study student behavior in groups. They employed momentary time sampling to record these sessions. Thirty-second time intervals were used to observe and record group members over a period of 30 minutes. In this system, if a behavior is observed within the time interval it is recorded for the particular student. Two colleagues volunteered to observe the class and generated the data for the first observation schedule. Each class was observed four different times based on their availability. The observers were coding the observation based on four different categories. The four categories include:
Cooperative behavior – defined a task-oriented group behavior. Were the students listening to each other? Working together? On-task? Were they talking to each other?

Noncooperative behavior – defined as competitive behaviors. Were the students talking over each other? Were they working against a common goal? Were they off-task? Were they discussing things not relevant to the problem at hand?

Individual task-oriented behavior – defined as working alone on task.

Individual non-task behavior and confusion – defined as not participating in group activities and not working individually.

Each observer was given an overview of the rationale for the coding scheme and its objectives, including clarifying definitions of key terms, such as what should be classified as cooperative behavior, and what is classified as noncooperative behavior. The descriptions given to the observers are similar to the questions written and defined above. Each observer was given an opportunity to visit a class to practice the coding before the study started. The observers were able to walk around in the back of the classroom to both see each student’s individual iPad screen, as well as hear each individual conversation while the class was in progress.

Classroom Setting. A particular unit in class usually started off with a lecture; this created a general outline of what was to be covered in a chapter of the textbook. A typical lecture class usually contained a PowerPoint presentation as well as an open class discussion for each main topic covered. For instance, if the chapter was dealing with Thermodynamics, discussions revolved around heat, and what that meant in both the molecular level as well as in terms of chemical reactions. Typical questions would revolve around: “Why do some types of
reactions release more energy than other types of reactions? What are possible applications that you can see, that can utilize the concepts around endothermic and exothermic reactions?”

Depending on how familiar a particular topic is, we could spend one or two class periods on a particular topic.

After the introduction to the main concepts involved in class, the group activities began. There is usually one day of lecture, typically half of the 45-minute class period, and the rest of the week is devoted to classroom group activities. Typically, they formed their own groups and started answering AP level problems. Most of the class was spent analyzing the problem, bouncing off ideas either within the group or across the room. Most of the time, students worked at their tables, and conferred with students at other tables once the other tables had reached a solution to their particular problem. Students at each table typically projected their work on the board as soon as they were finished with one step of the problem. Most often each group was asked to “host” a problem, which meant that they were tasked to discuss the problem to completion. Students who could not start a problem usually waited for a step to be posted by one of the groups; and as soon as they could analyze and process what was posted they would take that and run with their own solution of the problem. The class spent one or two days solving these types of problems.
After the classroom problem-solving tasks were completed, there was usually a laboratory component to the unit. Students used the iPad as a lab manual where they could record their data as well as document images in Notability, and shared it with their group as the lab progresses. The laboratory component was usually a designed lab where students were responsible for figuring out parts of the procedure based on their knowledge of the topic at hand. For instance, parts of the procedure would say “Add 50 mL of 0.10 M of NaOH into a cup” or “Design a constant pressure calorimeter.” These would require students to design part of the procedure because they have to figure out how to prepare their own solution, what type of glassware to use, and they have freedom in their experiment to decide what they want to do and how they want to create their solution. Most labs had unknowns that they have to analyze at the end. An example was in the acid-base titration lab, each group was given an unknown concentration acid, and it is their task to figure out the concentration based on titration. Another example was in redox titrations, the groups had to create a cost-benefit analysis of two different
bleaches, a generic brand and a famous brand. Each group had to come up with their own titrations and create their own analysis based on the results of their experiment. At the end of the lab, there is usually a blog post question posted on SeeSaw relating to the experiment where students were asked to design or explore a procedure or reaction further.

![Figure 3.5. Seesaw blogpost example](image)

The last day of the unit was usually devoted to answering multiple-choice questions. In this case, students typically use Kahoot! This app allowed for class discussions in between questions and allow for student feedback as well as teacher feedback for a particular question. For instance, if only one or two students got the correct answer, there may be an underlying alternative conception that would require an open discussion to establish what was known and what was not known and how each concept may or may not be related to each other. After this, students were assigned an in-class assessment covering the entire unit.
Data Analysis

Teacher Observations on Group Activity. The observation protocol was used to establish evidence of verbal interaction as well as group behavior in the classroom. It generated an overview of student interactions with the use of the iPad. The observation protocol, located in Appendix A, was used to tally the data and see the difference between students working individually and students working in groups, as well as students who were on task vs. off-task. After the teacher observations, each teacher observer was interviewed for their observations on how group activities worked or did not work with the use of the iPad (Appendix B).

Learning Outcomes. Learning outcomes were measured using criterion categories from Bloom’s taxonomy, with question stems patterned after Lord and Baviskar (2007). The following list provides specific examples.

1 – Knowledge (Students are expected to be able to recall memorized information). Typical AP level questions ask for students to identify, name, describe, list or label. Some examples of past AP questions are:

“Identify the oxidizing agent”

“Label the cathode and the anode in the electrochemical cell”
“Define electron affinity”

“What is the hybridization of the central atom in NH₃”

2 – Comprehension (Students are expected to summarize in their own words). Typical AP level questions ask for students to describe, explain, interpret, distinguish, compare and predict. Some examples of past AP questions are:

“If an element Q were to be discovered and have the atomic number of 119, predict the charge of the ion that Q would create”

“Describe the trend of ionization as you move across a period in the periodic table”

“Would the substance be acidic or basic? Why?”

3 – Application (Students are expected to be able to apply rules or concepts to a problem). Typical AP level questions would ask students to calculate, solve, construct, classify, or illustrate. Some past AP questions are:

“Calculate the amount of energy released in the following reaction”

“Calculate the pH of the following acid weak acid dissociation”

4 – Analysis (Students are expected to be able to break concepts into parts and analyze how different parts are related to one another). Although the AP does emphasize breaking concepts apart, much of the expectation does not lie in the how the question is stated but the expectation that students should be able to read a problem and create a way to solve the problem by breaking down their understanding of a particular concept.

5 – Synthesis (Students are expected to create something new from different concepts). Typical AP level questions would ask students to propose or devise an outline based on the information given. Some examples from past AP questions are:
“Based on the information above, describe a method to determine what the unknown compound could be”

“Based on the data gathered, what could have introduced an error in the experiment, and devise a method to fix the error”

6 – Evaluation (Students are expected to evaluate, argue in support/against an idea). Typical AP level questions would ask students to assess and justify statements. Most AP questions ask students to justify their answer at the end of a lower level Bloom’s taxonomy question. For instance, students could be asked to categorize a compound, then asked to predict whether this substance would be soluble under specific conditions then asked to justify their claim. In this particular question, it covered comprehension, and evaluation at the same time.

Student Perceptions. A survey (Appendix C) patterned after Knezek, Mills and Wakefield (2012) was used to determine student perceptions both of collaborative group learning as well as of the use of the iPad in the classroom. Ideas about how the iPad was used can be further explored in terms of which works best for students and if it is applicable to other subjects as well. Based on their responses to the survey questions, students were asked to respond to some post-survey questions. Sample questions are attached in Appendix D. Students were given a choice to answer any or all of the post-survey questions to explore further the students’ perceptions of the experiences using the iPad in the classroom. Finally, a semi-structured group interview protocol patterned after Galletta (2013) was added to gain further information about the students’ academic performance and the role the iPad played in social collaboration. The starting open interview questions are included in Appendix H.
Reliability and Validity

In terms of reliability and validity, this research is limited to the scope of a 11th grade single gender classroom. This research, therefore, has limited generalizability at this stage and would require much more replication for external validity. As far as internal validity is concerned, the time frame of this project history and maturation would be of no concern as the study is based on two units in a class. Face validity was estimated through the surveys and interviews as a source of feedback. There were multiple sources for the data that were used as sources of reliability in the form of triangulation of the data generated. This included class artifacts, the class observations, and the interviews to obtain a better picture or snapshot of what the students were thinking at a particular moment in time. One of the biggest concerns I had to address was that I acted as both researcher and teacher at the same time. These students were students that I have taught before in 8th grade. The class I teach has an open book policy, which means when the students request it, they have an opportunity to see all of their grades and so there is no question that any part of the research would affect their grades, nor did they have a feeling that they need to change their answers or adapt it to the research to get a better standing in class. These students have been very open in the past as to the positive and negative aspects of class, knowing full well that I have their best intentions in mind, and they do have the comfort of being honest and open about things they like or dislike about the class. Other teachers were invited to observe the classroom and generate feedback on how technology is used in the classroom. This was highly important to ensure the reliability of the study despite my familiarity with the students. In order to protect the privacy of the students, pseudonyms were used whenever data was recorded.
Research Questions

The overall research question: “How does the process of blending iPad technology with classroom constructivist learning activities in 11th grade Chemistry classroom influence classroom practice and learning outcomes?” is divided into three specific research sub-questions. Each research sub-question and related data collection methods are presented in Table 3.1.

Table 3.1. Summary of research sub-questions and data collection methods

<table>
<thead>
<tr>
<th></th>
<th>What are the dynamics of student interaction in collaborative learning when augmented with the iPad-enabled constructivist learning?</th>
<th>What are the students’ perceptions of social interaction when the iPad-enabled constructivist learning is used to promote collaborative learning in the classroom?</th>
<th>How do students develop shared understandings of a concept during iPad-enabled constructivist learning, and how does it relate to chemistry learning outcomes?</th>
</tr>
</thead>
</table>
| 1.) | Teacher observations of Group Activity (Appendix A)  
Teacher Perception Questions (Appendix B) | Students’ Perception Survey (Appendix C)  
Students’ Perception Survey Post-Questions (Appendix D) | Teacher Perception Questions (Appendix B)  
Breakdown of Bloom’s taxonomy  
Quizzes (Appendix E & F)  
Test (Appendix G)  
Group Interviews (Appendix H) |

In order to answer the main research question, three research sub-questions were also addressed. For the first question: *What are the dynamics of student interaction in collaborative learning when augmented with the iPad-enabled constructivist learning?* Dynamics as observed in a classroom was seen in different forms. This study used group observations, the observation protocol provided evidence of whether students were on-task or off-task. Of the students on task, how many were working together in a group, and how many of them were working individually? The record of what they wrote to each other as well as what they said were
recorded in their notes app to allow for a way to revisit each type of interaction in the classroom. In addition to this, teachers who observed the classroom were asked for their perceptions on the participation they observed in the classroom.

The second question: What is the students’ perception of social interaction when the iPad-enabled constructivist learning is used to promote collaborative group learning in the classroom? The data from the survey, which were expanded by survey questions, provided greater quality and depth in analyzing the student experience when using the iPad in the classroom. The survey generated an overall understanding of what was happening in the classroom, and the post-survey questions gave added information as to what the students perceived and how they explained the percepts in relation to the learning experience. Appendix C was used as a guide for the survey questions, which was expanded to elicit additional information, depending on the answers of the students. In order to generate more information a post-survey question was added for students to expand their choice, these question prompts could be found in Appendix D.

The last question: How do students construct shared understanding of a concept during iPad-enabled constructivist learning, and how does it relate to chemistry learning outcomes? The types of questions used in this assessment are AP-level questions; each of these types of questions have varying levels of cognitive demand associated with it. The levels were patterned after Bloom’s taxonomy. The students were interviewed in groups to better understand how the iPads affected their learning especially in group settings. The interview protocol is located in Appendix H.
CHAPTER 4

FINDINGS

The findings for each of the three research questions related to blending iPad technology with classroom activities in an 11th grade Chemistry classroom are presented in sequential order. The report of the findings is preceded by a brief synopsis of the classroom setting, sequence of learning activities, and evidence gathering activities that provides a context for the findings.

Synopsis of Class Schedule in February and Observations

The study took place starting the end of January through the month of February 2017, and a total of three curriculum units were taught: i.e. 1) Equilibrium, 2) Acids and Bases, and 3) Buffers and Salt Equilibria. A brief outline of the timeframe for each topic is outlined below.

There are two sections in 11th grade Chemistry, Class 1 and Class 2, as determined by school schedule and are not based on academic qualifications or performance. The Lecture on Equilibrium began January 30, 2017. The first class observation was made on February 2, 2017, when students started working in groups for the first group activity. Due to conflicting schedules, observations in Class 1 did not start until February 13, 2017.

There were two teacher observers in each class, Kate and Kenneth (all names in study are pseudonyms). They were both unfamiliar with my students as well as my teaching style. Kate, a 4th grade teacher, was located across the hall from my classroom, and thus had limited interaction with me. Kate was interested in educational research and volunteered to participate in the study. Kenneth, a new teacher at the school during the semester when the study began, came as a replacement for a teacher who was on maternity leave. He started working at the school in January 2017, and shared an office with me. He volunteered to come in on his free periods to see how the class progressed.
The unit on Equilibrium ended on February 6, 2017. The end of a unit is marked by a review game on Kahoot! The questions focus on the multiple-choice section of the AP Chemistry exam. Both sections took the quiz on Equilibrium on February 7, 2017. The questions that were asked on the quiz were then subdivided into the levels as explained in the Methods section.

The second unit covered in this study was Acids and Bases. Both sections of students began this unit on February 8, 2017. Due to weather conditions, both classes did not meet on February 9, 2017 because the school was closed. A lab on titration curves was scheduled on February 10, 2017. Lecture ended on February 13, 2017, and thus the first day of group activities started on February 14, 2017. The first in-class observations started on Class 1 (February 14, 2017). The problems for this session were noticeably harder than previous sections. Students had substantial difficulty going through the problems as evidenced by the limited number of questions they managed to complete in one class period. The unit also ended with a Kahoot! game and a quiz on February 16, 2017.

The chapter on Buffers and Solubility started on February 22, 2017. The first day of classwork began the very next day (February 23). Since neither one of the teachers had free periods on that day, the first day they could come and observe was on February 24, 2017. Group activities ended on February 28, 2017 (four days), and the class was given a test (culmination of chapters 14-16) on March 2, 2017. Table 4.1 outlines the lesson topics and summarizes the schedule for both sections in this study.

Table 4.1.

<table>
<thead>
<tr>
<th>Summary of schedule for both class sections (Class1 and Class 2).</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equilibrium Unit</td>
</tr>
<tr>
<td>Lecture</td>
</tr>
</tbody>
</table>
Research Question 1: How does the process of blending iPad technology with classroom constructivist learning in 11th grade Chemistry classroom influence classroom practice and learning outcomes, with respect to the dynamics of student interaction in collaborative learning when augmented with the iPad-enabled constructivist learning?

Group observation evidence. As described in Chapter 3, an observation protocol was used to obtain evidence of group dynamics. Table 4.2 and 4.3 present the observer’s codes for behaviors during the use of the iPads during February 2, 2017 to February 24, 2017 for Class 1 and Class 2, respectively. Overall, the students’ behavior alternated between cooperative activity (Category 1) and engagement in individual tasks (Category 3), and varying in relation to the topic and time of observation.

Class 1. In class 1, there are 10 students (Table 4.3). Here, Kenneth was the observer in the first and fourth session (2/14 and 2/28/17) while Kate observed the second and third session (2/15 and 2/24/17). February 14, 2017 was the first day the class started a group activity in the unit on Acids and Bases (Table 4.1). The group showed more instances of individual task behavior (Category 3) compared to cooperative behavior (Category 1) on this first day. However, there was a general trend toward an increase in cooperative behavior (Category 1) in the last two observation days. For example, Lester’s behavior started initially with nine codes for Category 1 and exhibited one code for Category 3 on the first coding day (2/14/17). Over the next three observation days he showed an increased amount of cooperative behavior (Category 1) reaching five codes for each Category 1 and Category 3 behavior. This trend of increased cooperative behavior also was evident with Luke, Terrence, Yuri and Larry. Victor, Cornelius, Enzo, Rick and Zeke showed a different trend; they had zero codes for cooperative behavior (Category 1) in
the first and last observation days but showed very good cooperative behavior in the second and third observation days. Overall, the general trend that appeared to develop was increased cooperative behavior in the last two observation days compared with the first two observation days.

