EXPLORING AND CONCEPTUALIZING TEACHER FORMATIVE ASSESSMENT PRACTICES AND DIGITAL APPLICATIONS WITHIN A TECHNOLOGY-ENHANCED HIGH SCHOOL CLASSROOM

A Dissertation Presented to

The Faculty of the Graduate School

At the University of Missouri

In Partial Fulfillment

Of the Requirements for the Degree

Doctor of Philosophy

By

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DECEMBER, 2017

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EXPLORING AND CONCEPTUALIZING TEACHER FORMATIVE ASSESSMENT PRACTICES AND DIGITAL APPLICATIONS WITHIN A TECHNOLOGY-ENHANCED HIGH SCHOOL CLASSROOM

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Dedicated to my parents and my brother. Emine, Nihat, and Mehmet Eray, you always have faith in me. It is through your love and support that I am able to achieve. Thank you.

ACKNOWLEDGEMENTS

This dissertation would not have been possible without the significant assistance and support of numerous people: mentors, colleagues, friends, and family. First, I want to gratefully acknowledge my advisor, Dr. Siegel, for your support, encouragement, mentorship and friendship. I would not be able to do this without your support and encouragement. You always valued my ideas and pushed me to think outside of the box. I am so grateful for all the opportunities you provided me in different research projects. I have been fortunate to have you as an advisor. I am looking forward to continuing working together in the future.

I would like to extend my sincere thanks to my dissertation committee members. Dr. Hanuscin, I cannot thank you enough for the research opportunities you provided me. I am very fortunate to work with you in several research projects; it was always enjoyable. I appreciate the support and mentorship you provided during my journey at the University of Missouri. Dr. Chandrasekhar, I am grateful to work with you during the Physics First project. I enjoyed our conversations on physics teacher development. Dr. de Araujo, thank you for supporting me during this dissertation process. I appreciate your valuable feedback and I have greatly benefitted from the different perspectives that you brought to my study.

I want to thank the participating teacher and her students for their participations in the study. Thank you for welcoming me and making me a part of your classroom.

In addition to committee members, I would like to thank several faculty members within Learning, Teaching, and Curriculum at MU. Thank you for your support, encouragement, and valuable conversations. I specifically want to acknowledge Dr.

Jahnke. Thank you for accepting me to work in the LexMizzou project. I enjoyed working with you and our conversations. I look forward to working together in the future. Dr. Klosterman, thank you for your encouragement, mentorship, and friendship. I have learned a lot about teaching, research, and academic life via our conversations.

I would like to thank all MU Science education graduate students that I have met during graduate school for their support and friendship. Suleyman Cite, thank you for your support and our meaningful conversations. Shannon Burcks, thanks for being such a supportive friend. I have always enjoyed our deep conversations about teaching, research, and life. Tamara Hancock and Andrew Kinslow, thank you for your support, our great conversations, and being my writing friends.

I want to extend my appreciation beyond academia. To Aysenur Argut Reed, thank you for believing in me, for your endless support, and great friendship. To my uncle Mesut and my aunt Zehra, thank you for always being with me throughout my journey in the USA. I appreciate your support and love. To Matthew Earlywine, I would not be able to write this dissertation without your endless support, care, and love. Thank you for listening to my ideas, complaints, and helping me in every step of this journey. To my family, thank you for believing in me and know that I could not be here without your endless support and love. To my brother, Mehmet Eray, thank you for your friendship. You are always there when I need you. To my mother, Emine, thank you for being a role model of a successful and independent woman. I am trying to follow your footsteps. To my father and educator, Nihat, I learned to appreciate teachers from you. You have been a great one.

I would like to extend my gratitude to the Turkish Ministry of National Education

for financially supporting me during my studies in the US. Without it, I would not be able to accomplish such a milestone in my academic career.

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ABSTRACT

Formative assessment is essential for improving student learning. Formative assessment research has predominantly used cognitive learning theories. In this dissertation study, I used sociocultural learning perspectives to understand how formative assessment supported student learning during interaction and how it empowered students. This dissertation included three manuscripts.

The first manuscript was a conceptual study. I developed a new formative assessment cycle that was built on sociocultural perspectives and prior formative assessment cycles. The model included four steps: building community, monitoring community, community mediation, and redefining goals. These steps were described in detail with examples, and the roles of the teacher, learners, and peers were discussed. Future researchers may potentially use the model to understand formative assessment practices. Practicing teachers and teacher educators may benefit from the provided examples for classroom implementation of the model.

In the empirical part of the dissertation, Chapter Three and Chapter Four, the participant teacher, who was a high school physics teacher, was selected from teachers that had been actively using iPads in their classrooms. This study was conducted at a public high school in the Midwest United States that had a diverse student population.

Data were collected across eighteen class sessions. Primary data sources included video recorded observation of class sections, iPad applications, and teacher interviews. Supporting secondary sources included pictures taken during observations, lesson plans, assessment examples, student-works, and student interviews.

In the second manuscript, I examined a high school physics teacher's technology-enhanced classroom to understand the impact of technology on the teacher's formative assessment practices, and how the iPad influenced the formative assessment process, by using sociocultural learning perspectives. The participant teacher's formative assessment practices were described (members, tools, and classroom norms). Results showed that influences of the iPad on the formative assessment process were: 1) transforming classroom community, 2) empowering students, and 3) facilitating evidence-based discussions. This study shed light on: the impact of technology use on the teacher's formative assessment practice, how the impact rebuilt the classroom norms, and how technology use impacted student identity development.

In the third manuscript, I focused on the most important aspect of formative assessment - feedback. I examined how well iPad applications (apps) supported providing feedback. Then, I compared the app affordances with teacher practice. To enable analysis of data, I enhanced Hatzipanagos and Warburton's (2009) feedback dimensions. Analysis revealed app diversity in supporting different feedback dimensions, and the teacher, through additional discussion and interactions with students, was able to support dimensions that an app did not. The provided examples of app affordances and teacher practices may be beneficial to prospective and practicing teachers. Application designers may benefit from this study towards improving their apps to support effective feedback.

CHAPTER ONE

Introduction

With the release of *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas and Next Generation Science Standards* [NGSS], science education faced a significant change. The framework aimed to make science education within the classroom closely match the work of scientists and emphasized the importance of building coherent understanding over time (NGSS Lead States, 2013; National Research Center [NRC], 2012). Within the framework student learning has been conceptualized as harmonic interactions among three dimensions, namely: core ideas, practices, and crosscutting concepts. To meet the NGSS requirements, it is pivotal to shift the approach to assessment from solely focusing on student knowledge to how students participate in practices by using their knowledge (National Research Council [NRC], 2014).

Research has shown that formative assessment can enhance student learning (Bell & Cowie, 2001a; 2001b; Black, & Wiliam, 1998; Ruiz-Primo, & Furtak, 2006; 2007; Herman, Osmundson, Dai, Ringstaff & Timms, 2015). To date research on formative assessment in science education has predominantly used cognitive learning theories, which mainly focus on tracking changes in students' understanding (e.g., Ruiz-Primo & Furtak, 2006, Bell & Cowie, 2001a; 2001b). Adopting a sociocultural perspective for formative assessment may help create an environment to support student participation and improvement of student learning, student learning capacity, and autonomy (Cowie, Moreland, & Otrel-Cass, 2013), which fulfills NGSS requirements by stressing the importance of involvement. Technology has the potential to support the teacher during

this process. Yet, there is limited research that aims to foster learning and empowerment of students by using technology within formative assessment (e.g., Cowie, et al., 2013).

To that end, I have established a research agenda on formative assessment in K-12 classrooms. My dissertation study explores the potential of formative assessment to support student learning in a science classroom and the potential of mobile technology (iPad) for supporting formative assessment practices. To understand the formative assessment process and technology impacts, I collected data from a high school physics teacher's technology-enhanced classroom and employed qualitative research methods.

This dissertation is organized into five chapters and includes three manuscripts situated in my research agenda. These manuscripts compose the core of the dissertation (Chapter Two through Chapter Four). In the first chapter, I articulate my research agenda and position this study within research on sociocultural perspectives, formative assessment, and technology education. Later in the chapter, I provide detailed outlines for each of these manuscripts. Chapter Five presents a synthesis of conclusions of the manuscripts.

Theoretical Perspective

Sociocultural Perspectives

Sociocultural learning theories are different from earlier theories in terms of emphasizing the social and cultural aspects of learning (Wertsch, 1991; Wenger, 1998; Lemke, 2001). Learning occurs through participating in practices. During the participation students interact with each other to explain their needs and share their experiences (Lave & Wenger, 1991; Wenger, 1998). While sharing their ideas and experiences, students reflect on their own or their peers' ideas and collectively produce

learning. As earlier researchers stated, with participation learners will not only learn new knowledge but also will gain new perspectives (Murakami, 2015; Wenger, 1998). Learners will expand their view of the world and of themselves by merging these new perspectives with their own. Thus interaction and participation are sources for developing the identity of self. Lave and Wenger (1991) underlined this by defining learning as "becoming". The interaction will lead learners to grow within the society (Boreham & Morgan, 2004).