Table 4.2. Summary of Observation Protocol Codes (Class 1) for Each Student During February 2, 2017 to February 24, 2017

<table>
<thead>
<tr>
<th>Date:</th>
<th>2/14/17</th>
<th>2/15/17</th>
<th>2/24/17</th>
<th>2/28/17</th>
</tr>
</thead>
<tbody>
<tr>
<td>Behaviors</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Cornelius</td>
<td>1</td>
<td>9</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Enzo</td>
<td>6</td>
<td>4</td>
<td>9</td>
<td>1</td>
</tr>
<tr>
<td>Larry</td>
<td>2</td>
<td>8</td>
<td>8</td>
<td>2</td>
</tr>
<tr>
<td>Lester</td>
<td>1</td>
<td>9</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Luke</td>
<td>4</td>
<td>6</td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td>Rick²</td>
<td>0</td>
<td>10</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Terrence</td>
<td>4</td>
<td>6</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>Viktor</td>
<td>0</td>
<td>10</td>
<td>8</td>
<td>2</td>
</tr>
<tr>
<td>Yuri</td>
<td>0</td>
<td>10</td>
<td>7</td>
<td>3</td>
</tr>
<tr>
<td>Zeke</td>
<td>0</td>
<td>10</td>
<td>8</td>
<td>2</td>
</tr>
<tr>
<td>Average</td>
<td>1.8</td>
<td>8.2</td>
<td>6.6</td>
<td>3.4</td>
</tr>
</tbody>
</table>

Note. Behavior Definitions and table footnotes:
1) Cooperative behavior – defined as task-oriented group behavior. Were the students listening to each other? Working together? On-task? Were they talking to each other?
2) Noncooperative behavior – defined as competitive behaviors. Were the students talking over each other? Were they working against a common goal? Were they off-task? Were they discussing things not relevant to the problem at hand?
3) Individual task-oriented behavior – defined as working alone on a task.
4) Individual non-task behavior and confusion – defined as not participating in group activities and not working individually.

²Rick was absent on 2/28/17

Class 2. In class 2, there were 10 students. Here was evidence of a general trend or pattern of behaviors over the course of the observations that characterized a subset of the students in the class as detailed below. For example, Sterling, largely exhibited cooperative behavior during the first coding day (2/2/17) with eight codes for Category 1, but also included two instances of individual task behavior (Category 3). This fundamental pattern persisted in the second coding day (2/3/17), but became more pronounced with more individual behavior in the
third coding day (2/14/17). However, on the last coding day (2/24/17), Sterling’s behavior was very similar to that of the first coding day. A similar pattern was exhibited by Jerry, and to a degree, by Peter and Jiannis. However, compared to this general trend in behavior, Moes profile is somewhat different; and began with a substantially cooperative behavior (Category 1), but became increasingly focused on individual tasks in the last two days of coding with a proportionately larger frequency of Category 3 codes. Sinbad presents yet a rather different profile, beginning with largely individualized task behavior on the first coding day, then becoming more cooperative (Category 1) on the second coding day; but then largely focused on individualized tasks, before being absent on the last coding day.

The remaining four students each exhibited individual patterns—Karl largely had larger instances of Category 1 behavior compared to Category 3, except during the third observation period. Ron initially had equal instances of Category 1 and Category 3 behavior, but tended toward more of Category 1 behaviors in the latter three observations. David and Twain were absent during some key periods of observation, and largely had a mixed pattern of responding in Categories 1 and 3. See the footnotes to Table 4.3 for additional information.

It is important to note that February 14, 2017 was the beginning of a new chapter, thus all problems were difficult and needed some adjustment. Perhaps it takes time to process new information before they can start working together, and this may account in part for the change in behavior profiles of some of the students with a tendency for some to exhibit more individualized work.
### Table 4.3.
Summary of Observation Protocol Codes (Class 2) for Each Student During February 2, 2017 to February 24, 2017

<table>
<thead>
<tr>
<th>Date</th>
<th>2/2/17</th>
<th>2/3/17</th>
<th>2/14/17</th>
<th>2/24/17</th>
</tr>
</thead>
<tbody>
<tr>
<td>Behaviors</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>David&lt;sup&gt;a&lt;/sup&gt;</td>
<td>5</td>
<td>5</td>
<td>3</td>
<td>7</td>
</tr>
<tr>
<td>Jerry</td>
<td>8</td>
<td>2</td>
<td>7</td>
<td>3</td>
</tr>
<tr>
<td>Jiannis</td>
<td>7</td>
<td>3</td>
<td>8</td>
<td>2</td>
</tr>
<tr>
<td>Karl</td>
<td>7</td>
<td>3</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>Moes</td>
<td>7</td>
<td>3</td>
<td>9</td>
<td>1</td>
</tr>
<tr>
<td>Peter</td>
<td>9</td>
<td>1</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>Ron&lt;sup&gt;b&lt;/sup&gt;</td>
<td>5</td>
<td>5</td>
<td>8</td>
<td>2</td>
</tr>
<tr>
<td>Sinbad&lt;sup&gt;c&lt;/sup&gt;</td>
<td>4</td>
<td>6</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>Sterling</td>
<td>8</td>
<td>2</td>
<td>7</td>
<td>3</td>
</tr>
<tr>
<td>Twain&lt;sup&gt;d&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>6.7</td>
<td>3.3</td>
<td>6.7</td>
<td>3.3</td>
</tr>
</tbody>
</table>

**Note.** Behavior Definitions and table footnotes:

1) Cooperative behavior – defined as task-oriented group behavior. Were the students listening to each other? Working together? On-task? Were they talking to each other?
2) Noncooperative behavior – defined as competitive behaviors. Were the students talking over each other? Were they working against a common goal? Were they off-task? Were they discussing things not relevant to the problem at hand?
3) Individual task-oriented behavior – defined as working alone on a task.
4) Individual non-task behavior and confusion – defined as not participating in group activities and not working individually.

<sup>a</sup>David was absent 2/14/17, <sup>b</sup>Ron moved to a different table between 2/2 and 2/3/17 and may account for some differences in group work. <sup>c</sup>Sinbad was absent on 2/24/17, <sup>d</sup>Twain was absent the two days when class was observed (2/2 and 2/3/17).

**Teacher observer reports.** Each teacher observer was asked some questions to further elaborate on what they saw in the classroom. Below is a summary of each one’s observations and their interpretation of the observed classroom evidence. Both observers agreed that the students exhibit a strong focus in class as well as a good amount of collaboration among the students at each table. Both observers think that the projection of the students’ work on screen gave them an added motivation to work together as well as lead the whole class in solving problems. Apart from one instance during the observation periods, all students were on task and working on the problem projected on screen.
Kate. I noticed that using the iPad in the group activities fostered a lot of collaborations and conversations among the students especially when they see each other’s screens on the board, including the following verbatim comments.

I feel like the organization of seating is very important, because in their pods they constantly talk and it feels like they are part of a team. From what I can observe, they were never off task nor were they arguing. They were also always on topic and not having a different discussion. I think the projection on the screen keeps them engaged and involved. They were competitive but in a healthy way, which is good since boys are inherently competitive. I also think that the projection and the working in teams gives them an incentive to perk up and get involved. It is highly motivating for them if they can see other people’s work. Once it starts, conversation just exploded. It is productive and informative. I think this could be replicated in other classes, in fact in any class. All we need is a good group project. I am thinking of incorporating this in Math in 4th grade. I think maybe if a check-in is added that could increase motivation more. The students are motivated because of the public show of their work, so a check-in added to it may get them to increase more participation.

Kenneth. Kenneth noted the following verbatim comments.

Students were either working as a group or individually, and working rather well. They seem to be involved in what they are doing. I think that their work being shown on the board gives them some accountability. The full accountability that people can see what they are doing keeps them involved in their work. Possibly they don’t want to seem like they don’t know what they are doing in front of their peers. I think them seeing everyone else struggling is a form of encouragement. They see that they are not the only ones having a hard time so it brings them together, almost like “let’s work on this together and get through it together.” In order to
replicate this in other classes, I think that students have to be highly motivated to do work. There needs to be a certain order in class. The students need to know what they are doing once they get into the classroom. In terms of increasing participation, everyone was working towards a common goal. When you have 100% buy in it's almost impossible to do something else for that.

**Summary of researcher observations on class participation.** I have taught this course for the last five years. Comparing this with previous years of teaching this course, I found the implementation of the iPad using the combination of Notability and AirPlay made a difference in both student focus and participation. It is very rare to have full student participation in class where each student is on task. Before the class started using this method, the use of any technology they wished such as laptops, tablets, Chromebooks or iPads caused much greater distractions in class which resulted in a lot of off-task behavior. I did observe that with the use of AirPlay, with or without outside observers, the students seemed to be on task much more than usual. I think this was mostly because students were held accountable to their work, and it involved the whole class. Usually in class discussions you get the same people willing to raise their hands and answer questions. When their work is shown on the board every student is now participating and involved in the problem-solving process.

**Research Question 2: What are the students’ perceptions of social interaction when the iPad-enabled constructivist learning is used to promote collaborative learning in the classroom?**

**Student Perception Survey.** As described in Chapter 3, students were given a survey in order to understand student perception on using iPads in group activities. This survey was administered after the test on the third unit of this research period. Tables 4.4 and 4.5 contain the results of the survey for class 1 and class 2, respectively. The results are presented as
percentages to better display the distribution of responses to each item and also to satisfy the statistical requirements for ordinal data (Sullivan & Artino, 2013).

**Class 1.** Class 1 reported very strong positive perceptions to items pertaining to community, feedback and interactive features of the iPad. The summary of the responses is located on Table 4.4 below contains 15 survey questions.

Table 4.4.
Summary of Survey Results – Class 1

<table>
<thead>
<tr>
<th>Question</th>
<th>SD</th>
<th>D</th>
<th>U</th>
<th>A</th>
<th>SA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 I feel a sense of community</td>
<td>20%</td>
<td>10%</td>
<td>50%</td>
<td>20%</td>
<td></td>
</tr>
<tr>
<td>2 Learning becomes interactive</td>
<td>50%</td>
<td>20%</td>
<td>30%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 Posting questions to my peers help me understand concepts better</td>
<td>30%</td>
<td>50%</td>
<td>20%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 I am able to get faster feedback from my peers</td>
<td>40%</td>
<td>30%</td>
<td>30%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 I am able to get faster feedback from my instructor</td>
<td>20%</td>
<td>50%</td>
<td>30%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 I am able to communicate effectively</td>
<td>10%</td>
<td>10%</td>
<td>20%</td>
<td>30%</td>
<td>30%</td>
</tr>
<tr>
<td>7 I am able to connect with peers more easily than face-to-face</td>
<td>20%</td>
<td>30%</td>
<td>20%</td>
<td>30%</td>
<td></td>
</tr>
<tr>
<td>8 I increase my participation in classes when I am allowed to contribute through the use of the iPad</td>
<td>10%</td>
<td>30%</td>
<td>20%</td>
<td>20%</td>
<td>20%</td>
</tr>
<tr>
<td>9 I learn best without iPads (R)</td>
<td>10%</td>
<td>60%</td>
<td>20%</td>
<td>10%</td>
<td></td>
</tr>
<tr>
<td>10 More classroom learning should include interactive communicative experiences using the iPad</td>
<td>10%</td>
<td>10%</td>
<td>30%</td>
<td>50%</td>
<td></td>
</tr>
<tr>
<td>11 I learn more when I regulate my own learning experience and seek information on things I want to learn about.</td>
<td>20%</td>
<td>40%</td>
<td>40%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12 I find the iPad very distracting and does not allow me to focus on class activities (R)</td>
<td>10%</td>
<td>50%</td>
<td>20%</td>
<td>20%</td>
<td></td>
</tr>
<tr>
<td>13 I find that group activities with the iPad help me learn better than working alone</td>
<td>10%</td>
<td>30%</td>
<td>30%</td>
<td>30%</td>
<td></td>
</tr>
<tr>
<td>14 I feel more confident about what I learned when using the iPads</td>
<td>40%</td>
<td>30%</td>
<td>20%</td>
<td>10%</td>
<td></td>
</tr>
<tr>
<td>15 I find learning more exciting when using apps like Kahoot!</td>
<td>20%</td>
<td>30%</td>
<td>50%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\(n=10\)
This table shows the students’ perceptions toward the use of iPads in group activities. For example, in item 1 where the students were asked if they felt a sense of community, 70% responded with agree or strongly agree; whereas 10% were undecided and 20% disagreed with the statement. This is also evident in the third survey item related to understanding concepts when working in the group. Again, 70% chose agree or strongly agree and 30% were undecided. In their perceptions of feedback (items 4 and 5) positive responses (agree and strongly agree) were 60% and 80%, respectively; while the remaining were undecided. As for the interactive experiences with the iPad (items 2 and 15), students indicated a strong positive interest in interactive features such as Kahoot! with 80% agreeing and 20% undecided. Item 12 addressed whether these interactive features could be distracting. Sixty percent did not find it distracting with 20% undecided and 20% finding it distracting. This provides a general perspective that the students believe that the iPads are useful for effective feedback and positive interactions as well as a sense of community when it is used in group work. This can also be seen in item 9 when students were asked whether they learn best without iPads, 10% disagreed, 60% were undecided and 30% either chose to strongly agree or agree to the statement.

Other more neutral responses can also be seen on item 13 and 14. In item 13, when asked whether group activities with the iPad helps them learn better compared to working alone, 40% chose to either strongly disagree or disagree to the statement, 30% were undecided and 30% agreed that group activities did help them better when compared to working along. In terms of confidence, 40% disagreed with the statement that they felt more confident when using the iPads to learn, 30% were undecided and 30% chose to either agree or strongly agree to the statement (item 14).
There are interesting differences however in terms of communication. For item 6, where students were asked whether they could communicate effectively the classroom with the iPad, they responded that they were able to communicate effectively, 60% reporting agree and strongly agree, 20% undecided and 20% disagreeing with the statement. When asked about communicating using interactive features (item 10), the same trend can be seen, 50% agreeing, 30% undecided and 20% in the disagree categories.

It is interesting however when they were asked to compare iPad interaction vs. face-to-face interaction (item 7) only 30% agreed that the iPad is more useful in connecting with their peers, 20% undecided and 50% responded in the agree or strongly disagree options, which meant that they preferred face-to-face interaction more than the interaction with the iPad in the classroom. This can also be seen when they were asked about their participation in class when they were using the iPads (item 8) 10% strongly disagreed and 30% disagreed whereas 20% were undecided and the last 40% chose to either strongly agree or agree that the iPad did increase their class participation.

Finally, item 11 asked whether you can learn more when there is more independence and freedom in the way they learn by seeking information on things they do want to learn, 20% disagreed with the statement, 40% were undecided and 40% agreed with the statement.

**Class 2.** Class 2 showed a very similar trend to Class 1 in their generally positive perceptions. The summary of the survey questions for Class 2 is located below.

In this table, it can be seen that this class showed stronger positive perception when compared to the other class. This can be seen in questions on community where 90% agreed with the statement that they felt a sense of community in the classroom when using the iPads in group work where 10% disagreed with the statement (item 1). The interactive features of the
iPad also showed 90% of the class agreeing with the idea that learning becomes more interactive and 10% undecided (item 2). This is the same trend seen in feedback both from the teacher and peers as well as interactive features like Kahoot! where 90% agreed and 10% were undecided (item 15).

Table 4.5. Summary of Survey Results – Class 2

<table>
<thead>
<tr>
<th>Question</th>
<th>SD</th>
<th>D</th>
<th>U</th>
<th>A</th>
<th>SA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. I feel a sense of community</td>
<td>10%</td>
<td>60%</td>
<td>30%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Learning becomes interactive</td>
<td>10%</td>
<td>50%</td>
<td>40%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Posting questions to my peers help me understand concepts better</td>
<td>10%</td>
<td>50%</td>
<td>40%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. I am able to get faster feedback from my peers</td>
<td>10%</td>
<td>10%</td>
<td>40%</td>
<td>40%</td>
<td></td>
</tr>
<tr>
<td>5. I am able to get faster feedback from my instructor</td>
<td>10%</td>
<td>10%</td>
<td>20%</td>
<td>60%</td>
<td></td>
</tr>
<tr>
<td>6. I am able to communicate effectively</td>
<td>10%</td>
<td>70%</td>
<td>20%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. I am able to connect with peers more easily than face-to-face</td>
<td>10%</td>
<td>20%</td>
<td>40%</td>
<td>20%</td>
<td></td>
</tr>
<tr>
<td>8. I increase my participation in classes when I am allowed to contribute through the use of the iPad</td>
<td>20%</td>
<td>20%</td>
<td>40%</td>
<td>20%</td>
<td></td>
</tr>
<tr>
<td>9. I learn best without iPads (R)</td>
<td>10%</td>
<td>30%</td>
<td>50%</td>
<td>10%</td>
<td></td>
</tr>
<tr>
<td>10. More classroom learning should include interactive communicative experiences using the iPad</td>
<td>10%</td>
<td>20%</td>
<td>50%</td>
<td>20%</td>
<td></td>
</tr>
<tr>
<td>11. I learn more when I regulate my own learning experience and seek information on things I want to learn about.</td>
<td>40%</td>
<td>40%</td>
<td>20%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12. I find the iPad very distracting and does not allow me to focus on class activities (R)</td>
<td>20%</td>
<td>60%</td>
<td>10%</td>
<td>10%</td>
<td></td>
</tr>
<tr>
<td>13. I find that group activities with the iPad help me learn better than working alone</td>
<td>40%</td>
<td>10%</td>
<td>30%</td>
<td>20%</td>
<td></td>
</tr>
<tr>
<td>14. I feel more confident about what I learned when using the iPads</td>
<td>10%</td>
<td>10%</td>
<td>40%</td>
<td>20%</td>
<td>20%</td>
</tr>
<tr>
<td>15. I find learning more exciting when using apps like Kahoot!</td>
<td>10%</td>
<td>20%</td>
<td>70%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*n=10

There is a greater split on questions that probe comparison between iPads and face-to-face interactions; 30% agreed and 30% disagreed with the statement that iPads allow for better
connections when compared to face-to-face interactions with 40% undecided (item 7). In terms of communication as seen in items 3 and 6, 90% agreed that posting questions helped them understand concepts better whereas 10% disagreed and this was similar trend on the effectiveness of communication.

Feedback can be seen on items 4 and 5 where 80% agreed with the statement that feedback is faster from peers when iPads are used in group activities and 10% were undecided and 10% disagreed with the statement. For feedback from the instructor, the same trend can be seen where 80% agreed and 10% remained undecided and 10% disagreed with the statement. On item 8, when asked whether participation increased with the use of the iPad, 60% agreed, 20% remained undecided and 20% disagreed with the statement.

Item 9 asked about learning with or without iPads, 40% disagreed with the statement that they learn best without iPads 50% remained undecided and 10% agreed with the statement. Items 10 and 11 asked about classroom experiences in using the iPad, both on interactive features as well as self-motivation in learning. 70% agreed with the interactive features where as 60% agreed with the independence in learning.

In terms of the possibility of distractions with the use of the iPad, 80% disagreed on the statement that the iPads were distracting whereas 20% agreed that the iPad can be distracting (item 12). Item 13 asked about the group activities with the use of the iPads, 50% agreed that group activities with the use of the iPad helped them learn better, whereas 10% were undecided and 40% disagreed. This shows the versatile nature of the use of the iPad in class where students can opt to work individually or in a group, something that suits their learning styles.
Finally, item 14, asked about the confidence in what was learned when iPads are used, 40% agreed that they were more confident when iPads were used, 40% were undecided and 20% disagreed with the statement.

**Summary of Students’ Post-Survey Questions.** Post-Survey items were embedded in the survey. Out of ten students in the class, six to seven students chose to fill in the post-survey questions for both Class 1 and Class 2, respectively. Each of the post-survey questions presents a part of the survey expanded to gather better understanding of the use of the iPads in group activities. The student responses for Class 1 and 2 are compiled in Appendix I and J respectively.

**Class 1.** The data summarized in this subsection are presented in a large table (Appendix I). In Class 1 60% agreed with the statement that iPads aid in better communication, 20% disagreed and 20% remained undecided. Based on this question, students were asked to gauge the iPad as a communication tool. Students overall felt that the iPad is a good communication tool if used well. It is able to help classmates get questions answered more quickly than in a more traditional setting. It can be something that can generate discussion and critique and thus greater focus when answering questions. One student felt that since he was able to see what he is doing wrong and is able to ask questions to tables further away from him by just looking at the board. One student felt that the ability to point out their work in the middle of class discussion aided in the discussion more when compared with traditional classroom discussions. Another student pointed out that the size of the screen made it difficult to communicate effectively. This was observed in class when students could not fit the entire solution in a page so there would be a constant zooming in and out of the screen. This does indeed pose a challenge to the students when trying to solve a complex problem. One person pointed out the use of GoSoapBox, which
is something that is used in class but not included in this study. GoSoapBox is a web based Q&A system that students can display whether or not they are confused during a lecture as well as post questions real-time on the app and have it answered either by their peers or by their teacher within the lecture.

The second feature that was explored in the post-survey questions is participation. In Class 1, the survey was split between 40% agreeing, 40% disagreeing, and 20% undecided. Of the seven answers received, most had a split between the positive and negative aspects of this method of projection of the iPad on the board. Students felt motivated in a sense that there was pressure to do well for the group as well as for the class. One student said, the motivation came from the ease of use of the iPad in class discussion, another thought that the competition aspect comes into play because you are no longer just solving the problems for yourself, but for other groups as well. He looked at it as whoever gets it first gets some form of internal reward that is not seen when problems are solved on paper. One student suggested that the motivation comes from helping the group and since he can see what other students are doing, he does not feel too much pressure in contributing to the group discussion because problems become easier to follow once it is projected on the screen. Several students found the ease of using technology in communication a factor in their motivation to participate in the class. One student’s response summarized this very succinctly: “I am under pressure to perform because I am effectively working in front of the entire class. That may sound negative, but I feel as proud when I do something correctly as embarrassed when I do something incorrectly.”

The third question is more of a merge of the first and second question. Do students feel that they are able to communicate more/less in class? Most often when any piece of technology is used, you do see a decline in communication. It would be interesting therefore to see how the
students thought about whether or not the iPads allowed them to communicate more or less in class. Most of the students claim that it helps them communicate more citing the projection of their work to aid class discussion. One student felt that the competitive aspect of how it was used caused the students to be too enthusiastic thus he felt like he communicated less. Another student felt that there was no big difference in the way he communicates in class with and without the use of the iPad.

The fourth question studied was applicability to other classes. Students feel like it would be a good method in problem-solving oriented classes. They find that the type of discussion is very suited to science and math classes, but not very helpful in a more abstract and discussion based class like English or History. Students think that the ability to effectively discuss problems was useful because there are multiple methods of solving a problem, and it is useful to see what is happening in all different locations. The quick feedback serves this purpose well, but not when students are trying to discuss one thing, as is common in humanities classes. Another student sums up this perspective very well, “I would not recommend that, since many of the functions the iPad performs are specific to some elements of the class. It might work for something like math, but for a more reading and discussion-heavy class such as Latin or History, it would not be very effective.” This is an interesting comparison with the studies that use the iPad for social studies. The iPads were used to connect to worlds outside the classroom as opposed to creating a space within the classroom for students to collaborate.

The fifth main topic questioned is feedback. In the survey, 60% agreed that feedback was easier from peers with 40% undecided, and 80% agreed that feedback from teacher was faster and 20% was undecided. This shows that the class had a positive outlook on the use of the iPads as a tool for feedback. Students feel that it is easier to see what everyone is doing at once.
As a result, they can see immediately if they are on the right track and, if not, they can ask someone who is doing the problem where they went wrong. Feedback given during the use of iPads was helpful. This was because the teacher was able to view work by simply looking at the projector. In addition to this, their classmates were able to view and give feedback as well they were able to quickly hear what other people thought of their work and that is valuable. Students are able to correct mistakes, and the teacher can use it as a point in discussion, especially when mistakes are made and caught live on the board. There is also a lot more feedback, this can be a good thing as well as can be a bad thing as well. One student explains this more thoroughly: “Feedback comes faster and there is more of it. This is generally a good thing, but sometimes it is important to complete problems with no feedback at any point, to see whether I am capable of doing a task independently.”

The sixth item covered is distractions. Students were well aware of the distractions that technology presented. In the survey, 60% disagreed with the statement that the iPad is distracting in the classroom, 20% were undecided and 20% agreed with the statement that it can be a distraction in the classroom. When probed further, one student concluded that as long as the class was moving progressively fast, distractions do not become an issue. Another student said that the rigor of the course kept them engaged and stopped them from succumbing to possible distractions. One student summarized this very well: “Distractions are a very real concern with technology in the classroom. I think the best way to avoid distractions is for everyone to buy into the effectiveness of iPads in class. If everyone is invested and learning effectively in this system, students will avoid distractions in order to get the most out of the class.”

The last item asked whether iPads were good for motivation or was it distracting when they were using interactive apps, one student that it was a motivation. When other students can
see both students excelling as well as failing, there is a sense of motivation and camaraderie. One student wrote that there is no difference, “If the iPad is being used strictly the way we have been using it. Notability is interactive, but paper is just as interactive. The AirPlay function is really what makes the iPad so helpful.” One student summed up his observation: “In this context, I would call it a motivation. With our teacher encouraging learning and working with our iPads, we were able to focus ourselves on an educational purpose with them. Sometimes in my other classes, I notice my classmates using their iPads to distract themselves during a lecture, it was never the case here. I think that when given the opportunity, students can both use iPads efficiently and remain engaged simultaneously.”

**Class 2.** (Appendix J) In Class 2, 90% agreed that communication was more effective and 10% disagreed with the statement. This class was asked to gauge the iPad as a communication tool. Students felt that apps like Kahoot! aided in class discussion because the class can stop when majority of the students get the wrong answer and concepts can be reexamined. There is also the ability to mirror multiple screens on the board that can allow for easy communication since multiple solutions can be seen at a particular time. This also aids in class discussion. One student felt that it was more of a group work tool as opposed to a communication tool.

With respect to the second feature “participation,” 60% agreed that it increased participation, 20% disagreed and 20% remain undecided. Most of those who responded said that criticism from classmates and from the teacher on the work projected helped them process information more easily and thus makes them more comfortable to participate. One student claimed that he feels indifferent since he normally participates in class already, the use of the iPad just promotes the same type of participation in class discussion. Others see it as a way of learning faster, when they are able to follow what is going on from different perspectives, they
can choose one that suits them better and this leads to an increase in confidence when they are looking at ways to participate in class. One student feels like it is not participation that it promotes, but discussion. “I feel indifferent about the iPads being able to promote participation. I feel that it facilitates communication between classmates because it can allow a student in another table to ask questions to a student three tables away. It certainly facilitates discussion.”

On the third question, “opportunity to communicate,” most of the students answered more opportunities were available to communicate, apart from one student who thinks that they communicate about the same amount. One student cites that everyone has an opportunity to participate which may not be the case in a classroom where only the more vocal students get to participate. One student cites the effectiveness comes from the fact that they could see what others are writing on their iPads.

In terms of applicability in other classes there is a lot of similarity with the other class in terms of what the students thought was applicable or not applicable with classes. Most students thought that it was beneficial in other classes to remember facts or calculations, but may not be as helpful in writing portions of English or History for example. The reasoning why problem-solving classes would benefit from this method is because it forces students to participate and work together to find a solution. One scenario depicted by a student was the iPad in humanities versus science and math classes: “I feel that it works best for chemistry and for math in certain scenarios. I feel that when doing class work it allows the teacher and other students to quickly fix any mistakes. We are using it in a similar method for English, in which we have the eBook and take notes in class on the book from last night’s reading (which is in the iPad). This allows the teacher to be on the same page and reduce clutter for the students having to carry a textbook or book.”
In terms of feedback, students feel like it motivates them to participate more since it creates more feedback every time they participate. Students in the classroom are more aware of what other people are doing, which can usually help solve problems faster. As a result, there is also quicker teacher feedback, since it is easy for the teacher to point out any mistake right away. In addition to teacher feedback, students are also able to receive feedback from their peers. Communication is easier because students are able to see everyone’s work on the board, this means that mistakes are easily fixed and feedback is instantaneous.

With all the benefits of the iPad, the interactive features also occasioned some distractions. Students in the interview thought that with proper control, distractions are not even an issue in the classroom. Students said that they play video games at times in other classes, so it shows that with the proper motivation, they can be focused and not get distracted with video games. Other forms of distraction included using the iPad as a tool to do work for other classes. Since the iPad contains much data and information, students have used this method to do work for other classes while class is ongoing. With the projection of the iPad on the screen, it keeps them accountable for how they are using it and the purpose in which they use the technology in the classroom. One student pointed out that “It is certainly a possibility but nobody in my table was ever using it for games, and on the contrary I felt that the screen projection method created incentive to stay on task for fear of being spotted being off task.” On the other hand, one student said strongly “If you give an ADHD teenager a box with science and videogames in it, you can’t expect him to pick science every time.”

The last question asked about motivation to participate. The students see it as a motivation to be able to show their work to everyone at once, receive feedback and limits distraction when they are fully committed to their learning. Each student thought that the
interactive features were not distracting, as long as it is put in the right classroom setting. Even the student who preferred to use pen and paper did not find the interactive features of the iPad distracting. One student summarizes it rather well “Motivation, if used correctly, creates a group sense, motivates a competitive class, and students receive help from peers and their teacher immediately. Distracts students in other classes when their use is not monitored. Unfortunately, cannot take students on faith.”

**Research Question 3: How do students develop shared understandings of a concept during iPad-enabled constructivist learning, and how does it relate to learning outcomes?**

**Learning Outcomes.** The three chemistry textbook chapters covered in this study: Equilibrium, Acids & Bases, Buffers and Solubility are typically among the hardest chapters and generally where students have struggled in the past. Each of the assessment questions came directly from College Board and are questions typically asked in Advanced Placement Chemistry exams. The summary of test results for each class is presented in Tables 4.8 – 4.13. Each column in the tables shows the number of items correctly answered (out of a total of 30) by each student relative to each level of Bloom’s taxonomy (I – VI), as well as their overall grade in the in-class assessment (final column in each table). Students in each of the two classes presented a strong showing in the first quiz with no one student standing out as struggling in these chapters.

**First Unit: Class 1.** Class 1 (Table 4.6) showed some difficulty in answering Level IV (Analysis) and Level VI (Evaluation) problems (with overall means of 43% and 35%, respectively), but excelling the most in Level III (Application) and Level V (Synthesis) problems (mean scores of 73% and 75%, respectively). This is possibly due to the way problems and activities were structured in class. Most of the problems covered in class focused on Level III problems. Students who struggled with low-level problems also struggled with high- level
problems. Level I (Knowledge) problems mostly focused on conceptual definitions, 60% of the class was able to get at least three of the four problems correctly. These questions require either knowledge of terms or simple identification problems. This shows the same pattern in Level II (Comprehension) questions as well. Due to the amount of practice students received in Level III problems, there is a distinct improved performance in how well they did in these problems. The biggest difference between Level III and Level IV problems are that Level IV problems require much more than practice but rely on skill development. Level IV problems are not the typical one- or two-step calculations, but require gathering information from multiple sources and using it in calculations. The biggest difference between Level VI problems and Level V problems is an emphasis on the ability to argue using conceptual understanding as opposed to gathering information that exists within the problem. This shows that although students were able to calculate things very well, they had a difficult time justifying their answers using their conceptual understanding. It is also interesting to note that the students who were able to do well in the justification type questions, were students who were more prone to collaborative discussion in the classroom, whereas those who did poorly in Level VI questions were students who were more interested in working individually on the problems, when in fact they would have benefited by the discussion and collaboration.