Power relations both between teacher and students and among students, impacts the student learning process. According to sociocultural perspectives, sharing power with students encourages them to take responsibility for their own learning and improves both student learning and their confidence (Crossouard, 2009; Murakami, 2015). Sharing authority will help students to become more critical of what they are learning (Crossouard, 2009). Increased participation results in greater learning, causing learners to become more confident of their ideas and in themselves. These teaching and learning practices will influence learners' sense of who they are and who they become (Cobb, 2004). Having more opportunities for them to participate in classroom activities and use authority while learning will help learners develop identities.

Research Strands

View of Assessment

Research in assessment is affected by changes in the views of learning. Views of learning have changed from behaviorism to cognitive and sociocultural views. According associationism and behaviorism perspectives, learning occurs by accumulating pieces of knowledge. Therefore assessments aim to measure the amount of accumulated

knowledge. Recall questions are used as the main assessment strategy in this view. These assessments use "one-skill-at-a-time test items" and frequent testing to make sure students reach the desired level.

Cognitive theories are interested in how the minds of learners work. According to these theories, during the learning process, learners use their existing knowledge and beliefs in new learning situations. Thus cognitive views assert students need to use higher order thinking skills. Students' prior knowledge, misconceptions, and conceptual changes are foci of the researchers who follow this theory. Assessment, according to cognitive theories, is interested in tracking student understanding.

Unlike earlier views on learning, sociocultural perspectives emphasizes the importance of social and cultural impacts on learning. According to sociocultural learning theories, learning occurs through participation in practices. During participation, learners interact with each other, share their experiences, reflect both on their own and peers experiences, and collectively create an understanding (Lave & Wenger, 1991; Wenger, 1998). In this view, researchers focus on identity development, classroom norms, interactions, and power relationships (e.g., Crossouard, 2009; Fusco & Calabrese Barton, 2001; Murakami, 2015).

Assessment, conducted with a sociocultural lens, is focused on open-ended performance tasks in which students can solve complex problems and apply their knowledge in real-world contexts (Shepard, 2000). These tasks give opportunities to learners to interact with each other, exchange their experiences, to make decisions, and act on their decisions. Interaction also assists in creating shared goals and interests. Having shared goals is important as it helps students improve their learning experience

and academic accountability (Cowie et al., 2013). This perspective underlines the importance of the context, classroom culture, and empowering students during assessment. It promotes complex problems, for which there is not a simple answer, requiring students need to interact, discuss, and participate to solve the problem. During this, a teacher should focus on assessing student's shifting beliefs and reasoning within the group. Thus individuals need to be assessed for contributions while in a group activity (Gipps, 2002).

Sociocultural perspectives assert that, during assessment, students can reconsider the meaning of being a learner and of being a knower through interaction. Cowie (2005) says assessment is "a meaning making activity embedded in and accomplished through interaction, one that shaped what it means to be a student and how individuals see themselves as knowers and learners of science" (p. 209).

Formative assessment. There have been significant increases in student learning resulting from formative assessment (Bell & Cowie, 2001b; Black & Wiliam, 1998; Shepard, 2000; Siegel, 2007) and this has led to an increase in research on formative assessment within the assessment literature. Highly cited study by Black and Wiliam (1998) define formative assessment as "... all activities undertaken by teachers, and/or by their students, which provide information to be used as feedback to modify the teaching and learning activities in which they are engaged." (p. 10).

Researchers define formative assessment as a process that needs to be embedded in instruction (Popham, 2008). It includes gathering information from students, interpreting student response, providing feedback to students, and modifying instruction to improve student-student learning (Abell & Siegel, 2011; Black & Wiliam, 1998; Bell,

& Cowie, 2001b; Ruiz-Primo & Furtak, 2006, 2007; Buck & Trauth-Nare, 2009). Earlier studies indicate that one of the weakest sides of teachers' formative assessment practices is using information in order to both provide feedback to students and to modify instruction (Bell, & Cowie, 2001b; Gottheiner & Siegel, 2012; Ruiz-Primo & Furtak, 2007).

Though this view on formative assessment gives me great information on fostering student learning, it lacks the social aspects of learning. Without understanding these social aspects and their impact on assessment one cannot expect teachers to implement a formative assessment properly. First, for a successful formative assessment students need to be active, participate in practices, and take responsibility for their own learning by reflecting on their experiences (Cowie et al., 2013). Teachers provide opportunities to students and encourage them to take on responsibilities and to also be involved in the assessment process by negotiating and discussing the outcomes (Furtak, Thompson, & van Es, 2016). This produces responsibility for their learning via self-monitoring. It also encourages students to create a classroom culture through shared goals and interpretations of knowledge. Through these practices a teacher can gather information about students both individual and communal learning progress situated in the classroom community (Radinsky, Oliva, & Alamar, 2010).

I define formative assessment as: the process in which students and/or teacher recognize and respond to learning progress while participating in the learning practices within community. During the process, students are expected to interact with each other and/or the teacher, and reflect on, and via mediating each other improve, their work.

Formative assessment aims to improve student understanding within community, improve student autonomy, and assists adjusting instruction based on community needs.

Feedback. Feedback is an essential part of formative assessment that has a pivotal effect on learning development (Abell & Siegel, 2011; Black & Wiliam, 1998; Sadler, 1989; Ruiz-Primo & Li, 2013). Although researchers agree feedback is an important part of assessment what is considered to be feedback varies (Shute 2008; Li & De Luca, 2014; Evans, 2013). Kepner defined feedback as "any procedure used to inform a learner whether an instructional response is right or wrong" (as cited in Jones & Blankenship, 2014, p. 2). In this view grades, check marks, and smiley faces are considered as feedback. Yet other researchers think the aim of feedback is helping students to seek and determine the correct answers (Li & De Luca, 2014). In this view teachers provide comments to students on how to find the correct answer. According to sociocultural perspectives feedback is dialogue, which occurs during interaction. The aim of feedback is helping students through the learning process. In this view, feedback is provided by asking questions and offering suggestions to clarify student ideas and support student thinking. The learner can then reflect on the feedback and act upon it to reach their goals within the community.

Feedback type (Hattie, 2007), difficulty of task (Hattie, 2007; Evans & Waring, 2011;Evans, 2013), timing of feedback (Black & Wiliam, 1998; Hattie & Timperley, 2007), and direction of feedback (Hatzipanagos & Warburton, 2009) affect feedback's impact on learning. Some types of feedback are more effective than others (Black & Wiliam, 1998; Hattie & Timperley, 2007; Evans, 2013). Praise, reward, and punishment are the least effective types of feedback (Hattie & Timperely, 2007). Feedback has the

greatest effect when goals are specific and challenging (Hattie & Timperely, 2007; Evans, 2013), task complexity is low (Kluger and DeNisi, 1996; Hattie & Timperely, 2007), and feedback provides guidance towards improving learning (Bell & Cowie, 2001b; Evans, 2013). Mathan and Koedinger (2002) argue that timing of feedback depends on the nature of the assessment task and student readiness. Feedback should be provided soon enough to be useful for students (Hatzipanagos &Warburton, 2009) and can be provided by teacher, peers, or self (Hattie & Timperely, 2007; Evans, 2013; Hatzipanagos & Warburton, 2009; Ruiz-Primo & Furtak, 2007). Feedback by self or peer allows students to take more responsibility and increase engagement in their learning (Nicol & Macfarlane-Dick, 2006; Sadler 1989; McConnell 2006; Hatzipanagos & Warburton, 2009). By using them, students take responsibility for their own and their peers' learning, and also enable mediation external to the student-teacher relationship, both of which can empower students.

Technology Education

The twenty-first century has been seen as "era of transformation and reforms" (Barak, 2017). In this century, technology has rapidly advanced the behaviors of users and the norms of the culture built upon technology's use. This new way of communication and information flow has impacted different aspects of life, including education. The way of learning is changed as learners use the Internet to answer questions, explore new places, and communicate with others to discuss issues (Jahnke, 2016). The National Education Technology Standards for Teachers (NETST) suggests that teachers should have competency in using technology for teaching so they can support students' use of technology for learning during problem solving, inquiry,

knowledge construction, and creative processes (International Society for Technology in Education [ISTE], 2008).

The need for improvement in science education and technology education has been emphasized in recent standards (NGSS Lead States, 2013; National Research Council [NRC], 2012). The Next Generation Science Standards (NGSS) has focused on integration of twenty-first century competencies in science classrooms (NGSS Lead States, 2013). With these new standards teacher expectations are enhanced. Thus, it requires rethinking of teaching and the roles of assessment (NRC, 2014).