Table 4.6 shows the result of the first assessment for Class 1, which was a quiz on Equilibrium taken on February 7, 2017. The numbers in parentheses denote the total number of questions, and the Roman numeral denotes the Level of questions from Bloom’s Taxonomy.
Table 4.6.
Bloom’s Taxonomy Results: First Assessment: Equilibrium – Class 1

<table>
<thead>
<tr>
<th>Level (# of questions)</th>
<th>I (4)</th>
<th>II (7)</th>
<th>III (12)</th>
<th>IV (3)</th>
<th>V (2)</th>
<th>VI (2)</th>
<th>Grade:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cornelius</td>
<td>3</td>
<td>4</td>
<td>8</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>83%</td>
</tr>
<tr>
<td>Enzo</td>
<td>3</td>
<td>4</td>
<td>9</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>88%</td>
</tr>
<tr>
<td>Larry</td>
<td>3</td>
<td>5</td>
<td>6</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>80%</td>
</tr>
<tr>
<td>Lester</td>
<td>2</td>
<td>4</td>
<td>7</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>78%</td>
</tr>
<tr>
<td>Luke</td>
<td>2</td>
<td>4</td>
<td>10</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>88%</td>
</tr>
<tr>
<td>Rick</td>
<td>3</td>
<td>2</td>
<td>9</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>86.5%</td>
</tr>
<tr>
<td>Terrence</td>
<td>4</td>
<td>7</td>
<td>12</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>100%</td>
</tr>
<tr>
<td>Victor</td>
<td>3</td>
<td>5</td>
<td>10</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>91%</td>
</tr>
<tr>
<td>Yuri</td>
<td>2</td>
<td>5</td>
<td>9</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>87%</td>
</tr>
<tr>
<td>Zeke</td>
<td>1</td>
<td>4</td>
<td>8</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>83%</td>
</tr>
<tr>
<td>Average</td>
<td>65%</td>
<td>63%</td>
<td>73%</td>
<td>43%</td>
<td>75%</td>
<td>35%</td>
<td>86.5%</td>
</tr>
</tbody>
</table>

Note: Bloom’s Taxonomy Levels and corresponding quiz questions:
Level I: Multiple Choice 3, Free Response 1.a, 2.b, 3.a
Level II: Multiple Choice: 1, 2, 4, 7, 10, Free Response 3.d(i), 3.e(i)
Level III: Multiple Choice 5, 6, 8, 9 Free Response 1.b(i), 1.b(ii), 1.c, 1.d, 2.a(i), 2.a(ii),
2.c(ii), 3.c(ii)
Level IV: Free Response 1.e, 2.c(i), 2.d
Level V: Free Response 3.b, 3.c(i)
Level VI: Free Response 3.d(ii), 3.e(ii)

First Unit: Class 2. Class 2 (Table 4.7) showed much higher quiz scores compared to Class 1. Class 2 had an average of 90.4% whereas Class 1’s average was 86.5%. Class 2 has a better conceptual understanding as evidenced by a comparison of their averages (80% for Class 2 as opposed to 65% for Class 1). Similar to Class 1, Class 2 also showed a good mastery over Level III problems (class average of 75%). This class also showed impressive mastery over conceptual/identification type questions (Level 1). Also similar to Class 1, the two sections where they showed the greatest difficulty are Level IV and Level VI problems (63% and 55% respectively). This can be due to the fact that most of the practice received in class rarely covered these types of questions. It is interesting to see in this class that students are able to answer basic conceptual problems but have some difficulty in justification type problems based on their own conceptual understanding of the problems. It is of interest to note that the students
in Class 2 showed greater collaboration and participation during group work, compared to Class 1. This class also showed a better grasp of Level V problems (class average of 90%). In the past assessments, both classes were usually within the same average range with Class 1 at times scoring higher than Class 2. This was the first instance where there was a larger difference in their class averages.

Table 4.7.
Bloom’s Taxonomy Results: First Assessment: Equilibrium – Class 2

<table>
<thead>
<tr>
<th>Level (# of questions):</th>
<th>I (4)</th>
<th>II (7)</th>
<th>III (12)</th>
<th>IV (3)</th>
<th>V (2)</th>
<th>VI (2)</th>
<th>Grade:</th>
</tr>
</thead>
<tbody>
<tr>
<td>David</td>
<td>3</td>
<td>2</td>
<td>10</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>92%</td>
</tr>
<tr>
<td>Jerry</td>
<td>3</td>
<td>5</td>
<td>10</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>93%</td>
</tr>
<tr>
<td>Jiannis</td>
<td>4</td>
<td>7</td>
<td>9</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>94%</td>
</tr>
<tr>
<td>Karl</td>
<td>3</td>
<td>5</td>
<td>8</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>85%</td>
</tr>
<tr>
<td>Moes</td>
<td>3</td>
<td>4</td>
<td>7</td>
<td>3</td>
<td>2</td>
<td>0</td>
<td>86%</td>
</tr>
<tr>
<td>Peter</td>
<td>1</td>
<td>4</td>
<td>7</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>84%</td>
</tr>
<tr>
<td>Ron</td>
<td>4</td>
<td>7</td>
<td>12</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>100%</td>
</tr>
<tr>
<td>Sinbad</td>
<td>3</td>
<td>5</td>
<td>12</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>92%</td>
</tr>
<tr>
<td>Sterling</td>
<td>4</td>
<td>6</td>
<td>5</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>84.5%</td>
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<td>Twain</td>
<td>4</td>
<td>4</td>
<td>10</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>93%</td>
</tr>
<tr>
<td>Average</td>
<td>80%</td>
<td>70%</td>
<td>75%</td>
<td>63%</td>
<td>90%</td>
<td>55%</td>
<td>90.4%</td>
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</table>

Note: Bloom’s Taxonomy Levels and corresponding quiz questions:
Level I: Multiple Choice 3, Free Response 1.a, 2.b, 3.a
Level II: Multiple Choice: 1, 2, 4, 7, 10, Free Response 3.d(i), 3.e(i)
Level III: Multiple Choice 5, 6, 8, 9 Free Response 1.b(i), 1.b(ii), 1.c, 1.d, 2.a(i), 2.a(ii), 2.c(ii), 3.c(ii)
Level IV: Free Response 1.e, 2.c(i), 2.d
Level V: Free Response 3.b, 3.c(i)
Level VI: Free Response 3.d(ii), 3.e(ii)

Second unit: Class 1. (Table 4.8) On the second unit: Acids and Bases, Class 1 showed an improvement in Level IV and level VI questions. On the first assessment relative to Level IV and VI questions, Class 1 averaged a 43% and 35%, respectively; whereas on this assessment Class 1 averaged 68% and 65%. There seems to be a more consistent degree of competence from Level I to VI questions for these results compared to results reported above for the first unit. This could be due to the fact that students received more practice on Level VI questions after the results of the first quiz. These students also showed some improvement in Level I
questions (65% on the first assessment and 80% on this assessment). Similar to the first quiz, there was no student that stood out as doing poorly in this assessment. Encouraging was more students who were able to correctly answer Level VI questions. Students were also given techniques during in-class practice on how to look at Level IV type questions, which could account for the improvement in their performance for Level IV questions.

Table 4.8.
Bloom’s Taxonomy Results: Second Assessment: Acids & Bases – Class 1

<table>
<thead>
<tr>
<th>Level (# of questions):</th>
<th>I (6)</th>
<th>II (5)</th>
<th>III (9)</th>
<th>IV (4)</th>
<th>V (2)</th>
<th>VI (4)</th>
<th>Grade:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cornelius</td>
<td>4</td>
<td>3</td>
<td>5</td>
<td>4</td>
<td>1</td>
<td>4</td>
<td>88%</td>
</tr>
<tr>
<td>Enzo</td>
<td>3</td>
<td>2</td>
<td>4</td>
<td>3</td>
<td>1</td>
<td>4</td>
<td>81%</td>
</tr>
<tr>
<td>Larry</td>
<td>4</td>
<td>3</td>
<td>5</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>81%</td>
</tr>
<tr>
<td>Lester</td>
<td>2</td>
<td>4</td>
<td>5</td>
<td>3</td>
<td>0</td>
<td>3</td>
<td>81%</td>
</tr>
<tr>
<td>Luke</td>
<td>4</td>
<td>4</td>
<td>8</td>
<td>4</td>
<td>1</td>
<td>4</td>
<td>93%</td>
</tr>
<tr>
<td>Rick</td>
<td>4</td>
<td>4</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>79%</td>
</tr>
<tr>
<td>Terrence</td>
<td>6</td>
<td>5</td>
<td>9</td>
<td>4</td>
<td>2</td>
<td>4</td>
<td>100%</td>
</tr>
<tr>
<td>Victor</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>83%</td>
</tr>
<tr>
<td>Yuri</td>
<td>5</td>
<td>5</td>
<td>6</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>91%</td>
</tr>
<tr>
<td>Zeke</td>
<td>5</td>
<td>1</td>
<td>7</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>84%</td>
</tr>
</tbody>
</table>

Average: 68% 72% 63% 68% 50% 65% 86.1%

Note: Bloom’s Taxonomy Levels and corresponding quiz questions:
Level I: Multiple Choice 1, 4, 7, Free Response 1.b(i), 2.b, 3.a
Level II: Multiple Choice 2, 8, 9, 10, Free Response 2.d(ii)
Level III: Multiple Choice 3, 5, Free Response 1.b(iii), 1.c(i), 1.c(iii), 2.a, 2.d(i), 2d(iv), 3.d
Level IV: Free Response 1.b(ii), 1.c(ii), 2.d(iii), 3.b
Level V: Multiple Choice 6, Free Response 3.e
Level VI: Free Response 1.a, 2.c, 3.c(i), 3.c(ii)

Second unit: Class 2. (Table 4.9) On the second unit of Acids and Bases, Class 2 also showed a major improvement on Level IV and Level VI questions. On the first assessment, this class averaged a 63% and 55%, respectively for Level IV and VI questions. However, on this assessment, the class averaged a 80% and 68% for Level IV and Level VI questions, respectively. Compared to the first assessment, this class did much better on Level IV questions in comparison with the other section. Class 2 averaged a 43% on the first assessment and an 80% on the second assessment, still higher than 68% from Class 1. These students were also
consistent in their improved performance with Level III questions, showing some improvement when compared with the first assessment (Class 1 averaged 75% in the first assessment, and an 82% in the second assessment). They showed a decrease however in their Level V questions, where they received a 90% in the first assessment, but only a 45% on this assessment. This is perhaps due to the fact that most of the practice they received in this chapter focused on Level III, IV, and VI problems. Also similar to the first assessment, there is no one student that directly stands out as having a difficult time in this chapter. It is of interest to note that in both sections, Level V questions showed a significant drop in correct answers (50% for Class 1 and 45% for Class 2). It appears, that the type of questions covered in the activity sheets when problem-solving occurred has a direct impact on how well they can solve each level of problems from Bloom’s Taxonomy.

Table 4.9.
Bloom’s Taxonomy Results: Second Assessment: Acids & Bases – Class 2

<table>
<thead>
<tr>
<th>Level (# of questions):</th>
<th>I (6)</th>
<th>II (5)</th>
<th>III (9)</th>
<th>IV (4)</th>
<th>V (2)</th>
<th>VI (4)</th>
<th>Grade:</th>
</tr>
</thead>
<tbody>
<tr>
<td>David</td>
<td>4</td>
<td>3</td>
<td>8</td>
<td>4</td>
<td>1</td>
<td>2</td>
<td>91%</td>
</tr>
<tr>
<td>Jerry</td>
<td>5</td>
<td>4</td>
<td>8</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>91%</td>
</tr>
<tr>
<td>Jiannis</td>
<td>4</td>
<td>2</td>
<td>8</td>
<td>4</td>
<td>1</td>
<td>3</td>
<td>89%</td>
</tr>
<tr>
<td>Karl</td>
<td>3</td>
<td>3</td>
<td>6</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>81%</td>
</tr>
<tr>
<td>Moes</td>
<td>5</td>
<td>4</td>
<td>6</td>
<td>3</td>
<td>0</td>
<td>3</td>
<td>85%</td>
</tr>
<tr>
<td>Peter</td>
<td>4</td>
<td>2</td>
<td>6</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>81%</td>
</tr>
<tr>
<td>Ron</td>
<td>6</td>
<td>5</td>
<td>9</td>
<td>4</td>
<td>1</td>
<td>4</td>
<td>98%</td>
</tr>
<tr>
<td>Sinbad</td>
<td>3</td>
<td>2</td>
<td>7</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>79%</td>
</tr>
<tr>
<td>Sterling</td>
<td>6</td>
<td>4</td>
<td>7</td>
<td>4</td>
<td>1</td>
<td>4</td>
<td>95%</td>
</tr>
<tr>
<td>Twain</td>
<td>4</td>
<td>5</td>
<td>9</td>
<td>4</td>
<td>1</td>
<td>4</td>
<td>95%</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td><strong>73%</strong></td>
<td><strong>68%</strong></td>
<td><strong>82%</strong></td>
<td><strong>80%</strong></td>
<td><strong>45%</strong></td>
<td><strong>68%</strong></td>
<td><strong>88.5%</strong></td>
</tr>
</tbody>
</table>

*Note: Bloom’s Taxonomy Levels and corresponding quiz questions:*
Level I: Multiple Choice 1, 4, 7, Free Response 1.b(ii), 2.b, 3.a
Level II: Multiple Choice 2, 8, 9, 10, Free Response 2.d(ii)
Level III: Multiple Choice 3, 5, Free Response 1.b(iii), 1.c(i), 1.c(iii), 2.a, 2.d(i), 2d(iv), 3.d
Level IV: Free Response 1.b(ii), 1.c(ii), 2.d(iii), 3.b
Level V: Multiple Choice 6, Free Response 3.e
Level VI: Free Response 1.a, 2.c, 3.c(i), 3.c(ii)
**Last Assessment: Class 1.** (Table 4.10) On the last assessment, the test included a combination of items from three different units. The length of the test may have something to do with the lower scores in this assessment. Although the scores are lower, the students still did relatively well for a three-unit assessment (Class 1 averaged an 83%). There was a drop in Level IV questions, as well as a surprising drop in Level III questions (33% and 58%, respectively). There was however a good number of questions answered correctly for both Level II and Level VI questions (72% and 74%, respectively). This shows that the practice the students received previously on Level VI questions definitely helped them in the last three units. The grades the students received were also fairly consistent across the three assessments, many of which are different from how they did in past assessments.

Table 4.10.
Bloom’s Taxonomy Results: Last Assessment: Equilibrium, Acids & Bases, Buffers & Salts – Class 1

<table>
<thead>
<tr>
<th>Level (# of questions):</th>
<th>I (7)</th>
<th>II (8)</th>
<th>III (13)</th>
<th>IV (7)</th>
<th>V (3)</th>
<th>VI (6)</th>
<th>Grade:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cornelius</td>
<td>6</td>
<td>7</td>
<td>6</td>
<td>3</td>
<td>1</td>
<td>4</td>
<td>86%</td>
</tr>
<tr>
<td>Enzo</td>
<td>3</td>
<td>6</td>
<td>9</td>
<td>3</td>
<td>0</td>
<td>3</td>
<td>79%</td>
</tr>
<tr>
<td>Larry</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>5</td>
<td>65%</td>
</tr>
<tr>
<td>Lester</td>
<td>6</td>
<td>6</td>
<td>5</td>
<td>3</td>
<td>1</td>
<td>5</td>
<td>83%</td>
</tr>
<tr>
<td>Luke</td>
<td>6</td>
<td>7</td>
<td>11</td>
<td>4</td>
<td>3</td>
<td>6</td>
<td>92%</td>
</tr>
<tr>
<td>Rick</td>
<td>2</td>
<td>7</td>
<td>5</td>
<td>0</td>
<td>1</td>
<td>5</td>
<td>79%</td>
</tr>
<tr>
<td>Terrence</td>
<td>7</td>
<td>8</td>
<td>12</td>
<td>4</td>
<td>3</td>
<td>6</td>
<td>97.5%</td>
</tr>
<tr>
<td>Victor</td>
<td>7</td>
<td>7</td>
<td>8</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>86%</td>
</tr>
<tr>
<td>Yuri</td>
<td>7</td>
<td>6</td>
<td>9</td>
<td>2</td>
<td>2</td>
<td>5</td>
<td>91%</td>
</tr>
<tr>
<td>Zeke</td>
<td>1</td>
<td>2</td>
<td>7</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>69%</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td>69%</td>
<td>74%</td>
<td>58%</td>
<td>33%</td>
<td>43%</td>
<td>72%</td>
<td>83%</td>
</tr>
</tbody>
</table>

*Note: Bloom’s Taxonomy Levels and corresponding quiz questions:*
- Level I: Multiple Choice: 3, 4, 5, 12, 18, 19, 20
- Level II: Multiple Choice: 8, 11, 13, 14, 16, Free Response: 1.a(i), 2.a(i), 3.b
- Level III: Multiple Choice: 1, 2, 6, 10, 15, Free Response: 1.a(ii), 1.a(iii), 2.a(ii), 2.c, 2.d, 3.c, 3.d, 4.a
- Level IV: Multiple Choice: 7, 17, Free Response: 1.b(ii), 1.b(iii), 3.e, 4.c, 4.d
- Level V: Multiple Choice: 9, Free Response: 1.c, 2.b
- Level VI: Free Response: 1.b(i), 2.c, 3.a, 4.b, 4.e(i), 4.e(ii)
In summary, it seems like Class I students excelled in Level III problems in the first assessment (73%), Level II problems in the second assessment (72%), and Level II and Level VI questions in this last assessment (74% and 72%, respectively).

**Last Assessment: Class 2.** (Table 4.11) Class 2 students showed a fairly similar trend as observed for Class I students. Students from both sections seemed to have struggled in Level IV and Level V questions (33% and 43% for Class 1, while 47% and 50% for Class 2). Even with the combination of three different units in this one assessment, students still did relatively well (Class 2 averaged an 86.5%).

Table 4.11.
Bloom’s Taxonomy Results: Last Assessment: Equilibrium, Acids & Bases, Buffers & Salts – Class 2

<table>
<thead>
<tr>
<th>Level (# of questions):</th>
<th>I (7)</th>
<th>II (8)</th>
<th>III (13)</th>
<th>IV (7)</th>
<th>V (3)</th>
<th>VI (6)</th>
<th>Grade:</th>
</tr>
</thead>
<tbody>
<tr>
<td>David</td>
<td>5</td>
<td>6</td>
<td>5</td>
<td>5</td>
<td>2</td>
<td>5</td>
<td>84.5%</td>
</tr>
<tr>
<td>Jerry</td>
<td>5</td>
<td>5</td>
<td>6</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>85%</td>
</tr>
<tr>
<td>Jiannis</td>
<td>6</td>
<td>6</td>
<td>12</td>
<td>6</td>
<td>1</td>
<td>4</td>
<td>92%</td>
</tr>
<tr>
<td>Karl</td>
<td>4</td>
<td>3</td>
<td>8</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>78%</td>
</tr>
<tr>
<td>Moes</td>
<td>5</td>
<td>4</td>
<td>7</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>79%</td>
</tr>
<tr>
<td>Peter</td>
<td>7</td>
<td>6</td>
<td>7</td>
<td>4</td>
<td>1</td>
<td>4</td>
<td>89%</td>
</tr>
<tr>
<td>Ron</td>
<td>7</td>
<td>8</td>
<td>13</td>
<td>5</td>
<td>3</td>
<td>6</td>
<td>99%</td>
</tr>
<tr>
<td>Sinbad</td>
<td>6</td>
<td>4</td>
<td>6</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>79%</td>
</tr>
<tr>
<td>Sterling</td>
<td>7</td>
<td>3</td>
<td>10</td>
<td>4</td>
<td>2</td>
<td>3</td>
<td>89%</td>
</tr>
<tr>
<td>Twain</td>
<td>5</td>
<td>6</td>
<td>11</td>
<td>3</td>
<td>1</td>
<td>5</td>
<td>90%</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td><strong>81%</strong></td>
<td><strong>64%</strong></td>
<td><strong>65%</strong></td>
<td><strong>47%</strong></td>
<td><strong>50%</strong></td>
<td><strong>63%</strong></td>
<td><strong>86.5%</strong></td>
</tr>
</tbody>
</table>

*Note:* Bloom’s Taxonomy Levels and corresponding quiz questions:
Level I: Multiple Choice: 3, 4, 5, 12, 18, 19, 20
Level II: Multiple Choice: 8, 11, 13, 14, 16, Free Response: 1.a(i), 2.a(i), 3.b
Level III: Multiple Choice: 1, 2, 6, 10, 15, Free Response: 1.a(ii), 1.a(iii), 2.a(ii), 2.c, 2.d, 3.c, 3.d, 4.a
Level IV: Multiple Choice: 7, 17, Free Response: 1.b(ii), 1.b(iii), 3.e, 4.c, 4.d
Level V: Multiple Choice: 9, Free Response: 1.c, 2.b
Level VI: Free Response: 1.b(i), 2.e, 3.a, 4.b, 4.e(i), 4.e(ii)

In summary, students in Class 2 excelled in Level V questions in the first assessment (class average of 90%), Level III and Level IV questions in the second assessment (class average of 82% and 80%, respectively), and Level I questions in the last assessment (class average of
Although there was a general improvement in Level VI questions, this was not their best section in all three assessments. This probably means that students need a little more work in how to justify their answers based on conceptual understanding. One interesting observation is that there are times that students chose the wrong answer, but a good and proper justification that would not get credit due to a wrong conclusion in the first place. This should probably be taken into account when thinking about ways to improve student performance in Level VI questions.

**Summary of Group Interviews.** Students have shown good learning outcomes. It would be interesting to see what they thought about the use of the iPads as it relates to their development of conceptual understanding. Toward that end, the group interviews help in looking at what the students thought in terms of how the iPad relates to how they learned the topics covered in this research study. There was a total of three groups from each class that was interviewed. Students were interviewed in their tables and chose to answer some or all of the questions. Examples are presented of the students’ interview responses.

**Class 1: summary of quotations.** The thing we like about the iPad is that it is able to encourage people to stay focused. Students come in first period on Monday and they are forced to focus because their work is being projected. We want to work to help our group and help the class arrive at an answer so it forces us to keep focus. The one thing though is that the text box is too small and you would have to zoom in to be able to see work clearly or to write things out clearly. The organization aspect though is great. You can have your notes outlined and organized without much work and you do not lose things since we can just take a picture of worksheets and compile it into the notes. Before we used the iPad in the class this way, there was a lot less focus. Students can just be playing games on the computer, there was a lot less involvement in terms of class participation, it’s always the same few kids. With the use of this
method, we were more focused. We are also forced to write detailed solutions out so when we get home it’s easier to follow. Feedback is also amazing! We can get input from everyone! We definitely did better, not sure about score wise but in terms of learning and understanding, we thought the last chapters were easier when we used this method because we had way more practice and saw more problems reflective of what we were assessed on. We also got through a lot more examples because we were all working together.

**Class 2: summary of quotations.** The thing we like about the iPad is the ability to project them on the screen and receive live feedback. This ensures that we are on the right track. It was really easy to know what is being shared and makes information easily accessible. It is easier to explain what others are thinking through the projection instead of trying to verbally explain what is going on in the problem. It gives us the capability to follow different methods of solving problems in real time, there is a good feeling to group work making problem-solving easier to follow. The interactivity helps us keep focus in class, it is difficult to lose focus when people are working together towards a common goal. It encourages more cooperation in terms of having people critique each other’s work. There is always temptation to get distracted because the iPads have games on it, but when it is projected and full class discussion is going on, it becomes really obvious when you are doing something you are not supposed to do. One of the most useful things that can be used for studying is that all notes are congregated in one place, it is organized, makes it easy to find stuff, so makes students much more prepared for problems. Students usually lose their notes, so this method makes it extremely difficult to lose notes for the class. With the projection, discussions were a whole lot faster giving us more time to work on more problems, thus getting more practice. We had a whole lot more practice so there was definitely a larger understanding in terms of how to approach different types of problems and
how to solve them. It was also easier to ask questions on the spot without having to disrupt class, by stopping the teacher and asking questions.
CHAPTER 5

DISCUSSION & CONCLUSION

The intent of this study was to look at the process of blending iPad technology with classroom activities in an 11th grade Chemistry classroom with respect to each of the following research questions:

1.) What are the dynamics of student interactions in collaborative learning when augmented with the iPad-enabled constructivist learning?

2.) What are the students’ perceptions of social interaction when the iPad-enabled constructivist learning is used to promote collaborative learning in the classroom?

3.) How do students develop shared understandings of a concept during iPad-enabled constructivist learning, and how does it relate to learning outcomes?

In order to accomplish this goal, mixed methods were used to gain insight on student perceptions through surveys and interviews, including classroom observations made by other teachers, as well as an analysis of classroom learning assessments (Creswell, 2014). The results of this study may not generalize beyond the 20 students who participated due in part to the fact that it is fairly specific to an all boys’ private school in New York City; but it may have implications that go beyond the participants in this study.

Research Question 1: How does the process of blending iPad technology with classroom constructivist learning activities in 11th grade Chemistry classroom influence classroom practice and learning outcomes, with respect to the dynamics of student interaction in collaborative learning when augmented with the iPad-enabled constructivist learning?

Results from the classroom observations are based on four observation days for each class. The overall conclusions based on the observations showed that the students were on task
and either engaged individually or as a group during classroom activities. From the evidence based on teacher observations, the students were actively engaged in communication, whether they were working individually or in a group, in both cases they were still engaged in classroom discussion. This finding is in line with previous findings on computer stimulated collaborative learning (Zhan, Fong, Mei & Liang, 2015). This also shows that the use of technology is quite effective in communication as would be predicted from cognitive theory of multimedia learning (Paivio, 1991).

With the increasing use of technology in the classroom, it is very important that interpersonal communication is not lost. The ability to project work on the board allows for students to have a common experience and a place for communication to occur. Teachers who observed the class noted that the class exploded with conversation. Strijbos (2016) defined collaborative learning as: “a learning phenomenon where individuals in a social constellation within a physical and/or virtual environment, interact on the same or different aspects of a shared task to accomplish implicit or explicit shared and individual learning goals” (p.302). In the case of this classroom, students are allowed to interact in different aspects of a shared task. Students were given problems to solve and they could work out different solutions to reach a shared learning goal. The results from the teacher observations coincided with the study by Arama, Macedo, Bendella and Santos (2015), which noted that the success of collaborative learning experience relies heavily on effective functioning of learning groups. The contribution of each learner to the group, and the interaction between the learners, is the key to success, as was evident in this study. Particularly, this can be seen with Ron’s behaviors in Class 2. When he moved to a different table, his behavior changed and he worked mostly individually, rather than working collaboratively.
Although the iPad use in this study did not rely solely on apps, but rather was used as a method of creating a space for conversation to occur, the apps used in this study (Notability, Seesaw, and Kahoot!) certainly did contribute to the motivation for collaboration. One teacher observer noted the competitive aspect of the projection of information on the large screen, and apps like Kahoot! certainly do contribute a lot to the competitiveness seen in the classroom.

**Research Question 2: What are the students’ perceptions of social interactions when the iPad-enabled constructivist learning is used to promote collaborative learning in the classroom?**

Students have a very strong opinion about the concept of community when they use iPads. They showed great appreciation for feedback and communication when the iPad are used. Students still value the face-to-face interaction over communicating through virtual interactions. This is supported by the way the iPad can be used in the classroom that utilizes virtual aspects without losing the face-to-face interaction.

One of the greatest strengths of technology is the use of imagery, and how properly created spaces where this could be maximized enhances learning (Chandler & Sweller, 1991). This could definitely be seen in how the students interacted with the projection of their work on their screen. This created a new space for interaction that they did not have before. According to Bandura (1977) social learning occurs most effectively with constant social interactions. Students perceived the use of the iPad in the classroom as a good tool for communication as well as a good tool for collaborative efforts in problem-solving. Students saw the opportunity to talk to people outside of their group, but work in their own group at the same time. This showed that proper flexibility in group use of the iPad promoted the ability to create relationships among other groups of learners on the same activity (Moore, 1998).
Students also felt an improved motivation to participate with interactive apps such as Kahoot! Among other sources of evidence, this shows that there is a considerable benefit in using apps in the classroom to create an environment that fosters healthy competition, as well as an individual-centered space where they can push themselves to learn.

Hirsch and Ng (2016) describes collaborative learning using computers as members interacting by sharing experiences and taking on asymmetrical roles. This can be seen in this study throughout the group activities when students were working together on a problem where they participated in active roles, such as writing out the problem or deciphering the problem or actively engaged in listening to the discussion. Among all of these different ways, they were engaged and motivated to learn.

Research Question 3: How do students develop shared understandings of a concept during iPad-enabled constructivist learning, and how does it relate to learning outcomes?

Students’ learning evaluations showed strong learning outcomes in all three units of the course. As was pointed out by Mayer (2002) multiple modalities must be engaged for effective learning outcomes. Moreover, Edelson (1997) comments on the use of visualization, communication and collaboration tools for effective integration. This study has shown that the iPad’s flexibility as a tool favoring visualization, communication, and collaboration certainly aided in student participation in the classroom as well as created a space where collaboration could flourish.

Arama, Macedo, Bendella and Santos (2015) showed that there is an improvement of skills using technology in collaboration. Although generalizations from this study are limited, the results here do show that students were fully engaged in the problem-solving process. This can be seen in the results reported for research question one, and they have very good learning
outcomes as evidenced by their learning assessment scores. Based on evidence from the group interviews, students found the ability to keep track of how they solve a particular problem helpful in solving problems individually later on in the unit. They also attributed much of their satisfaction with and success in learning due to the feedback and constant communication in the classroom, especially their understanding of problem-solving. Much of their successful performance was also attributed to how much practice they were able to complete in the classroom. The capacity to project their work on a screen for others to see avoids having students “stuck” on a problem for very long as they are free to have the option of working at their own pace, or asking anyone in the room about how to proceed. Hence, they are able to work out problems much faster, but also generate an understanding of why something happens as opposed to waiting for feedback from their worksheets, which may or may not answer their immediate questions at a particular moment in time.

Implications

Technology Use. It is clear that the iPad is not being used to its full potential in many classroom applications presently, although there are multiple ways and means of using the iPads in the classroom, the interplay between the virtual and physical classroom, in many cases has not been brought together. Among the advantages of this model of iPad use as presented in this study are the benefits of the collaborative nature of a physical classroom and opportunity for students to interact in both worlds (virtual and in-person).

Teachers. The iPad provides substantial flexibility in its uses and functions. It has a unique way of allowing for virtual interaction as well as face-to-face interaction. There are numerous apps that provide ways for students to practice a skill or concept, but it is very limiting when it comes to collaborative learning. There are very few apps available, when it comes to
problem-solving, but the iPad provides features such as AirPlay that can turn the classroom into a place where students and teachers can interact simultaneously.

The data from this study also shows that the role of the teacher is very important in the use of technology in the classroom. The way that the class is designed, as well as the pattern of grouping, and how the teacher interacts with the students all have a role in the success or failure of the incorporation of technology in the classroom. Students who tend to work individually, when they work in a table where they feel comfortable, tend to participate in group collaboration. This can be seen in the difference in Ron’s participation when he changed from one table to another. It is recommended therefore that teachers think about the way groups are structured as this would definitely make a difference in group collaboration.

Personally, I consider myself tech savvy, and thus I did a lot of the troubleshooting myself. Some issues that may occur is the maintenance of the iPads, if the Wi-Fi is not on the same channel, or if the software of the iPad has not been updated, AirPlay will not work. There are instances when apps will crash or refuse to load, so some flexibility in how technology is used needs to be considered when designing group activities. In the case of my school, although the iPads were maintained by the tech department, the troubleshooting in class usually falls on the teacher. Some ways I have found around the problem is to make sure that when the students’ iPads are updated, the AirServer on the laptop needs to be up to date as well. If the iPads are updated when they receive the request for updates, it usually fixes a lot of the bugs in the program. Another way I found around the Wi-Fi problem is to create a mobile hotspot in the classroom specific for the class, and this usually solves any of the problems involving the ability to AirPlay.
These problems in technology are consistent with studies as to why teachers have been hesitant to use more technology in the classroom (Rodrigues, 2007), few have the same degree of competence in troubleshooting that I have. There is a definite need for more professional development directed at strategies for incorporating technology in the classroom.

**Students.** Students show great motivation in participating in collaborative settings. This study showed that they did prefer the use of technology in the classroom. Compared to prior learning experiences over six years with similar students in the same school, the quality of group collaboration and learning outcomes were at least as good, and in some cases better, than achieved in previous years. Data also showed that students prefer face-to-face communication compared to virtual communication so a proper balance of both technology and classroom time would be beneficial for them. This is especially true with the emergence of blended learning and the balance that needs to be set between the online classroom and the physical classroom. According to Garrison and Ganuka, (2003) the real test of blended learning is the effectiveness of the integration of both the online learning and the face to face classroom interactions.

In terms of distractions, students have noted that when the iPads were used in a setting that promoted collaboration, distractions were not as much of an issue. The pace and timing of the class also has something to do with their engagement with the topic. The data shows that the classroom setting (particularly adequate individual autonomy and flexibility in use of the technology) is very important in terms of their level of engagement in the class.

In terms of feedback, students feel that the direct and immediate feedback was more useful to their learning compared to when work had to be submitted, graded and then returned. Feedback can also be received in multiple ways: from the teacher or from their peers.
Science Education. The use of the iPads in the classroom is limiting when students are just given apps to explore. The use of apps defeats the purpose of having a collaborative classroom learning environment. The way the study was designed allowed for the use of apps in a collaborative setting. The creation of a space where students are not limited by what they see on their own screen opened the opportunity for conversation beyond just the student and the device.