Integrating educational technologies into the classroom has "a potential to fundamentally change the ways that learning and teaching are carried out" (Manuguerra & Petocz, 2011, p. 61). Technology can provide opportunities to improve scientific learning, engage in varied scientific practices (e.g. Buckley, Gobert, & O'Dwyer, 2010; Hickey et al., 2012), and increase engagement in those practices (e.g. Hickey, Ingram-Goble, & Jameson, 2009).

Technology also transformed the assessment process. It is commonly used for formative assessments and for several other purposes: reaching more students (e.g. Penuel & Yarnall, 2005; Feldman & Capobianco, 2008), motivating and engaging students (e.g. Kay & Knaack, 2009; Hoadley & Linn, 2000; Tan & Towndrow, 2009), modifying lessons (e.g. Gerard, Spitulnik, & Linn, 2010; Lee, Feldman, & Beatty, 2011; Maeng, 2016), enabling assessment in new environments and ways (e.g. Buckley et al., 2010; Hickey et al., 2012), providing feedback and scaffolding (e.g. Hickey et al., 2009; Yarnall, Schechtman, & Penuel, 2006; Maeng, 2016), and reviewing student knowledge (e.g. Koch & Sackman, 2004; Penuel & Yarnall, 2005).

Situating the Dissertation Manuscripts Within My Research Agenda

As I stated earlier, my research agenda is on formative assessment in K-12 classrooms. Under this broad agenda, I focus on the impacts of technology on formative assessment practices in K-12 science classrooms. To explore the impacts I use sociocultural views on learning. I merge the research on formative assessment and research on technology education (Figure 1.1).

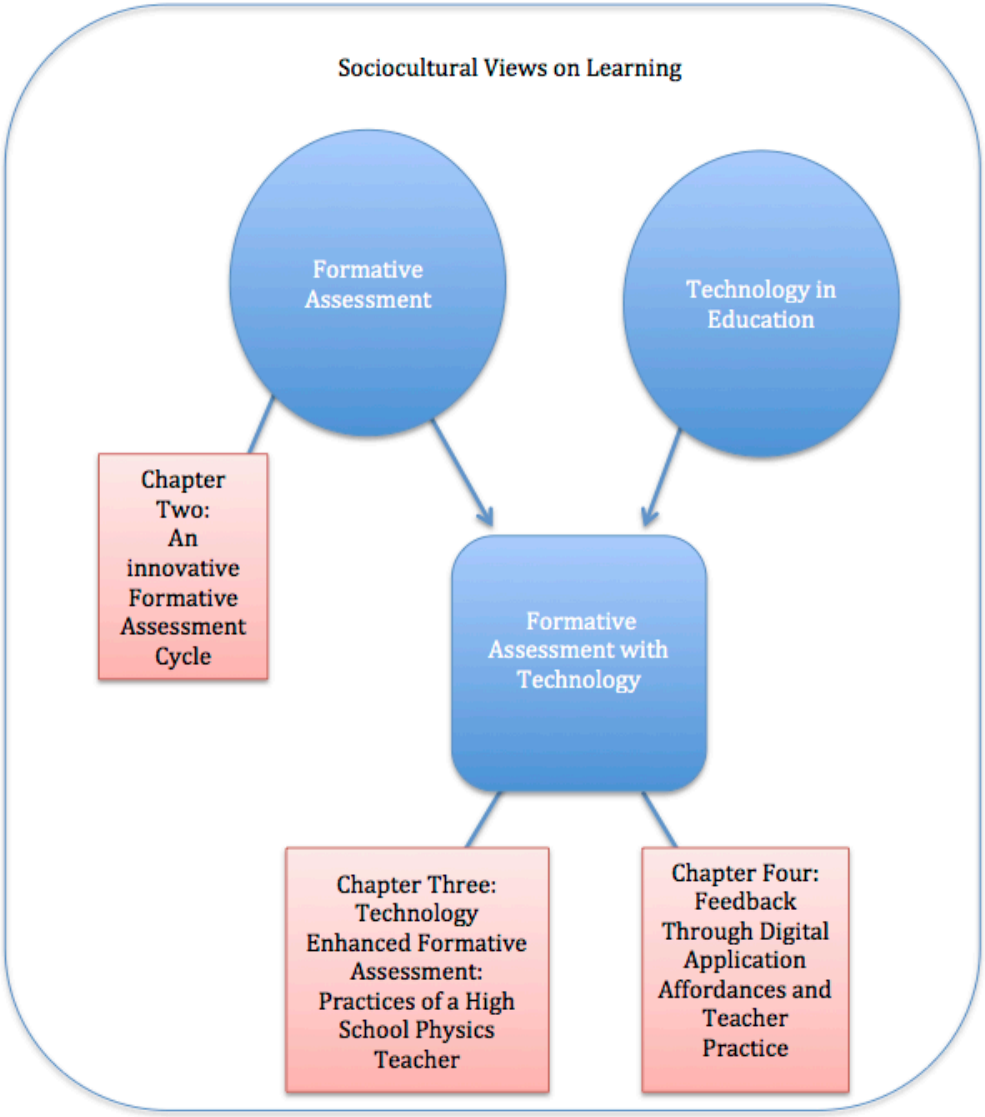

Figure 1.1 *Dissertation Chapters Situated Within My Research Agenda*

Formative assessment occurs via interaction between teachers and students (Bell, & Cowie, 2001a; Cowie & Bell, 1999; Gipps, 1994; Ruiz-Primo & Furtak, 2006; 2007). To better understand the process and practice, researchers developed formative assessment cycles (Wiliam & Black, 1996; Bell & Cowie, 2011a; Ruiz-Primo & Furtak, 2006; 2007). Though these cycles laid out a starting point for how and when the formative assessment takes place in the classroom, and for student and teacher responsibilities, they fail to recognize the effect of power relationships, students' backgrounds, and the surrounding environment on student learning. Thus in Chapter Two, I develop a new model for a formative assessment cycle based on sociocultural perspectives. Within this manuscript, targeted for the *Journal of Science Teacher Education*, I provided examples to explain the ideal formative assessment practices in a physics classroom. This new model is based on a literature review of sociocultural perspectives (Gipps, 2002; Crossouard, Pryor, & Torrance, 2004) and on prior formative assessment cycles (Bell & Cowie, 2001a; Ruiz-Primo & Furtak, 2006; Wiliam & Black, 1996; Haug & Ødegaard, 2015). The model is idealized and embedded in teaching. To implement the model in the classroom, there must be changes in curriculum, teachers need to have an understanding of learning in sociocultural learning, and teachers need to be supported before and during implementation. Thus this study can help teacher educators, professional developers, curriculum developers, and researchers.

Research has shown that technology education helps the teacher to: collect data faster, provide statistical analysis, be enabled to provide feedback, and improve student learning. There is limited research on how technology and formative assessment combine to foster learning and empower students that is also interested in student-teacher

relationships. Chapter Three is an empirical study on technology's influence upon a formative assessment process. This manuscript is targeted for the journal *Research in Science Education*. This study examined formative assessment process in a technology-enhanced high school physics classroom. The aim of this dissertation study is to understand how technology supports or hinders both formative assessment process and the classroom culture.

The specific research questions that guide this study are:

What is the nature of formative assessment in the context of using technology based assessment?

a) What do the formative assessment practices of a teacher using the iPad look like from a sociocultural perspective?
b) How does iPad use affect the formative assessment process?

This study differs from prior research by examining the influence of technology upon formative assessment process in regards to transformation of classroom culture, empowerment of students, and assistance towards student identity development.

Chapter Four is an empirical study on the potential of iPad applications for providing effective feedback. This manuscript is targeted for the *Journal of Science Education and Technology*. Feedback is an essential part of formative assessment that has a pivotal effect on learning development (Abell & Siegel, 2011; Black & Wiliam, 1998; Sadler, 1989; Ruiz-Primo & Li, 2013). Learners and teachers can benefit from educational technologies during the feedback process (Gilbert, Whitelock, & Gale, 2011). The purpose of this study is to identify the feedback dimensions that were fulfilled by iPad applications and compare teacher practice to affordances of apps.

The specific research questions that guide this study are:

Which defined feedback dimensions are fulfilled by iPad applications used in the classroom?

a) To what extent do iPad apps fulfill the feedback dimensions?

b) To what extent does teacher use of iPad fulfill the feedback dimensions?

This chapter provides recommendations for teachers, teacher educators, and app designers to support use of apps for effective feedback.

These three manuscripts helped me understand the potential of supporting teacher formative assessment practices and the role of technology during this process.