The flexibility of the use of the iPad in the classroom should open new ways of looking and thinking about how students interact with each other through both the use of the device and through interactions with their peers in the classroom. The beauty about science learning with the iPads is that the ability to write solutions to mathematical equations that is very difficult to collaborate on paper and online on computers. In AP Chem, much of the difficulty lies in ways to visualize and solve complex problems. Using Notability and AirPlay allows students to not only look at steps to solving problems, but look at different ways of solving problems as well.

Recommendations

Data Sources. The data for this study was generated from a single-gender private school. These students have been using the iPads for the last three years and can be considered quite tech savvy. These students have also been in my classroom the previous year and are used to my teaching style. In future studies, I believe that a more diverse sample would be beneficial to gain broader insights and improve generality of the findings. Future studies can also look at how iPads are integrated in the teaching of other subjects, such as English or History where this type of application may not necessarily be as useful.
It would also be interesting to see how students adapt to the different ways technology is used in each classroom and see if narrowing down the use of technology to a uniform standard may be more of a benefit for students.

In addition, the study ended with group interviews, which provided information to tie in research questions two and three. Future studies can include more in-depth individual interviews to create a richer description of how each student felt about the use of iPads in the classroom. Another recommendation would be to include other teachers’ voices in the study to generate a deeper understanding on the integration of iPads in the classroom.

**Classroom Setting.** This study was conducted using three Chemistry textbook chapter units. The timing of the AP exams as well as the difficulty of the chapters created a limit as to how much each unit could be expanded. It would be interesting to see more if a longitudinal study from the beginning of the school year until the end of the school year. It would be interesting to see if there is a difference in the easier content within the same discipline compared to the more difficult topics, and the role the iPad plays in each of the different types of units.

In this classroom setting, there is less time afforded for AP compared to other schools, because it does not offer the double period meeting times that is standard for most AP classes. Thus, there is a big constraint as to what needs to get done in a class. It would be interesting to see the applications of this study in a regular AP class setting where each class period receives more time allotted for exploration. The timing of the study also occurred towards the end of the school year, whereas activities, projects, and labs occur towards the beginning of the semester. It would be interesting to see what the students thought of the use of the iPad in different types of activities as well, including blog posts, design, and projects.
Class 1 and 2 also meets at different times in the two-week period and they were also observed during learning of different units. It would be beneficial if observations can occur on the same day by the same person on the same topic.

**Suggestions for future research.** One of the data sets that was collected in this study possibly worthy of further exploration is the stored recording of each iPad screen that was projected in the classroom, and the process in which the students looked at the problems. Questions such as what were they discussing in each particular step of the problem, and if there were any particular steps in the problem solving that were difficult in all groups, could be explored further. Probing these further could increase the understanding of problem-solving from the students’ perspective.

**Summary**

In this chapter, I presented the discussions, implications and recommendations for future studies. What I found was that students could collaborate in group activities using the iPad. This collaboration came in different forms, either working on the iPad or having physical conversations with people around the room. The benefits of the collaborative setting were shown in their learning outcomes and favorable opinions obtained in the group interviews. The results of this study have implications for teachers and students as well as science education in general regarding the use of iPads in the classroom. Finally, I offered some recommendations for future studies on iPad integration in the classroom.
References


Galletta, A. (2013). *Mastering the semi-structured interview and beyond: From research design to analysis and publication*. NYU Press.


Appendix A. Momentary Time Sampling Form

Student’s Name: ______________  Date: ______________  
Period: ______________  Section: ______________  

<table>
<thead>
<tr>
<th>Behavior Definition:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Cooperative behavior – defined a task-oriented group behavior. Were the students listening to each other? Working together? On-task? Were they talking to each other?</td>
<td></td>
</tr>
<tr>
<td>(2) Noncooperative behavior – defined as competitive behaviors. Were the students talking over each other? Were they working against a common goal? Were they off-task? Were they discussing things not relevant to the problem at hand?</td>
<td></td>
</tr>
<tr>
<td>(3) Individual task-oriented behavior – defined as working alone on task.</td>
<td></td>
</tr>
<tr>
<td>(4) Individual non-task behavior and confusion – defined as not participating in group activities and not working individually.</td>
<td></td>
</tr>
</tbody>
</table>

Total Observation Time: 30 mins  Length of Interval: 30 secs

<table>
<thead>
<tr>
<th>Date</th>
<th>Interval #</th>
<th>Total times behavior occurred</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 2 3 4 5 6 7 8 9 10</td>
<td></td>
</tr>
<tr>
<td>(1-4)</td>
<td></td>
<td>1- 2- 3- 4-</td>
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</table>

<table>
<thead>
<tr>
<th>Date</th>
<th>Interval #</th>
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<tr>
<td></td>
<td>1 2 3 4 5 6 7 8 9 10</td>
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<td>(1-4)</td>
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<tr>
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<tr>
<td></td>
<td>1 2 3 4 5 6 7 8 9 10</td>
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<tr>
<td>(1-4)</td>
<td></td>
<td>1- 2- 3- 4-</td>
</tr>
</tbody>
</table>
Appendix B. Teacher Perception Questions

1. What are your observations on the level of participation that the students have in the group activities?

2. From your experience as a teacher, what are your thoughts on the reasoning behind the levels of participation observed?

3. Do you think this kind of participation can be replicated in other classes?

4. Is there anything that can be improved that can enhance their collaboration in the classroom?

5. What are your thoughts on how the students are creating and constructing knowledge from the group activity?
Appendix C. Students’ Perception Survey

Instructions: Select one level of agreement for each statement to indicate how you feel.

SD = Strongly Disagree, D = Disagree, U = Undecided, A = Agree, SA = Strongly Agree

<table>
<thead>
<tr>
<th>Statement</th>
<th>SD</th>
<th>D</th>
<th>U</th>
<th>A</th>
<th>SA</th>
</tr>
</thead>
<tbody>
<tr>
<td>When using iPads in group activities…</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 I feel a sense of community</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 Learning becomes interactive</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 Posting questions to my peers help me understand concepts better</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 I am able to get faster feedback from my peers</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 I am able to get faster feedback from my instructor</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 I am able to communicate effectively</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7 I am able to connect with peers more easily than face-to-face</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8 I increase my participation in classes when I am allowed to contribute through the use of the iPad</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9 I learn best without iPads (R)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 More classroom learning should include interactive communicative experiences using the iPad</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11 I learn more when I regulate my own learning experience and seek information on things I want to learn about.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12 I find the iPad very distracting and does not allow me to focus on class activities (R)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13 I find that group activities with the iPad help me learn better than working alone</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14 I feel more confident about what I learned when using the iPads</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15 I find learning more exciting when using apps like Kahoot!</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix D. Post-Survey Interview Questions

1. Do you feel like the iPad can be used as a good communication tool?
2. Do you feel more motivated to participate in class with the way the iPad is used?
3. Are you able to communicate more/less when using the iPad in the classroom?
4. Would you recommend the method we use of iPads to your other classes? Why or why not?
5. How do you feel about feedback when the iPad is in use compared to a traditional classroom?
6. How do you feel about possible distractions when using this as a communication tool in the classroom?
7. Is the interactive feature of the iPad a motivation? Or is it distracting?
Appendix E: First Assessment: Equilibrium

I. Multiple Choice

1.) PCl₃(g) + Cl₂(g) ⇌ PCl₅(g) + energy

Some PCl₃ and Cl₂ are mixed in a container at 200º C and the system reaches equilibrium according to the reaction above. Which of the following causes an increase in the number of moles of PCl₅ present at equilibrium?

I. Decreasing the volume of the container
II. Raising the temperature
III. Adding a mole of He gas at constant volume

(A) I only
(B) II only
(C) I and III
(D) II and III

2.) In which of the following systems would the number of moles of the substances present at equilibrium NOT be shifted by a change in the volume of the system at a constant temperature?

(A) N₂(g) + 3H₂(g) ⇌ 2NH₃(g)
(B) N₂(g) + 2O₂(g) ⇌ 2NO₂(g)
(C) N₂O₄(g) ⇌ 2NO₂(g)
(D) NO(g) + O₃(g) ⇌ NO₂(g) + O₂(g)

3.) Which of the following is the correct equilibrium expression for the hydrolysis of CO₃²⁻?

(A) K= [HCO₃⁻] / [CO₃²⁻][H₂O⁺]
(B) K= [HCO₃⁻][OH⁻] / [CO₃²⁻]
(C) K= [CO₃²⁻][OH⁻] / [HCO₃⁻]
(D) K= [CO₃²⁻] / [CO₂][OH⁻]

4.) 2NO(g) + O₂(g) ⇌ 2NO₂(g) ΔH<0

Which of the following changes alone would cause a decrease in the value of Kₐeq for the reaction represented above?

(A) Decreasing the temperature
(B) Increasing the temperature
(C) Decreasing the volume of the reaction vessel
(D) Increasing the volume of the reaction vessel

5.) H₂C₂O₄ + 2H₂O ⇌ 2H₂O⁺ + C₂O₄²⁻

Oxalic acid is a diprotic acid with K₁= 5.36x10⁻² and K₂= 5.3x10⁻⁵. For the reaction above, what is the equilibrium constant?

(A) 5.36x10⁻²
(B) 5.3x10⁻⁵
(C) 2.8x10⁻⁶
(D) 1.9x10⁻¹⁰

6.) 2SO₂(g) + O₂(g) ⇌ 2SO₃(g)
When 0.40 mole of SO$_2$ and 0.60 mole of O$_2$ are placed in an evacuated 1.00-liter flask, the reaction represented above occurs. After the reactants and the product reach equilibrium and the initial temperature is restored, the flask is found to contain 0.30 mole of SO$_3$. Based on these results, the equilibrium constant, $K_c$, for the reaction is:

(A) 20  
(B) 10  
(C) 6.7  
(D) 2.0

7.) 2SO$_2$(g) $\leftrightarrow$ 2SO$_2$(g) + O$_2$(g)

After the equilibrium represented above is established, some pure O$_2(g)$ is injected into the reaction vessel at constant temperature. After equilibrium is reestablished, which of the following has a lower value compared to its value at the original equilibrium?

(A) The total pressure in the reaction vessel  
(B) Amount of SO$_3$(g) in the reaction vessel  
(C) The amount of O$_2(g)$ in the reaction vessel  
(D) The amount of SO$_2$ in the reaction vessel

8.) At a certain temperature, the value of the equilibrium constant, $K$, for the reaction: H$_2$(g) + Br$_2$(g) $\leftrightarrow$ 2HBr(g) is 2.0 X 10$^5$. What is the value of $K$ for the reverse reaction at the same temperature?

(A) -2.0 X 10$^{-5}$  
(B) 5.0 X 10$^{-6}$  
(C) 2.0 X 10$^{-5}$  
(D) 5.0 X 10$^{-5}$

9.) MnS(s) + 2H$^+$ $\leftrightarrow$ Mn$^{2+}$ + H$_2$S(g)

At 25$^\circ$C the equilibrium constant, $K_e$ for MnS is 5x10$^{-15}$ and the acid dissociation constants $K_1$ and $K_2$ for H$_2$S are 1x10$^{-7}$ and 1x10$^{-13}$, respectively. What is the equilibrium constant for the reaction represented by the equation above at 25$^\circ$C?

(A) 1x10$^{-13}$ / 5x10$^{-15}$  
(B) 5x10$^{-15}$ / 1x10$^{-7}$  
(C) 1x10$^{-7}$ / 5x10$^{-15}$  
(D) 5x10$^{-15}$ / 1x10$^{-20}$

10.) HCO$_3$(aq) + OH$^-$(aq) $\leftrightarrow$ H$_2$O(l) + CO$_3^{2-}$(aq)  $\Delta$H = -41.4 kJ

When the reaction represented by the equation above is at equilibrium at 1 atm and 25$^\circ$C, the ratio [CO$_3^{2-}$]/[HCO$_3^-$] can be increased by doing which of the following?

(A) decreasing the temperature  
(B) adding acid  
(C) adding a catalyst  
(D) diluting the solution with distilled water
II. Free Response (30 pts)

1.) \(2 \text{H}_2\text{S}(g) \rightarrow 2 \text{H}_2(g) + \text{S}_2(g)\)

When heated, hydrogen sulfide gas decomposes according to the equation above. A 3.40 g sample of \(\text{H}_2\text{S}(g)\) is introduced into an evacuated rigid 1.25 L container. The sealed container is heated to 483 K, and \(3.72 \times 10^{-2}\) mol of \(\text{S}_2(g)\) is present at equilibrium.

(a) Write the expression for the equilibrium constant, \(K_c\), for the decomposition reaction represented above.

(b) Calculate the equilibrium concentration, in \(\text{mol} \cdot \text{L}^{-1}\), of the following gases in the container at 483 K.
   (i) \(\text{H}_2(g)\)
   (ii) \(\text{H}_2\text{S}(g)\)

(c) Calculate the value of the equilibrium constant, \(K_c\), for the decomposition reaction at 483 K.

(d) Calculate the partial pressure of \(\text{S}_2(g)\) in the container at equilibrium at 483 K.

(e) For the reaction \(\text{H}_2(g) + \frac{1}{2} \text{S}_2(g) \rightarrow \text{H}_2\text{S}(g)\) at 483 K, calculate the value of the equilibrium constant, \(K_c\).

2.) Answer the following questions regarding the decomposition of arsenic pentafluoride, \(\text{AsF}_5(g)\).

(a) A 55.8 g sample of \(\text{AsF}_5(g)\) is introduced into an evacuated 10.5 L container at 105°C.
   (i) What is the initial molar concentration of \(\text{AsF}_5(g)\) in the container?
   (ii) What is the initial pressure, in atmospheres, of the \(\text{AsF}_5(g)\) in the container?

At 105°C, \(\text{AsF}_5(g)\) decomposes into \(\text{AsF}_3(g)\) and \(\text{F}_2(g)\) according to the following chemical equation:

\[\text{AsF}_5(g) \rightleftharpoons \text{AsF}_3(g) + \text{F}_2(g)\]

(b) In terms of molar concentrations, write the equilibrium-constant expression for the decomposition of \(\text{AsF}_5(g)\).

(c) When equilibrium is established, 27.7 percent of the original number of moles of \(\text{AsF}_5(g)\) has decomposed.
   (i) Calculate the molar concentration of \(\text{AsF}_5(g)\) at equilibrium.
   (ii) Using molar concentrations, calculate the value of the equilibrium constant, \(K_{eq}\), at 105°C.

(d) Calculate the mole fraction of \(\text{F}_2(g)\) in the container at equilibrium.

\[\text{C(s)} + \text{CO}_2(g) \leftrightarrow 2 \text{CO(g)}\]
3.) Solid carbon and carbon dioxide gas at 1,160 K were placed in a rigid 2.00 L container, and the reaction represented above occurred. As the reaction proceeded, the total pressure in the container was monitored. When equilibrium was reached, there was still some C(s) remaining in the container. Results are recorded in the table below.

<table>
<thead>
<tr>
<th>Time (hours)</th>
<th>Total Pressure of Gases in Container at 1,160 K (atm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>5.00</td>
</tr>
<tr>
<td>2.0</td>
<td>6.26</td>
</tr>
<tr>
<td>4.0</td>
<td>7.09</td>
</tr>
<tr>
<td>6.0</td>
<td>7.75</td>
</tr>
<tr>
<td>8.0</td>
<td>8.37</td>
</tr>
<tr>
<td>10.0</td>
<td>8.37</td>
</tr>
</tbody>
</table>

(a) Write the expression for the equilibrium constant, $K_p$ for the reaction.
(b) Calculate the number of moles of CO$_2$(g) initially placed in the container. (Assume that the volume of the solid carbon is negligible.)
(c) For the reaction mixture at equilibrium at 1,160 K, the partial pressure of the CO$_2$(g) is 1.63 atm. Calculate
   (i) the partial pressure of CO(g), and
   (ii) the value of the equilibrium constant, $K_p$
(d) If a suitable solid catalyst were placed in the reaction vessel, would the final total pressure of the gases at equilibrium without the catalyst equal to the final total pressure of the gases at equilibrium without the catalyst? Justify your answer. (Assume that the volume of the solid catalyst is negligible.)
In another experiment involving the same reaction, a rigid 2.00 L container initially contains 10.0 g of C(s), plus CO(g) and CO$_2$(g), each at a partial pressure of 2.00 atm at 1,160 K.
(e) Predict whether the partial pressure of CO$_2$(g) will increase, decrease, or remain the same as this system approaches equilibrium. Justify your prediction with a calculation.
Appendix F: Second Assessment: Acids & Bases

I. Multiple Choice

1.) A molecule or an ion is classified as a Lewis acid if it
   (A) accepts a proton from water
   (B) accepts a pair of electrons to form a bond
   (C) donates a pair of electrons to form a bond
   (D) donates a proton to water

2.) A 1-molar solution of which of the following salts has the highest pH?
   (A) NaNO₃
   (B) Na₂CO₃
   (C) NH₄Cl
   (D) NaHSO₄

3.) H₂C₂O₄ + 2 H₂O ⇌ 2 H₃O⁺ + C₂O₄²⁻ Oxalic acid, H₂C₂O₄, is a diprotic acid with K₁ = 5 x 10⁻² and K₂ = 5 x 10⁻⁵. Which of the following is equal to the equilibrium constant for the reaction represented above?
   (A) 5 x 10⁻²
   (B) 5 x 10⁻⁵
   (C) 2.5 x 10⁻⁶
   (D) 5 x 10⁻⁷

4.) HSO₄⁻ + H₂O ⇌ H₃O⁺ + SO₄²⁻ In the equilibrium represented above, the species that act as bases include which of the following?
   I. HSO₄⁻
   II. H₂O
   III. SO₄²⁻
   (A) III only
   (B) I and II
   (C) I and III
   (D) II and III

5.) A 0.20-molar solution of a weak monoprotic acid, HA, has a pH of 3.00. The ionization constant of this acid is
   (A) 5.0 x 10⁻⁷
   (B) 2.0 x 10⁻⁷
   (C) 5.0 x 10⁻⁶
   (D) 5.0 x 10⁻³

6.) As the number of oxygen atoms increases in any series of oxygen acids, such as HXO, HXO₂, HXO₃, ...., which of the following is generally true?
   (A) The acid strength increases.
   (B) The acid strength decreases only if X is a nonmetal.
   (C) The acid strength decreases only if X is a metal.
   (D) The acid strength decreases whether X is a nonmetal or a metal.
7.) All of the following species can function as Brönsted-Lowry bases in solution EXCEPT
   (A) H₂O
   (B) NH₃
   (C) S²⁻
   (D) NH₄⁺

8.) If the Ka for an acid HA is 8 x 10⁻⁴, what percent of the acid is dissociated in a 0.50-molar solution of HA at 25°C?
   (A) 2%
   (B) 4%
   (C) 6%
   (D) 8%

9.) The pH of a 0.1 M NH₃ solution is approximately
   (A) 1
   (B) 4
   (C) 7
   (D) 11

10.) What is the pH of a 1.0 x 10⁻² M solution of HCN? (Ka = 4.0 x 10⁻¹⁰)
    (A) 10
    (B) between 7 & 10
    (C) 7
    (D) between 4 & 7

II. Free Response:

Each of three beakers contains 25.0 mL of a 0.100 M solution of HCl, NH₃, or NH₄Cl, as shown above. Each solution is at 25°C.

   (a) Determine the pH of the solution in beaker 1. Justify your answer.
   (b) In beaker 2, the reaction NH₃(aq) + H₂O(l) ⇌ NH₄⁺(aq) + OH⁻(aq) occurs. The value of 
      K_b for NH₃(aq) is 1.8 x 10⁻⁵ at 25°C.
      (i) Write the K_b expression for the reaction of NH₃(aq) with H₂O(l).
      (ii) Calculate the [OH⁻] in the solution in beaker 2.
      (iii) Calculate the pH of the solution in beaker 2
   (c) In beaker 3, the reaction NH₄⁺(aq) + H₂O(l) ⇌ NH₃(aq) + H₃O⁺(aq) occurs.
(i) Calculate the value of $K_a$ for $\text{NH}_4^+(aq)$ at 25°C.
(ii) Calculate the equilibrium concentration of $[\text{H}_3\text{O}^+]$ and $[\text{OH}^-]$
(iii) Calculate the pH at equilibrium

2.) A pure 14.85 g sample of the weak base ethylamine, $\text{C}_2\text{H}_5\text{NH}_2$, is dissolved in enough distilled water to make 500. mL of solution.

(a) Calculate the molar concentration of the $\text{C}_2\text{H}_5\text{NH}_2$ in the solution. The aqueous ethylamine reacts with water according to the equation below.

$$\text{C}_2\text{H}_5\text{NH}_2(aq) + \text{H}_2\text{O}(l) \rightleftharpoons \text{C}_2\text{H}_5\text{NH}_3^+(aq) + \text{OH}^-(aq)$$

(b) Write the equilibrium-constant expression for the reaction between $\text{C}_2\text{H}_5\text{NH}_2(aq)$ and water.
(c) Of $\text{C}_2\text{H}_5\text{NH}_2(aq)$ and $\text{C}_2\text{H}_5\text{NH}_3^+(aq)$, which is present in the solution at the higher concentration at equilibrium? Justify your answer.
(d) A different solution is made by mixing 500. mL of 0.500 $M$ $\text{C}_2\text{H}_5\text{NH}_2$ with 500. mL of 0.200 $M$ $\text{HCl}$. Assume that volumes are additive. The pH of the resulting solution is found to be 10.93.
   (i) Calculate the concentration of $\text{OH}^-(aq)$ in the solution.
   (ii) Write the net-ionic equation that represents the reaction that occurs when the $\text{C}_2\text{H}_5\text{NH}_2$ solution is mixed with the $\text{HCl}$ solution.
   (iii) Calculate the molar concentration of the $\text{C}_2\text{H}_5\text{NH}_3^+(aq)$ that is formed in the reaction.
   (iv) Calculate the value of $K_b$ for $\text{C}_2\text{H}_5\text{NH}_2$.

3.) $\text{CH}_3\text{CH}_2\text{COOH}(aq) + \text{H}_2\text{O} (l) \rightleftharpoons \text{CH}_3\text{CH}_2\text{COO}^-(aq) + \text{H}_3\text{O}^+(aq)$

Propanoic acid, $\text{CH}_3\text{CH}_2\text{COOH}$, is a carboxylic acid that reacts with water according to the equation above. At 25°C the pH of a 50.0 mL sample of 0.20 $M$ $\text{CH}_3\text{CH}_2\text{COOH}$ is 2.79.

a.) Identify a Bronsted-Lowry conjugate acid-base pair in the reaction. Clearly label which is the acid and which is the base.
b.) Determine the value of $K_a$ for propanoic acid at 25°C.
c.) For each of the following statements, determine whether the statement is true or false. In each case, explain the reasoning that supports your answer.
   i. The pH of a solution prepared by mixing the 50.0 mL sample of 0.20 $M$ $\text{CH}_3\text{CH}_2\text{COOH}$ with a 40.0 mL sample of 0.20 $M$ $\text{NaOH}$ is 7.00.
   ii. If the pH of hydrochloric acid solution is the same as the pH of a propanoic acid solution, then the molar concentration of the hydrochloric acid solution must be less than the molar concentration of the propanoic acid solution.

A student is given the task of determining the concentration of a propanoic acid solution of unknown concentration. A 0.173 $M$ $\text{NaOH}$ solution is available to use as the titrant. The student uses a 25.00 mL volumetric pipet to deliver the propanoic acid solution to a clean, dry flask. After adding an appropriate indicator to the flask, the student titrates the solution with the 0.173 $M$ $\text{NaOH}$, reaching the end point after 20.52 mL of the base solution has been added.

d.) Calculate the molarity of the propanoic acid solution.

e.) The student is asked to redesign the experiment to determine the concentration of a
butanoic acid solution instead of a propanoic acid solution. For butanoic acid the value of pKa is 4.83. The student claims that a different indicator will be required to determine the equivalence point of the titration accurately. Based on your response to part (b), do you agree with the student’s claim? Justify your answer.
Appendix G: Last Assessment: Equilibrium, Acids & Bases, Buffers & Salts

I. Multiple Choice (40 pts)

1.) The solubility of CuI is $2 \times 10^{-6}$ molar. What is the solubility product constant, $K_{sp}$, for CuI?
   (A) $1.4 \times 10^{-3}$
   (B) $2 \times 10^{-6}$
   (C) $4 \times 10^{-12}$
   (D) $2 \times 10^{-12}$

2.) $\text{H}_2\text{C}_2\text{O}_4 + 2 \text{H}_2\text{O} \rightleftharpoons 2 \text{H}_3\text{O}^+ + \text{C}_2\text{O}_4^{2-}$ Oxalic acid, $\text{H}_2\text{C}_2\text{O}_4$, is a diprotic acid with $K_1 = 5 \times 10^{-2}$ and $K_2 = 5 \times 10^{-5}$. Which of the following is equal to the equilibrium constant for the reaction represented above?
   (A) $5 \times 10^{-2}$
   (B) $5 \times 10^{-5}$
   (C) $2.5 \times 10^{-6}$
   (D) $5 \times 10^{-7}$

Use these answers for Questions 3-5
(A) a solution with a pH less than 7 that is not a buffer solution
(B) a buffer solution with a pH between 4 and 7
(C) a buffer solution with a pH between 7 and 10
(D) a solution with a pH greater than 7 that is not a buffer solution

Ionization Constants:
$\text{CH}_3\text{COOH} = 1.8 \times 10^{-5}$
$\text{NH}_3 = 1.8 \times 10^{-5}$
$\text{H}_2\text{CO}_3$; $K_1 = 4 \times 10^{-7}$
$\text{H}_2\text{CO}_3$; $K_2 = 4 \times 10^{-11}$

3.) A solution prepared to be initially 1 M in NaCl and 1 M in HCl

4.) A solution prepared to be initially 1 M in Na$_2$CO$_3$ and 1 M in CH$_3$COONa

5.) A solution prepared to be initially 0.5 M in CH$_3$COOH and 1 M in CH$_3$COONa

6.) What is the pH of a solution made of 0.50 M NH$_3$ and 0.80 M NH$_4$Cl given that $K_b = 1.8 \times 10^{-5}$?
   (A) 4.74
   (B) 4.94
   (C) 7.0
   (D) 9.05

7.) $\text{HC}_2\text{H}_3\text{O}_2(aq) + \text{CN}^-(aq) \rightleftharpoons \text{HCN}(aq) + \text{C}_2\text{H}_3\text{O}_2^-(aq)$
The reaction represented above has an equilibrium constant equal to $3.7 \times 10^4$. Which of the following can be concluded from this information?
   (A) $\text{CN}^-$ (aq) is a stronger base than $\text{C}_2\text{H}_3\text{O}_2^-$ (aq)
   (B) $\text{HCN}(aq)$ is a stronger acid than $\text{HC}_2\text{H}_3\text{O}_2(aq)$
   (C) The conjugate base of $\text{CN}^-$ (aq) is $\text{C}_2\text{H}_3\text{O}_2^-$ (aq)
   (D) The equilibrium constant will increase with an increase in temperature.
8.) A solution of calcium hypochlorite, a common additive to swimming-pool water, is
(A) basic because of the hydrolysis of the \( \text{OCl}^- \) ion
(B) basic because \( \text{Ca(OH)}_2 \) is a weak and insoluble base
(C) neutral if the concentration is kept below 0.1 molar
(D) acidic because of the hydrolysis of the \( \text{Ca}^{2+} \) ions

9.) As the number of oxygen atoms increases in any series of oxygen acids, such as \( \text{HXO, HXO}_2, \text{HXO}_3, \ldots \), which of the following is generally true?
(A) The acid strength increases.
(B) The acid strength decreases only if \( X \) is a nonmetal.
(C) The acid strength decreases only if \( X \) is a metal.
(D) The acid strength decreases whether \( X \) is a nonmetal or a metal.

10.) How many moles of \( \text{NaF} \) must be dissolved in 1.00 liter of a saturated solution of \( \text{PbF}_2 \) at 25 °C to reduce the \( [\text{Pb}^{2+}] \) to \( 1 \times 10^{-6} \) molar? (\( K_{sp} \) of \( \text{PbF}_2 \) at 25 °C = 4.0 x 10^{-8})
(A) 0.020 mole
(B) 0.040 mole
(C) 0.10 mole
(D) 0.20 mole

11.) The net ionic equation for the reaction that occurs during the titration of nitrous acid with sodium hydroxide is
(A) \( \text{HNO}_2 + \text{OH}^- \rightarrow \text{NO}_2^- + \text{H}_2\text{O} \)
(B) \( \text{HNO}_2 + \text{NaOH} \rightarrow \text{Na}^+ + \text{NO}_2^- + \text{H}_2\text{O} \)
(C) \( \text{H}^+ + \text{OH}^- \rightarrow \text{H}_2\text{O} \)
(D) \( \text{HNO}_2 + \text{H}_2\text{O} \rightarrow \text{NO}_2^- + \text{H}_3\text{O}^+ \)

12.) What is the pH of a 1.0 x 10^{-2}-molar solution of HCN? (\( K_a = 4.0 \times 10^{-10} \))
(A) 10
(B) Between 7 and 10
(C) 7
(D) Between 4 and 7

13.) Which, if any, of the following species is in the greatest concentration in a 0.100-molar solution of \( \text{H}_2\text{SO}_4 \) in water?
(A) \( \text{H}_2\text{SO}_4 \) molecules
(B) \( \text{H}_3\text{O}^+ \) ions
(C) \( \text{HSO}_4^- \) ions
(D) \( \text{SO}_4^{2-} \) ions

14.) The pH of 0.1-molar ammonia is approximately
(A) 1
(B) 4
(C) 7
(D) 11

15.) If the acid dissociation constant, \( K_a \), for an acid \( \text{HA} \) is 8 x 10^{-4} at 25 °C, what percent of the acid is dissociated in a 0.50-molar solution of HA at 25 °C?
(A) 0.2%
(B) 1%
(C) 2%
(D) 4%

16.) In which of the following systems would the number of moles of the substances present at equilibrium NOT be shifted by a change in the volume of the system at a constant temperature?
(A) CO(g) + NO(g) ⇌ CO₂(g) + ½N₂(g)
(B) N₂(g) + 3H₂(g) ⇌ 2NH₃(g)
(C) N₂(g) + 2O₂(g) ⇌ 2NO₂(g)
(D) NO(g) + O₃(g) ⇌ NO₂(g) + O₂(g)

17.) PCl₃(g) + Cl₂(g) ⇌ PCl₅(g) + energy
Some PCl₃ and Cl₂ are mixed in a container at 200°C and the system reaches equilibrium according to the reaction above. Which of the following causes an increase in the number of moles of PCl₅ present at equilibrium?
I. Decreasing the volume of the container
II. Raising the temperature
III. Adding a mole of He gas at constant volume

(A) I only
(B) II only
(C) I and III
(D) II and III

Questions 18-20
(A) NH₃ and NH₄Cl
(B) H₃PO₄ and NaH₂PO₄
(C) HCl and NaCl
(D) NaOH and NH₃

18.) The solution with the lowest pH

19.) A buffer at a pH>8

20.) A buffer at a pH<6

II. Free Response (40 pts)

1.) Answer the following questions about the solubility of some fluoride salts of alkaline earth metals.
(a) A student prepares 100. mL of a saturated solution of MgF₂ by adding 0.50 g of solid MgF₂ to 100. mL of distilled water at 25°C and stirring until no more solid dissolves. (Assume that the volume of the undissolved MgF₂ is negligibly small.) The saturated solution is analyzed, and it is determined that [F⁻] in the solution is 2.4 x 10⁻³ M.
   (i) Write the chemical equation for the dissolving of solid MgF₂ in water.
   (ii) Calculate the number of moles of MgF₂ that dissolved.
   (iii) Determine the value of the solubility-product constant, Ksp, for MgF₂ at 25°C.
(b) A beaker contains 500. mL of a solution in which both Ca\(^{2+}\)(aq) and Ba\(^{2+}\)(aq) are present at a concentration of 0.10 M at 25ºC. A student intends to separate the ions by adding 0.20 M NaF solution one drop at a time from a buret. At 25ºC the value of Ksp for CaF\(_2\) is 3.5 \times 10^{-11}; the value of Ksp for BaF\(_2\) is 1.8 \times 10^{-6}.

(i) Which salt will precipitate first, CaF\(_2\) or BaF\(_2\) ? Justify your answer.

For parts (b)(ii) and (b)(iii) below, assume that the addition of the NaF solution does not significantly affect the total volume of the liquid in the beaker.

(ii) Calculate the minimum concentration of F\(^-\)(aq) necessary to initiate precipitation of the salt selected in part (b)(i).

(iii) Calculate the minimum volume of 0.20 M NaF that must be added to the beaker to initiate precipitation of the salt selected in part (b)(i).