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CHAPTER TWO

An Innovative Formative Assessment Cycle: Formative Assessment from a Sociocultural Perspective

Abstract

Research in formative assessment is dominated by cognitive perspectives. To meet the objectives of new standards, the role of assessment should be reconsidered in science education (NRC, 2014). Assessment should shift from solely focusing on tracking student knowledge to focusing on student learning progress via participation in practices. This paper presents a model for the formative assessment cycle from a sociocultural perspective based upon literature regarding sociocultural perspective and prior formative assessment cycles. Key elements and characteristics of sociocultural perspectives are generated, and the relationship between these characteristics and assessment is discussed. Lastly, a new model of formative assessment that includes four steps is developed: building community, monitoring community, community mediation, and redefining goals. This paper describes and provides examples of these steps and defines the roles of teachers, learners, and peers within them.

***Keywords*:** formative assessment, sociocultural learning perspectives

Introduction

To date, assessment has been conceptualized by cognitive theories, which mainly focus on tracking changes in students' understanding (e.g., Ruiz-Primo & Furtak, 2006, Bell & Cowie, 2001a; 2001b). With the recent release of Next Generation Science Standards [NGSS] (NGSS Lead States, 2013), assessment has become a focus of attention among science educators. With this new approach, student learning has been

conceptualized as harmonic interactions among three dimensions, namely core ideas, practices, and crosscutting concepts. It highlights the importance of involving students in practices, which necessitates a shift in our approach to assessment from solely focusing on student knowledge to how students participate in practices by using their knowledge. Similar to NGSS approach, sociocultural learning theories stress the importance of student involvement in community, and improving performance and understandings via this participation. From sociocultural perspectives, participation is mediated by identities of students, classroom culture, and power relationships (Crossouard, 2009; Kozulin, 2002).

To meet the objectives of new standards, the role of assessment should be reconsidered in science education (National Research Council [NRC], 2014); implementing formative assessment from a sociocultural perspective can help. Using the perspective will help implement the NGSS approach to participating in authentic practices and solving complex, cross-disciplinary problems. It can also support students in becoming active and responsible participants in society (Crossouard, 2009). Thus, in this paper I try to develop both teacher's and researcher's understanding of formative assessment in science classrooms.

This non-empirical paper explores sociocultural views on learning, its relationship to assessment, and defines a model of a formative assessment cycle from a sociocultural perspective. First, articles on sociocultural learning are examined and key elements are generated. Based on these elements, the common characteristics of sociocultural learning theories are categorized as: interaction, mediation, power, and identity**.** Their relationship with assessment is discussed. Four formative assessment cycles are introduced. Lastly, a

new model for a formative assessment cycle is developed based upon sociocultural views on learning. This model provides a new perspective in understanding the formative assessment process that is not fully explored in prior research models.

Literature Review and Theoretical Framework

Sociocultural Views on Learning

It is necessary to understand the sociocultural views on learning to discuss formative assessment from a sociocultural perspective. Sociocultural learning theory was established by Vygotsky in contrast to Piaget's cognitive development theory. According to Piaget, children learn using "logico-mathematical reasoning" (as cited in O'Loughlin, 1992, p. 794), which is used to solve mathematical problems and develop scientific rationality. Piaget believed that it is possible to get closer to objectivity and also asserted that the purpose of intellectual growth is coming to know reality more objectively (O'Loughlin, 1992). Thus Piaget was not interested in social and cultural effects on learning (O'Loughlin, 1992).

Sociocultural learning theories identified the agency of learning differently than other learning theories (Kozulin, 2002). Unlike Piaget, Vygotsky emphasized the importance of social and cultural aspects on learning. Though both theories agreed an individual learner is the agent, sociocultural learning theory criticized Piaget's cognitive development theory in two ways. First is the neglect in Piaget's theory of the importance of learners' interaction with parents, teachers, peers, and their environment upon learning. Individuals are always in a social environment (Moll, 1990). Vygotsky asserted interaction with the surrounding culture - which includes people and the environment - plays an essential role in learning. Second is the separation of cognition and instruction

(Kozulin, 2002). Vygotsky asserted that cognition and instruction are inseparable. Cognitive elements develop with and are advanced by instructional practices and surrounding culture. Learners' cognitive elements should be integrated with instructional practice (Kozulin, 2002).

Later, research emphasized that social interaction is central in the sociocultural perspective (Lemke, 2001; Wenger, 1998; Wertsch, 1991). The perspective's emphasis is collaboratively creating an environment and organizing the understanding of one's experiences (Moll, 1990). The sociocultural views of learning argue that knowledge is constructed socially and is context dependent. Humans are social beings and learning is an essential part of life; they construct knowledge by participating in valuable enterprises and actively engaging them (Wenger, 1998).

Lemke (2001) called this participation "cooperative human activity" (p. 296) and argues it is possible because humans create communities that share the same value systems, beliefs, languages, goals, and practices. Culture, historical background, and instructional setting have roles in constructing knowledge (Wertsch, 1991). Lemke (2001) states that sociocultural perspective not only emphasizes actions, but also emphasizes a variety of things such as: emotions, history, environment, linguistics, societal role, and culture. They all play a role in a community.

While these researchers focused on elements that play roles in community and shape learning, other researchers focused on how community participation affects the learning phase. Boreham and Morgan (2004) describe learning as "being embedded in social and cultural context" (p. 308) and they argue that the best way to learn is by participating in those contexts. While participating in those contexts, individuals and

society learn from each other and develop mutually (Wells & Claxton, 2002). When people work together as a group, the way they talk and solve problems and the constraints they face create a culture and every individual contributes to creating it. The way individuals think and behave change within this culture.

Wells and Claxton (2002) emphasized the importance of having different goals in the community which work to strengthen the community mindset. As an example, Leach and Scott (2003) argue that the scientific community has an impact on the construction of scientific knowledge as much as empirical data. They explained that science learning products (i.e, science concepts, etc.) are "validated through complex empirical and social process, and they are used within scientific communities for particular purposes. As such, scientific knowledge can only be learned through some process of social transmission" (Leach & Scott, 2003, p. 94).

Lave and Wenger (1991) viewed learning as situated activity and considered "legitimate peripheral participation" (p. 29) to be the central characteristic. It is defined as learners participating in the community of practices and improving their knowledge and skills towards becoming full participants. To become a part of community, new members need to learn the rules and culture of the community from older members who mediate newcomers with their experiences. Thus legitimate peripheral participation is interested in the ways that "old-timers" support "newcomers" in becoming full participants (Lave & Wenger, 1991, p. 29). They focused on the effect of mediation and scaffolding on learning and becoming a part of community.

In Vygotskian theory, child development is a formative process that includes maturational and experiential factors of a sociocultural nature. In social situations,

development has natural factors (genetic and maturational factors) interacting with social ones. It is impossible to separate natural factors from social factors because children are always exposed to interaction, "… either with the sociocultural symbolic systems (reading, writing, math) or the systematic experience of adults (parents, teachers, elders or prominent members of community)" (Kozulin, 2002, p. 8). Thus, according to sociocultural perspective, students learn via their environment.

The theory emphasizes the importance of the group-learning activities. In group-learning, individualism is maintained and individuals become self-aware (Bakhtin, 1973; 1981 as cited in Boreham & Morgan, 2004, p. 317). In group-learning environments students need to take responsibility for learning. Students need "to come to understand the scientific ideas, and to internalize (a version of) them for their own personal use" (Leach & Scott, 2003, p. 102). This can be done by comprehending the ideas presented, discussing and critiquing them, and finally applying these ideas to new contexts (Leach & Scott, 2003). These activities will teach students the importance of context since students will be discussing real scenarios. Group-learning activities are essential for students because of the roles and responsibilities they provide. During these activities, students become a part of community, learn to discuss and critique, use argumentation and analytical skills, take responsibility, and are respectful towards and help one another.

Though students become more active while learning, teachers still need to provide and organize an active learning environment. A teacher plays different roles (i.e., facilitator, supporter, evaluator, and active participant) to mediate students through the learning process (Moll & Whitmore, 1993). The aims of this mediation are helping students to both understand course materials and to apply their knowledge to new

contexts (Shepardson, 1999). One way to do this is to introduce scientific knowledge to students and facilitate internalization until it becomes *common knowledge* (Leach & Scott, 2003; Shepardson, 1999). Introducing students to new ways of thinking, persuading them of the usefulness and value of knowledge, and making key ideas available to them will help create this *common knowledge*. Nasir and Hand (2006) emphasized the importance of social and cultural processes in learning and development of children, specifically the effect of using tools. Nasir and Hand (2006) also added "… understanding learning requires a focus on how individuals participate in particular activities, and how they draw on artifacts, tools, and social others to solve local problems" (p. 450). While mediating, it is essential for teacher to remember learners' contributions to the classroom as the basis of their own learning. Focusing on the group and surrounding environment, rather than the individual learner, is a way to demonstrate this practice (Leach & Scott, 2003).