(c) There are several ways to dissolve salts that have limited solubility. Describe one procedure to redisolve the precipitate formed in part (b).

2.) Solve the following problem related to the solubility equilibria of some metal hydroxides in aqueous solution.

(a) The solubility of Cu(OH)\(_2\)(s) is 1.72 \times 10^{-6} gram per 100. milliliters of solution at 25ºC.

(i) Write the balanced chemical equation for the dissociation of Cu(OH)\(_2\)(s) in aqueous solution.

(ii) Calculate the value of the solubility-product constant, \(K_{sp}\), for Cu(OH)\(_2\) at 25ºC.

(b) The value of the solubility-product constant, \(K_{sp}\), for Zn(OH)\(_2\) is 7.7 \times 10^{-17} at 25ºC.

At 25ºC, 50.0 milliliters of 0.100-molar Zn(NO\(_3\))\(_2\) is mixed with 50.0 milliliters of 0.300-molar NaOH. Calculate the molar concentration of Zn\(^{2+}\)(aq) in the resulting solution once equilibrium has been established. Assume that volumes are additive.

The solubility of iron(II) hydroxide, Fe(OH)\(_2\), is 1.43 \times 10^{-3} gram per litre at 25ºC.

(c) Write the expression for the solubility product constant, \(K_{sp}\), and calculate its value.

(d) Calculate the pH of a saturated solution of Fe(OH)\(_2\) at 25ºC.

(e) A 50.0 millilitre sample of 3.00 \times 10^{-3} molar FeSO\(_4\) solution is added to 50.0 millilitres of 4.00 \times 10^{-6} molar NaOH solution. Does a precipitate of Fe(OH)\(_2\) form? Explain and show calculations to support your answer.

3.) A 1.22 g sample of pure monoprotic acid, HA, was dissolved in distilled water. The HA solution was then titrated with 0.250 M NaOH. The pH was measured throughout the titration, and the equivalence point was reached when 40.0 mL of the NaOH solution had been added. The data from the titration was recorded in the table below.

<table>
<thead>
<tr>
<th>Volume of 0.250 M NaOH Added (mL)</th>
<th>pH of Titrated Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>?</td>
</tr>
<tr>
<td>10.0</td>
<td>3.72</td>
</tr>
<tr>
<td>20.0</td>
<td>4.2</td>
</tr>
<tr>
<td>30.0</td>
<td>?</td>
</tr>
<tr>
<td>40.0</td>
<td>8.62</td>
</tr>
<tr>
<td>50.0</td>
<td>12.40</td>
</tr>
</tbody>
</table>
(a) Explain how the data in the table above provide evidence that HA is a weak acid rather than a strong acid.
(b) Write the balanced net-ionic equation for the reaction that occurs when the solution of NaOH is added to the solution of HA.
(c) Calculate the number of moles of HA that were titrated.
(d) Calculate the molar mass of HA.

The equation for the dissociation reaction of HA in water is shown below.

\[ \text{HA}(aq) + \text{H}_2\text{O}(l) \rightleftharpoons \text{H}_3\text{O}^+(aq) + \text{A}^-(aq) \quad K_a = 6.3 \times 10^{-5} \]

(e) Assume that the initial concentration of the HA solution (before any NaOH solution was added) is 0.200 \( M \). Determine the pH of the initial HA solution.

4.) A buffer solution contains 0.40 mole of formic acid, HCOOH, and 0.60 mole of sodium formate, HCOONa, in 1.00 litre of solution. The ionization constant, \( K_a \), of formic acid is \( 1.8 \times 10^{-4} \).

(a) Calculate the pH of this solution.
(b) If 100. millilitres of this buffer solution is diluted to a volume of 1.00 litre with pure water, the pH does not change. Discuss why the pH remains constant on dilution.
(c) A 5.00 millilitre sample of 1.00 molar HCl is added to 100. millilitres of the original buffer solution. Calculate the [\( \text{H}_3\text{O}^+ \)] of the resulting solution.
(d) A 800.–milliliter sample of 2.00–molar formic acid is mixed with 200. milliliters of 4.80–molar NaOH. Calculate the [\( \text{H}_3\text{O}^+ \)] of the resulting solution.
(e) Explain how this buffer solution resists a change in pH when:
   (i) Moderate amounts of strong acid are added.
   (ii) A portion of the buffer solution is diluted with an equal volume of water.
Appendix H. Group Interview Questions

1. How was this method different from the way other chapters were covered?

2. What was the best thing that helped you the most in using the iPad in terms of your conceptual understanding?

3. What was your least favorite thing that helped you the least in using the iPad in terms of your conceptual understanding?

4. Has there been a difference in the way you performed in these chapters compared to the past chapters? Why?
Appendix I. Summary of Post-Survey Questions for Class 1

<table>
<thead>
<tr>
<th>Question</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.) Do you feel like the iPad can be used as a good communication tool?</td>
<td></td>
</tr>
<tr>
<td>• Yes most definitely however I would have liked to have used gosoapbox more</td>
<td></td>
</tr>
<tr>
<td>• I do. I thought the use of iPads in class helped my fellow classmates and I communicate solutions and problem-solving methods effectively.</td>
<td></td>
</tr>
<tr>
<td>• It can, especially when we are able to point to our work for the class to see when explaining concepts to peers</td>
<td></td>
</tr>
<tr>
<td>• Not particularly. The screen is too small to be used to communicate effectively, no matter the size of the pen, not to mention it is constant distraction.</td>
<td></td>
</tr>
<tr>
<td>• It can certainly help with collaboration between classmates and helps get my questions answered more quickly than in a more traditional setting.</td>
<td></td>
</tr>
<tr>
<td>• The iPad can be a good communication tool, but I think it is more helpful for the person using it, whose work can be critiques by his peers.</td>
<td></td>
</tr>
<tr>
<td>• Yes, because I was able to see what I did wrong and ask the person who was excelling to explain the topic. I got to communicate with my peers and I was not distracted once so ever.</td>
<td></td>
</tr>
<tr>
<td>2.) Do you feel more motivated to participate in class with the way the iPad is used? Why or Why not?</td>
<td></td>
</tr>
<tr>
<td>• I feel more motivated because it's also easier to compute there</td>
<td></td>
</tr>
<tr>
<td>• The only reason I would say no is because regardless of whether or not we use iPads, I always feel motivated to participate in class. In other words, the iPad did motivate me to participate, but not any more than another method would have.</td>
<td></td>
</tr>
<tr>
<td>• I think my participation in class remains roughly unchanged, though I do participate in a different way</td>
<td></td>
</tr>
<tr>
<td>• You feel pressured to because it turns solving the problem into a competition wherein whoever to get it first gets an internal reward. When you use paper, however, it loses this competitive aspect.</td>
<td></td>
</tr>
<tr>
<td>• Yes, it is motivating because it is nice to interact with my other classmates via technology.</td>
<td></td>
</tr>
<tr>
<td>• I am under pressure to perform because I am effectively working in front of the entire class. That may sound negative, but I feel as proud when I do something correctly as embarrassed when I do something incorrectly.</td>
<td></td>
</tr>
<tr>
<td>• Yes I do because it pushes me to contribute and it helps me understand and ask questions.</td>
<td></td>
</tr>
</tbody>
</table>
3.) Are you able to communicate more/less when using the iPad in the classroom?

- I am able to communicate more. Being able to have my solutions and methods displayed on the projector seemed to help my classmates understand them better
- I communicate roughly the same
- I am able to communicate less. People become too hyper with them.
- I’m able to communicate more because the question are presented directly up on the board
- It is easier, since the iPad's screen is broadcast in front of everyone else, I can show somebody what I am doing, rather than having to explain it using lots of big words.
- More

4.) Would you recommend the method we use iPads to your other classes? Why or why not?

- Most definitely except in English class for I am a better reader on paperbacks
- I would recommend the method we used to other science classes and possibly some math classes because I found it quite helpful to have our problem-solving methods displayed on the board. For more humanities-based classes, such as English and history, however, I find discussion-based learning more helpful.
- I would for certain classes, especially those such as math and science
- In a problem-solving oriented class I think iPads used in the method in which we use them can be very helpful. However, in a more abstract and discussion based class like English or history, I think it would serve little purpose.
- I would not recommend that, since many of the functions the iPad performs are specific to some elements of the class. It might work for something like math, but for a more reading and discussion-heavy class such as Latin or History, it would not be very effective.
- Yes because it is possible I received two different ways of explaining the problem.

5.) How do you feel about feedback when the iPad is in use compared to a traditional classroom?

- I think the feedback given to me during our use of iPads was helpful. Not only was my teacher able to view my work by simply looking at the projector, but my classmates were too. I was, thus, able to quickly hear what other people thought of my work, and I find that valuable.
Question 5 continued

- Feedback is definitely more effective when the iPads are in use - I can correct my mistakes and the teacher can further correct my work, as she sees my corrections live on the board.
- I feel like it is less useful as it is less clear. On paper you can point to one thing and cross it out—you have a record of your mistake. On an iPad, there's no way to tell the order of operations.
- It is easier to see what everyone is doing at once. As a result, I can see immediately if I am on the right track and, if not, I can ask someone who is where I went wrong.
- It really depends on the type of lecture. The feedback on iPads are quick. Traditional classrooms do have their perks too.
- Feedback comes faster and there is more of it. This is generally a good thing, but sometimes it is important to complete problems with no feedback at any point, to see whether I am capable of doing a task independently.
- I enjoyed it because it brought a new interesting way to learn which I was interested in.

6.) How do you feel about possible distractions when using this as a communication tool in the classroom?

- As long as the class moves progressively fast I feel one would not be sucked into those distractions.
- Due to the rigor of the course, I felt that my classmates and I were able to remain engaged in class and not succumb to distraction ourselves.
- There is certainly a temptation to browse the internet, play games, etc. that wouldn't exist if the iPads had been set to only show the application relevant to the classwork.
- Distractions are a very real concern with technology in the classroom. I think the best way to avoid distractions is for everyone to buy into the effectiveness of iPads in class. If everyone is invested and learning effectively in this system, students will avoid distractions in order to get the most out of the class.
- I don't think it is a distraction because the screen is mirrored on the board. This makes it impossible to bring up anything else on the iPad without being seen.
- They are a serious risk, but not if the screen is broadcast to the room. I do not need to let everyone know how amazing I am at Angry Birds in the middle of Chemistry.
- I did not see any distractions when I used the iPad to do my work.
7.) Is the interactive feature of the iPad a motivation? Or is it distracting? Why?

- In this context, I would call it a motivation. With our teacher encouraging learning and working with our iPads, we were able to focus ourselves on an educational purpose with them. Sometimes in my classes, I notice my classmates using their iPads to distract themselves during a lecture. I think that when given the opportunity, students can both use iPads efficiently and remain engaged simultaneously.
- Although I do believe that the iPads are largely beneficial, their one significant downside is that they create a sense of distraction.
- I think, at least for most including myself, it is a motivation because it allows me to collaborate with my classmates and share our ideas, methods, and answers.
- It is motivation. you can watch other students excel in a certain chapter and be motivated.
- There is really no difference, if the iPad is being used strictly the way we have been using it. Notability is interactive, but paper is just as interactive. The AirPlay function is really what makes the iPad so helpful.
- I found it was motivating because we all pushed each other to understand the topic, and we all helped one another out because no one wanted to be left behind.
- It is incredibly distracting. It is so because it turns everything into a convoluted game—and when learning, the last thing you want is for it to be a race. It is best to slow the pace initially—interactivity does not help with this.
Appendix J. Summary of Post-Survey Questions for Class 2

<table>
<thead>
<tr>
<th>Question</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.) Do you feel like the iPad can be used as a good communication tool?</td>
<td>- For in class purposes I felt it was more of a group work tool than a communication tool.</td>
</tr>
<tr>
<td></td>
<td>- Yes—especially the mirroring system with three iPads on one screen.</td>
</tr>
<tr>
<td></td>
<td>- Yes, especially using air play made the information much more accessible.</td>
</tr>
<tr>
<td></td>
<td>- It can definitely be a medium that can allow for easy communication as your work can be displayed to everyone.</td>
</tr>
<tr>
<td></td>
<td>- Yes especially with apps such as Kahoot.</td>
</tr>
<tr>
<td></td>
<td>- Yes, however I prefer communicating more traditionally</td>
</tr>
<tr>
<td>2.) Do you feel more motivated to participate in class with the way the iPad is used? Why or Why not?</td>
<td>- Yes because I can receive criticisms from my classmates more easily if my process is incorrect.</td>
</tr>
<tr>
<td></td>
<td>- I do, because I like to demonstrate my own and my group's ability.</td>
</tr>
<tr>
<td></td>
<td>- Yes, I can follow two screens at once on the board and ask the students to walk me through their unique thought process.</td>
</tr>
<tr>
<td></td>
<td>- Yes, because it helps me understand concepts better and am more confident in my answers/questions</td>
</tr>
<tr>
<td></td>
<td>- I feel indifferent about the iPads being able to promote participation. I feel that it facilitates communication between classmates because it can allow a student in another table to ask questions to a student three tables away. It certainly facilitates discussion.</td>
</tr>
<tr>
<td></td>
<td>- I feel indifferent about my motivation to participate. Having the iPad does not really influence that.</td>
</tr>
<tr>
<td>3.) Are you able to communicate more/less when using the iPad in the classroom?</td>
<td>- I am able to communicate more because everyone receives an opportunity to participate.</td>
</tr>
<tr>
<td></td>
<td>- More so between peers and between students and teacher.</td>
</tr>
<tr>
<td></td>
<td>- I am able to communicate To me, communication is more effective when seeing what other people are writing on their iPads.</td>
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<td>- More. Promotes discussion.</td>
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<tr>
<td></td>
<td>- Around the same amount</td>
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<td>- Communicate more</td>
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4.) Would you recommend the method we use iPads to your other classes? Why or why not?

- I might recommend it for math, but I largely feel like pencil and paper help me focus more in class because it removes the distraction of the internet.
- In other classes to remember facts or calculations. It may not be as helpful in writing portions of English or History for example.
- I feel that it works best for chemistry and for math in certain scenarios. I feel that when doing class work it allows the teacher and other students to quickly fix any mistakes. We are using it in a similar method for English, in which we have the eBook and take notes in class on the book from last nights reading (which is in the iPad). This allows the teacher to be on the same page and reduce clutter for the students having to carry a textbook or book.
- Yes, it allows much faster sharing of info
- I do, if the teacher assigns one iPad per group and then projects those iPads on to a larger screen. This holds the students accountable. It is easier to become distracted and use the iPads for other purposes if the students are not monitored.

5.) How do you feel about feedback when the iPad is in use compared to a traditional classroom?

- It is more immediate and helpful.
- It's quicker-teacher can point out mistake right away.
- I am able to receive feedback from both my peers and teacher more often
- It allows for easier communication because everyone can see the iPad, as long as they can see the board. That allows for mistakes to be fixed quickly
- I feel like everyone in the classroom is more aware of what other people are doing, which can usually help solve problems faster
- I think that the feedback is pretty much the same. I think this is because I’m pretty vocal in class, and that communicating my problems isn’t a problem for me
6.) How do you feel about possible distractions when using this as a communication tool in the classroom?

• Not if the iPads are monitored on a larger screen the teacher is looking at.
• There are not many opportunities to be distracted because everyone is forced to participate, and iPads are airplay on the board.
• It is possible, however using the iPad in this way made u very focused
• It is certainly a possibility but nobody in my table was ever using it for games, and on the contrary I felt that the screen projection method created incentive to stay on task for fear of being spotted being off task.
• It can be tough, but if the teacher controls the class well, like Ms. Ting did, quite magnificently, it is no problem.
• Strongly. If you give an ADHD teenager a box with science and videogames in it, you can’t expect him to pick science every time.

7.) Is the interactive feature of the iPad a motivation? Or is it distracting? Why?

• It is a motivation because I can receive corrections from my classmates more easily.
• Motivation if used correctly. Creates a group sense, motivates a competitive class, and students receive help from peers and their teacher immediately. Distracts students in other classes when their use is not monitored. Unfortunately, cannot take students on faith.
• It is a motivation because I feel more confident in participating and am able to receive feedback from my peers more easily
• Motivation, more to work with and keeps you actively thinking
• It is more of a motivation than a distraction because in a classroom setting the amount of distraction available is limited.
• I don’t think the interactive feature is the distraction, I think the other uses of the ipad are the distraction. Also I just prefer pencil and paper