Key elements of sociocultural views on learning include [based on literature (e.g., Leach & Scott, 2003; Lemke, 2001; Wenger, 1998):

1. Learning demands social interaction.
2. Individuals cannot be separated from their social environment.
3. Individuals improve with society and together develop it.
4. Mediation helps individuals develop learning experience through human and symbolic means.
5. Tools help learning while shaping learners' thinking processes.
6. Sharing authority engages learners to take responsibility for learning and supports their identity development.

In the following section, I explain the characteristics of sociocultural views on learning. The characteristics are used later in the paper to explore the relationship between the theory and assessment. This assisted in understanding the theory for development of a new formative assessment cycle from a sociocultural perspective.

Characteristics of sociocultural views on learning. The common characteristics of sociocultural learning views on learning based on the key elements can be categorized as: (1) interaction, (2) mediation, (3) power, and (4) identity. These will now be explained in detail and used to establish their importance in learning.

Interaction: Social interaction is the core of the sociocultural perspective (Lemke, 2001; Nasir & Hand, 2006). Humans are social beings and need to interact with each other to communicate, explain their needs, and share experiences. Those interactions are included in learning which makes learning a social activity (Lave & Wenger, 1991; Wenger, 1998).

Groups of people who share interests, goals, or geographical space make up a community. Community participation requires interaction that involves actions, social relations, body language, and even emotions. To explain using an example: faculty members discuss in a departmental meeting how to support graduate students that are attending a national conference. This discussion is a form of interaction. Some faculty members share their ideas, some are silent, and some show their thinking via gestures. All these responses are participation. Via participation and interactions community members collectively produce learning (Boreham, 2000; Boreham & Morgan, 2004; Nasir & Hand, 2006). With participation learners will not only learn new knowledge but also will gain new perspectives (Murakami, 2015; Wenger, 1998). This participation

makes evolving and becoming a different person possible (Boreham & Morgan, 2004; Lave & Wenger, 1991; Lemke, 2001; Pryor & Crossouard, 2008).

In a community, individuals are exposed to different roles, encounter diverse opinions, and have different expertise. Thus community members mediate and teach each other which leads to learning. Communities create their own "meanings" via discussions and negotiations among the individuals or subgroups (Wenger, 1998). Though learners are embedded in communities they can still have their own ideas; this is essential for increasing diversity. These learners form a heterogeneous yet diverse community that values cultural differences among its members (Lemke, 2001). Since learning is becoming participating in a community helps a person increase self-awareness. Thus interaction and participation are sources for developing the identity of self. Social interactions within communities are essential for learning.

Mediation. Mediation is helping less experienced individuals become more capable of doing a task or learning a context. Mediation is another key aspect of the sociocultural perspective. It plays an important role in learning and child development. Tzuriel also asserted that mediation helps improve both students' learning capacity and test performance (as cited in Kozulin, 2002, p. 17). Klein and Portes showed that mediation is a stronger predictor of student achievement than SES, race, parental education, or parental marital status (as cited in Kozulin, 2002, p. 17).

There are two types of mediation: human and symbolic. Human meditation occurs when a more experienced person helps a less experienced one. An older sibling teaching a younger one to draw is an example and another is a teacher both demonstrating and helping students with an experiment. Interestingly research asserts that children are

mediated more at home than school (Kozulin, 2002). Parents who believe that there is greater chaos in real life than in school provide and ensure increased mediation for their children. School is more structured than real life; teachers think students do not need extensive mediation in the classroom. Without a rubric or lesson plan to follow at home children learn with mediation. A parent's mediation at home also provides improved classroom performance (Kozulin, 2002). This shows that mediation helps student performance and by extension improving mediation in the classroom will result in better student learning.

Tools are manufactured products that help communities express themselves and develop (Boreham & Morgan, 2004). Symbolic mediation is the act of an individual using a tool to improve his or her learning. For example using graphs to teach velocity is symbolic mediation and graphs are the tools. Symbolic mediators are important for child development and can take different forms (i.e., graphs, maps).

Sociocultural perspective emphasizes human mediation is not comprehended by the learner without a symbolic mediator and also that symbolic tools gain meaning via the community (Kozulin, 2002). Systematic exposure to symbolic mediators is more important than their individual forms (Kozulin, 2002). In other words the frequency and consistency of use of symbolic mediators are more important for student learning than their forms (e.g., graph, map). Without systematic exposure the symbolic mediators themselves become the content to learn instead of being functional within the learning environment. Thus both human and symbolic mediation are essential for learning. As different communities value symbolic mediation differently these mediations are culture specific. Nonetheless symbolic mediation is universal among different cultures.

Tools can be categorized as physical (e.g., a computer, maps) or symbolic (e.g., language, cultural artifacts). Both forms work together to help learners. While symbolic tools *provide a lens* to understand phenomena, technical tools help learners to improve *physically acting* upon them. "While technical tools provide children access to phenomena from different perspectives, it is only through psychological tools that children come to see the phenomena from different perspectives" (Shepardson, 1999, p. 629). Lemke (2001) argues that tools need to improve student access to diverse data sources; tools enable students to interact with peers and teachers and work long-term projects. Functions and limitations of tools regulate community activities and thinking.

Symbolic tools such as language and cultural artifacts help communities to develop and pursue common goals (Boreham & Morgan, 2004). Language is the main symbolic tool and it shapes an individual's thinking and voice (Leach & Scott, 2003; Lemke, 2001; Wells & Claxton, 2002). Language is used for both communication between people and within the mind of people serving as the basis for thought (Nasir & Hand 2006). Shepardson (1999) states that Vygotsky shows children interact with each other and understand the world around them using these same purposes of language.

Social language is created to develop a common understanding and create a shared meaning. Examples include " … a dialect used in a particular geographical area or a particular form of professional jargon, or indeed the way of talking about the natural world which is termed science" (Leach & Scott, 2003, p. 99). Scientific social language is created by the scientific community and differs from everyday language. While this helps scientists to discuss and develop science the differentiation from everyday language causes learners to have misunderstandings and develop misconceptions. Thus learning

this scientific social language becomes an essential part of science learning. Familiarity with the concepts from everyday language is not sufficient for students to improve their cognitive development even though symbolic mediators used in both scientific social language and everyday language can be used in different contexts. The language needs to be context appropriate otherwise students will have difficulty learning (Kozulin, 2002). Other learning theories also assert that students have difficulties in conceptual changes because everyday speech and school language are slightly different. According to Vygotskian learning theory learning must have content and a conceptual form. This demands content learners understand by using reasoning. In sociocultural perspective classroom activities are seen as constructing students' theoretical understanding in addition to being sharing exercises.

Power. Power is the source of authority in the classroom. Power relationships are important in learning because they affect the learning process (Boreham & Morgan, 2004). In a traditional classroom the teacher has the authority from this power and he or she decides most of the classroom activities using this authority. In reformed classrooms learners have more flexibility in choosing while learning - an example being choices among classroom assignments. Thus learners take more responsibility for their learning and share authority with the teacher (Murakami, 2015). Sharing authority will help students to become more critical of what they are learning (Crossouard, 2009). In science education this is especially important for the creation of a scientifically literate generation that takes the responsibility to criticize source material, discuss it, and apply criticism while making decisions. Therefore it is important to improve learners' skills of sharing authority and having power, which together help improve their identity.

Identity. Identity can be defined as the dominant characteristic within a person because it creates his or her self-image. Researchers argue that identity is essential for learning (Crossouard, 2009; Fusco & Calabrese Barton, 2001; Lave & Wenger, 1991; Nasir & Hand, 2006; Murakami, 2015) since learners' view of themselves as learners has a tremendous effect on their personal transformation, which affects their career goals. For example, learners who think they are not good at science might not participate in classroom discussions. This non-participation will influence their learning process. On the other hand learners who are more involved in activities will start to realize they learn from this involvement.

In sociocultural perspective learning is defined as "becoming" (Lave & Wenger, 1991). As defined above identity is related to both self-image and identity change via learning. Increased participation results in greater learning causing learners to become more confident of their ideas and of themselves. This is crucial in science education because of an increasing need for qualified STEM workers. Social minorities are underrepresented in STEM's qualified worker pool (National Science Foundation, 2017). One of the main reasons for this is that some learners see themselves as incapable in science related areas. This self-image is partially a result of social and cultural influence upon certain ethnicities (Nasir & Hand, 2006) and is influenced by gender discrimination (Calabrese Barton et al., 2013; Murakami, 2015). If there are more opportunities for students to participate in classroom activities and use authority while learning it will help them in identity development. This can lead to an increase in qualified STEM workers as additional learners take this identity into their career choices and career development.

Explaining the sociocultural characteristics and how they influenced learning

helped me explore the perspective. Through exploring formative assessment literature in the next section, I discuss both formative assessment from the sociocultural perspective and how each characteristic plays a role during formative assessment.

Formative Assessment

It is necessary to understand both formative assessment and how views of it evolve as learning theories change. As the view of learning shifted away from behaviorist, both teaching and assessment shifted and were redefined (Abell & Siegel, 2011; Gipps, 1994; 1999; Shepard, 2000). This enables me to discuss formative assessment from a sociocultural perspective.

View of assessment. Research in assessment is affected by changes in the view of learning. During the 20th century associationism and behaviorism were the dominant learning paradigms. Thorndike, Hull, Skinner, and Garner are advocates of them (Shepard, 2000). According to their view, learning occurs by accumulating pieces of knowledge. In this view, assessment is measuring whether or not learners can accumulate enough knowledge primarily using recall questions as the assessment strategy. Tests should be frequently used to make sure students reach the desired level. Tests were interested in evaluating students' mastery level with "one-skill-at-a-time test items" being used (Shepard, 2000, p. 5).

Cognitive theories focused on how the mind works, mental construction, and sense making. According to these theories, learners' existing knowledge and beliefs impact the learning process of acquiring new knowledge. Within cognitive theories, assessment aims to understand student learning. Views of assessment shifted away from associationism and behaviorism, to measuring high-order thinking skills and both

understanding and helping student progress. Shepard (2000) asserts higher order thinking, problem solving, and classroom discussions are more useful than memorization recall for assessing students. In this new view understanding students and improving student learning became important.

According to the sociocultural perspective, learning is supported through social interactions via participating learning activities. This perspective emphasizes the social and cultural impacts on learning. It focuses the importance of interactions during the participation, mediation of students, mediation among students, power relationships, and identity development (Crossouard, 2009; Kozulin, 2002). In this view, assessment should include open-ended performance tasks in which students can solve complex problems and apply their knowledge in real-world contexts (Shepard, 2000). During these tasks, assessment should provide students opportunities to participate in data collection and in discussions with peers and teacher. This perspective underlines the importance of the context, classroom culture, and empowering students during assessment. It promotes complex problems for which there is not a simple answer requiring students need to interact, discuss, and participate to solve the problem.

Formative assessment. Understanding of formative assessment is developed by the learning theories. In cognitive theories, the purpose of formative assessment is to improve student understanding by providing feedback and modifying teaching based on the information gathered from students (Bell & Cowie, 2001b; Black & Wiliam, 1998; Buck & Trauth-Nare, 2009; Furtak & Ruiz-Primo, 2008; Gipps, 1994; Popham, 2006; 2008; Sadler, 1989; Shepard, 2005). There have been significant increases in student learning resulting from formative assessment (Bell & Cowie, 2001b; Black & Wiliam,

1998; Shepard, 2000; Siegel, 2007) and this has led to an increase in research in formative assessment within the assessment literature.

Highly-cited Black and Wiliam (1998) define formative assessment as "... all activities undertaken by teachers, and/or by their students, which provide information to be used as feedback to modify the teaching and learning activities in which they are engaged." (p. 10). Popham (2008) highlighted that formative assessment is a process and that it uses "assessment-elicited evidence of students' status" to modify "ongoing instructional procedures"(p. 7). Other researchers also highlighted that formative assessment occurs during instruction (Cowie & Bell, 1999; Gipps, 1994; Popham, 2006, 2008; Shepard, 2005). The common characteristics of formative assessment can be summarized as: gathering information, assessing students' current understanding, modifying teaching and learning, providing feedback to students, and redefining goals.

Teachers have always used formative assessment to close the gap between students' current and desired level of performance (Black & Wiliam, 2009). Sadler (1989) asked three questions to explore formative assessment process: Where is the learner going? Where is the learner right now? How can the learner get there? Wiliam and Thompson (2007) adapted sociocultural perspective and emphasized student-teacher and student-student interactions and empowering students. They developed five key strategies of formative assessment: (1) clarifying and sharing learning intentions and criteria for success; (2) engineering effective classroom discussions and other learning tasks that elicit evidence of student understanding; (3) providing feedback that moves learners forward; (4) activating students as instructional resources for one another; and (5) activating students as the owners of their own learning. Wiliam and Thompson (2007)

believed during formative assessment both teachers and students (as learners or peers) need to take responsibility. By using Sadler's (1989) questions they created a matrix to explain which key elements people (teacher, learner, or peer) met in each step of the formative assessment process.

<table>
<tr><th></th><th>Where the learner is going</th><th>Where the learner is right now</th><th>How to get there</th></tr>
<tr><td>Teacher</td><td rowspan="3">1 Clarifying learning intentions and criteria for success

Understanding and sharing learning intentions and criteria for success

Understanding learning intentions and criteria for success</td><td>2 Engineering effective class-room discussions and other learning tasks that elicit evidence of student understanding</td><td>3 Providing feedback that moves learners forward</td></tr>
<tr><td>Peer</td><td colspan="2">4 Activating students as instructional resources for one another</td></tr>
<tr><td>Learner</td><td colspan="2">5 Activating students as the owners of their own learning</td></tr>
</table>

Figure 2.1 *Aspects of Formative Assessment* (Wiliam & Thompson, 2007)

Later, Cowie, Moreland, and Otrel-Cass (2013) were influenced by Wiliam and Thompson's (2007) differentiation of self, peer, and teacher roles in formative assessment and also by their findings in each classroom that indicated varied techniques could be used to implement their five strategies. Based on this influence, Cowie et al. (2013) defined formative assessment (stated by the authors as 'assessment for learning'):

> Assessment for learning encompasses those everyday classroom practices through which teachers, peers and learners seek/notice, recognise and respond to student learning, throughout the learning, in ways that aim to enhance student learning and student learning capacity and autonomy. *Assessment for learning also needs to reflect, be responsive to, and build on from how particular disciplines generate and legitimize meaning.* (p. 10) (emphasis as written).

This definition emphasized reflection, creating meaning, and enhancing student capacity and autonomy.

Hickey, Taasoobshirazi, and Cross (2012), Dunn and Mulvenon (2009), and

Black and Wiliam (2009) all criticize the common usage of formative and summative assessment. They argue a single assessment can be used for both summative and formative purposes. For example, a teacher can use assessment grades (summative) to inform parents (formative) and modify the instruction. Even high-stakes testing can be used for formative purposes; for example, by seeing what is emphasized poorly in the curriculum a teacher can pay more attention to that topic in the following year.

However, Filsecker and Kerres (2012) argued that standardized testing does not provide clear information about students' progression of their understanding and - even if it does - that teachers either narrow the curriculum to re-teaching for the test or do test-prep activities rather than modify their teaching based on students' needs. Filsecker and Kerres (2012) assert that for those reasons researchers such as Black and Wiliam (1998) focused on classroom assessment and learning. Although I do acknowledge Dunn and Mulvenon's (2009) viewpoint and agree with it within this study I define formative assessment as: the process in which students and/or teacher recognize and respond to learning progress while participating in the learning practices within community. During the process, students are expected to interact with each other and/or the teacher, and reflect on, and via mediating each other improve, their work. Formative assessment aims to improve student understanding within community, improve student autonomy, and assists adjusting instruction based on community needs.

After the recognition of the importance of formative assessment researchers began focusing on other aspects of formative assessment (e.g., Fusco & Calabrese Barton, 2001). Researchers generally focus on the English Language Learner's [ELL] needs (Lyon, Bunch, & Shaw, 2012; Siegel, 2007; Siegel et al., 2014; Siegel, Wissehr, &

Halverson, 2008); assessment sensitivity to cultural differences (e.g., Solano-Flores & Nelson-Barber, 2001); student and teacher interaction (e.g., Haug & Ødegaard, 2015; Ruiz-Primo & Li, 2013); sharing authority (e.g., Fusco & Calabrese Barton, 2001); and identity development (e.g., Crossouard, 2009; Fusco & Calabrese Barton, 2001).

These views on formative assessment and explanations of sociocultural perspective characteristics are a starting point for me to explore both formative assessment and sociocultural perspective and their relationship. In the next section, I explain the sociocultural characteristics and their influence on formative assessment.

Sociocultural Learning and Assessment

Formative assessment became popular at the beginning of the 1990's when researchers realized the general use of summative assessment does not fit well with constructivist learning theories (e.g., Bell & Cowie, 2001a; Black & William, 1998; Ruiz-Primo & Furtak, 2006; 2007; Shepard, 2003). In the following decade interest in the United Kingdom shifted to align formative assessment with sociocultural perspective (Cowie, 2005; Crossouard, 2009; 2011; Gipps, 2002; Pryor & Crossouard, 2008). Since schools mostly use the cognitive learning approach and are interested in student achievement in class and on standardized testing, it is not reasonable to expect teachers to use formative assessment to fully support the sociocultural perspective. Yet with slight accommodations teachers can support some characteristics of the sociocultural perspective. In this section, characteristics of sociocultural views on learning (discussed previously) are used to explain what formative assessment looks like from within a classroom using the sociocultural perspectives.

Interaction and assessment. Interaction is a key factor in formative assessment. The aim of formative assessment is to capture students' understanding to improve their learning. Teachers cannot do this without strong interaction which includes creating shared goals, students participating in discussions, teachers asking clarifying questions, and providing feedback to students (Furtak, Thompson, & van Es, 2016). Cowie (2005) says assessment is "a meaning making activity embedded in and accomplished through interaction, one that shaped what it means to be a student and how individuals see themselves as knowers and learners of science" (p. 209).

The interactions between students are as important as those with the teacher. Student-student interaction not only helps them mediate each other's knowledge, but also understand their comprehension and cultural differences. Additionally student-student interaction provides the opportunity to build a community. Being a part of community helps students take a variety of roles and build self-esteem through accomplishment. Communities have shared goals and interests. In assessment the teacher needs to communicate and create goals with students. Communicating academic goals is important since it will help students improve their learning experience and academic competence. However student and teacher goals do not match all the time; prior experiences and peer relationships could affect students' goals (Cowie, 2005). Creating and sharing goals with students thus becomes more important in order to overcome this bias; by this students can understand the aim of the assessment and have a meaningful learning experience. An instructor needs to have awareness of the shifting beliefs and reasoning within the group. Thus individuals need to be assessed, possibly in a group. Gipps (2002) stated "this can be afforded by assessing students in collaborative group

activity where they contribute a task and help others" (p. 76).

Mediation and assessment. Mediation is important in helping students extend their learning experiences. In assessment, mediation can be used as scaffolding that "supports the student in dealing with the item and/or learning from the assessment experience" (Siegel, 2007, p. 867). Scaffolding can be provided in different forms: simplifying text, providing images, text boxes, and graphs. Importantly while using scaffolding neither the content nor the difficulty of the assessment should change -only the presentation is simplified. In this way students are assessed on their knowledge not their vocabulary. It is particularly helpful for ELL (Siegel, 2007; Walqui, 2003) and disabled students.

Tools enhance mediation. According to Vygotsky using tools and supporting other learners helps learners improve mental function. Thus, "we should develop assessments which allows the use of auxiliary tools (including adult support) and thus produces best performance rather than typical performance" (Gipps, 2002, p. 75). Tools and artifacts should be used to assist to understand student ideas, however they should not lessen the critical role teacher plays in working with students' ideas and improving their understanding (Furtak et al., 2016).

It has been widely agreed that learning to use the language of science is essential for learning science (Lemke, 1990; Mortimer & Scott, 2003; Wellington & Osborne, 2001). Language is the main tool in sociocultural perspective (Lemke, 2001) and assessment. Both teacher and student create and/or use language to effectively communicate. Through this use an instructor understands the students' needs, process of learning, and can help produce the best performance. Using the same language during

teaching and assessment will prevent misunderstandings. Assessment should enable interaction between learner and instructor. In order to improve student learning it is necessary to understand, address, and assess the key concepts (Haug & Ødegaard, 2015).

Identity and assessment. Identity can be defined as how learning changes a person within the context of a community (Wenger, 1998). Using this definition indicates that culture plays a tremendous role in identity formation. Pryor and Crossouard (2008) highlighted that an individual has multiple identities that "are shaped by the cultural norms of society, its traditions, and institutions" (p. 7). Thus an individual cannot freely define his or her identities.

Assessment has an important impact on identity formation (Gipps, 1999). Crooks pointed out how assessment shapes a student's understanding of content comprehension, the perceptions of what content knowledge is important, and the perception of being a capable learner (as cited in Cowie et al., 2013). Cowie and her colleagues (2013) add "what it means to be a learner is locally defined, a product of the relationship and interactions between the teacher, the learner(s), and the task at hand (Elwood, 2006)" (p. 19). Because standardized tests and exams compare students they have a negative impact on students' self-image and self-respect. Pryor and Crossouard (2008) examine formative assessment as a way of shaping identities. The instructor can be assessor, teacher, subject matter expert, and learner. Classroom norms and instructor-student relationships differentiate based on the identities. There is a clear link between these identities and type of assessment (convergent and divergent). Teachers use convergent assessment while they are in assessor and subject matter expert roles and use divergent assessment while they are in the learner role. An instructor by using these different identities affects student

identity development. Cowie (2005) found that students believe assessment can shape the meaning of: being a student, learning science, and becoming "competent knowers of science" (p. 199).

Power and assessment. One reason it is useful to frame formative assessment as a sociocultural learning activity is because it involves students' participation. For a successful formative assessment, students need to actively participate, reflect on their experiences, and have some authority for their learning. Unlike traditional assessment in which the teacher holds the authority and the student is the follower, by using the sociocultural approach students are involved in the assessment process through negotiation and discussion of the assessment outcomes. This produces responsibility for their learning by requiring self-monitoring and reflecting on their own performance. It also encourages students to create a classroom culture through sharing goals and interpretations of knowledge. Sharing power with students will support students to be reflective about their learning process. By this there "… is a space where students can narrate into being new identities" (Pryor & Crossouard, 2008, p. 13). Sharing authority creates a healthy relationship between teacher and student that is based on mutual respect, which will allow the teacher to better understand the thought process and comprehension of learners (Cowie, 2005). Thus mutual trust and respect are essential for formative assessment (Torrance & Pryor, 1998).

I believe the application of sociocultural perspectives during instruction and assessment should improve learning through enhancing the participation in learning activities and empowerment of students. Thus in this section I explore the characteristics of formative assessment and sociocultural views on learning. To characterize the process

of formative assessment, a few cycles were developed by prior researchers (Wiliam & Black, 1996; Bell & Cowie, 2001a; 2001b; Ruiz-Primo & Furtak, 2006, 2007; Haug & Ødegaard, 2015), but they ignore the importance of classroom culture and environmental factors. In the following section, I explain and compare these formative assessment cycles and discuss their limitations.

Models for Formative Assessment

Formative assessment occurs via interaction between teachers and students (Bell, & Cowie, 2001a; Cowie & Bell, 1999; Gipps, 1994; Ruiz-Primo & Furtak, 2006; 2007). To better understand the process and practice, researchers developed formative assessment cycles (Wiliam & Black, 1996; Bell & Cowie, 2011a; Ruiz-Primo & Furtak, 2006, 2007; Haug & Ødegaard, 2015). Though these cycles laid out a starting point for how and when the formative assessment takes place in the classroom, and for students' and teacher's responsibilities, they fail to recognize the effect of power relationships, students' backgrounds, and surrounding environment on student's learning. Later in this section, four cycles are introduced to provide historical explanation of formative assessment process. This background is helpful in understanding the new model.

Wiliam and Black (1996) defined the assessment cycle components as: eliciting evidence, interpretation, and taking action based upon the interpretation. The cycle generally begins with eliciting evidence and completes with taking action. Cowie and Bell (1999) define formative assessment as "the process used by teachers and students to recognize and respond to student learning in order to enhance that learning, during the learning" (p. 101). Later, Bell and Cowie (2001a) describe a different formative assessment cycle consisting of planned formative assessment and interactive formative

assessment. During planned formative assessment the instructor plans both the activity and its purpose before instruction. Planned formative assessment aims to gather general information to determine class progress of learning. In contrast interactive formative assessment spontaneously occurs during student and teacher interaction during instruction. While the instructor cannot anticipate when and how the interactive formative assessment will occur the instructor can increase the chance by increasing opportunities for more interaction. Interactive formative assessment gathers specific information from individuals to determine their misconceptions and understanding. It enables teachers to "refine their short-terms goals for the students' learning within the framework of their long-terms goals" (Bell & Cowie, 2001a, p. 87).

Since these two formative assessments have different preparations and purposes their process steps are defined differently. Bell and Cowie (2001) defined the planned formative assessment characteristics: as eliciting, interpreting, and acting; they defined the interactive formative assessment characteristics of: noticing, recognizing, and responding. They are presented together below to increase understanding of their definition.

Planned formative assessment **Interactive formative assessment**

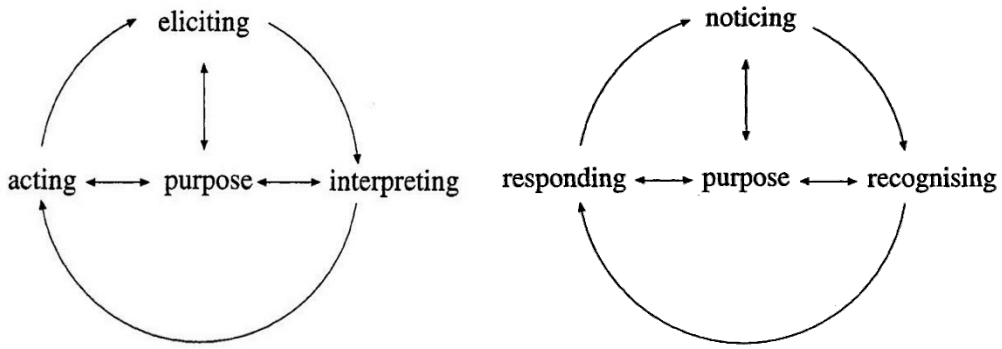

Figure 2.2 *Formative Assessment Cycles (Bell & Cowie, 2001a, p. 82, p. 86)*

Eliciting / Noticing. Eliciting is defined as gaining information about students' learning processes. Within science learning eliciting generally focuses on students' conceptions of the scientific topic. In the noticing step the information gained is ephemeral - not recorded. While it is much faster than eliciting teachers must be mindfully present in the moment because information is both hard to notice and not available later.

Interpreting / Recognizing. After teachers elicit information they interpret it to determine whether or not students meet expectations. Recognizing is defined as interpretation of information collected from students while observing students, talking with them, and listening to them. Typically recognizing occurs during class more often than after class.

Acting / Responding. After successfully interpreting teachers need to take an action to improve student learning by responding to students. Acting can be done through modifying instruction based on the purpose of the planned formative assessment. Responding can be achieved through providing immediate feedback to students. While both cycle terms are similar responding is more immediate.

Teachers' pedagogical knowledge (Shulman, 1986; 1987) plays an important role throughout planned and interactive formative assessments. For success teachers need to have a good understanding of the content knowledge being assessed and knowledge of both learners, and their content knowledge.

Both Bell and Cowie (2001a) and Ruiz-Primo and Furtak (2006; 2007) emphasize the continuum of the formative assessment in the classroom. While Bell and Cowie described formative assessment types as 'planned' and 'interactive' Ruiz-Primo and Furtak used 'formal' and 'informal'. Despite this descriptive similarity Ruiz-Primo and Furtak only focused on informal formative assessment, which can occur during any student-teacher interaction or during non-verbal interaction (e.g., observing students during small-group discussion). Their model, ESRU, explains the student-teacher interaction using four steps: Elicit (E), Student response (S), Recognition by teacher (R) and Use of information (U).

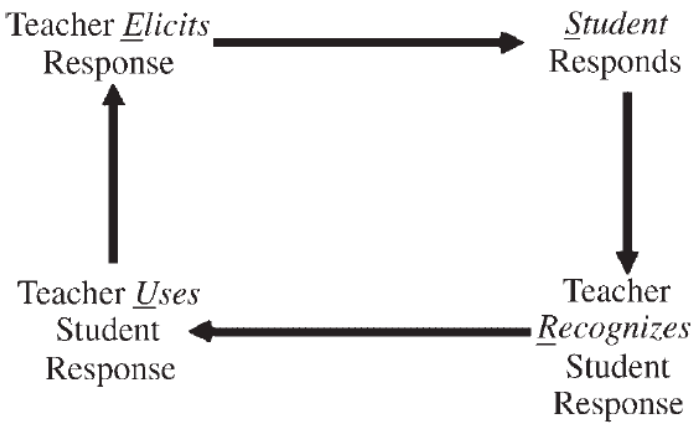

Figure 2.3 *Formative Assessment Cycle (Ruiz-Primo & Furtak, 2007, p. 61)*

Elicit (E). In this first step of the cycle teachers elicit students' ideas. Specifically teachers gather information about students' understanding by asking a question. This occurs during instruction and is spontaneous.

Student response (S). In this step a student responds to the teacher's question. This allows students to share their ideas and show their understanding. It also forces students to think explicitly to produce the response.

Recognition (R). In this step a teacher recognizes the student's response. It can be recognized in various ways including asking additional questions or simply paraphrasing the students' response. This recognition should remind students of the learning goals.

Use of information (U). In this step a teacher uses the information collected to support student learning. The purpose is to move students towards the learning goals. Examples range from simple encouragement to teaching the topic again.

Based on literature and their empirical data, Haug and Ødegaard (2015) developed a new model to explain the formative assessment cycle. It has a few contrasts in comparison to earlier models. Unlike prior methods, they included learning goals to their cycle. They broke down action into 'adapt teaching' and 'feedback'. The feedback is classified into types 'elaborative' and 'confirmative'. While confirmative feedback is used to confirm or disprove students' responses, elaborative is used to elicit student information and help them understand the learning process. Haug and Ødegaard's (2015) model shows that formative assessment is an iterative process in which teacher cycles among different overlapping paths based on student responses.

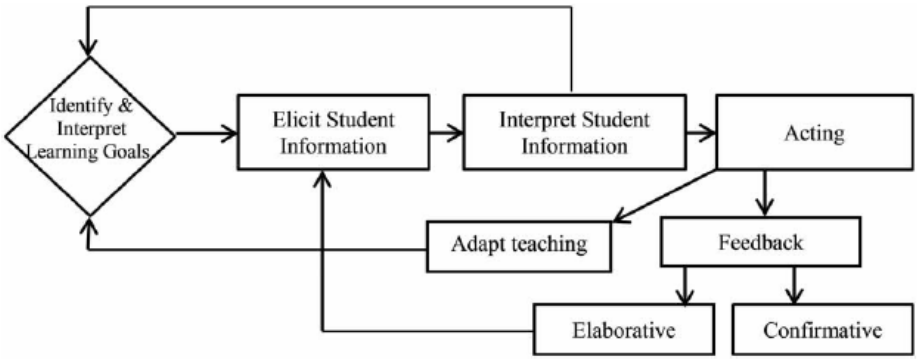

Figure 2.4 *Formative Assessment Cycles (Haug & Ødegaard, 2015, p. 651)*

Wiliam and Black (1996) assert formative and summative assessments follow the assessment cycle. Their cycle was pioneering in education. They focused on formative evaluation of assessment and emphasized the importance of feedback. Cowie and Bell (1999) and Bell and Cowie (2001a) focused on formative assessment. Their study categorized formative assessment as planned and interactive and highlighted their similarities and differences. Ruiz-Primo and Furtak (2006; 2007) only emphasized the importance of student-teacher interaction and focused on informal formative assessment. They studied teachers' formative assessment practices and found "use of information" is commonly skipped by teachers. Similar to Ruiz-Primo and Furtak (2006; 2007), Haug and Ødegaard (2015) focused on student-teacher interaction. As an addition to other frameworks they included identifying and interpreting learning goals, which happens during the preparation time. They also showed in their model how formative assessment process is iterative.

All of these cycles focused on improving students' content knowledge. Students need to improve their scientific and engineering skills and their confidence to become scientifically literate citizens. Using the sociocultural perspective classroom assessment

plays an important role in creating both individual and collective understanding about "what it is important to learn, what learning is and who learners are" (Haertel, Moss, Pullin & Gee, 2008, p. 9). I now define a new formative assessment cycle focused on student identity, creating a community, creating a shared language, and the power relationships among community members.

A New Formative Assessment Cycle Model

According to the sociocultural approach to learning, students learn within the society. A person and his or her surrounding culture are inseparable and their existence depends on their interaction (Nasir & Hand, 2006). Formative assessment occurs via interaction between teachers and students (Bell & Cowie, 2001a; Gipps, 1994; Ruiz-Primo & Furtak, 2006, 2007) that contributes to the classroom culture. Students should actively participate in assessment (Crossouard, Pryor, & Torrance, 2004). Such interaction is important for both learning and assessment.

The use of sociocultural learning theories has increased in education research (Wells & Claxton, 2002). Most research in education studies use the theory during analysis as a lens to investigate the classroom norms and teachers practices. Few studies focus on the application of the theory during teaching as a means to adapt teacher practice, for example, to empower students (e.g., Fusco & Calabrese Barton, 2001). Studies rarely focus on classroom assessment practices (e.g., Murakami, 2015; Cowie et al., 2013). This theoretical perspective needs to be used in teaching and assessment in addition to using it as a lens for research.

To advance my understanding of the formative assessment process, a formative assessment cycle is developed below based upon earlier models (Bell & Cowie, 2001b;

Ruiz-Primo & Furtak, 2006; Wiliam & Black, 1996; Haug & Ødegaard, 2015) and the sociocultural perspectives (Gipps, 2002; Crossouard et al., 2004). As in prior models, this model is based upon student-teacher interaction during formative assessment. In contrast to prior models, this cycle is embedded in instruction, emphasizes community, addresses the power relationship within the classroom, focuses on identity development, and acknowledges cultural differences both between students and within the community as a whole.

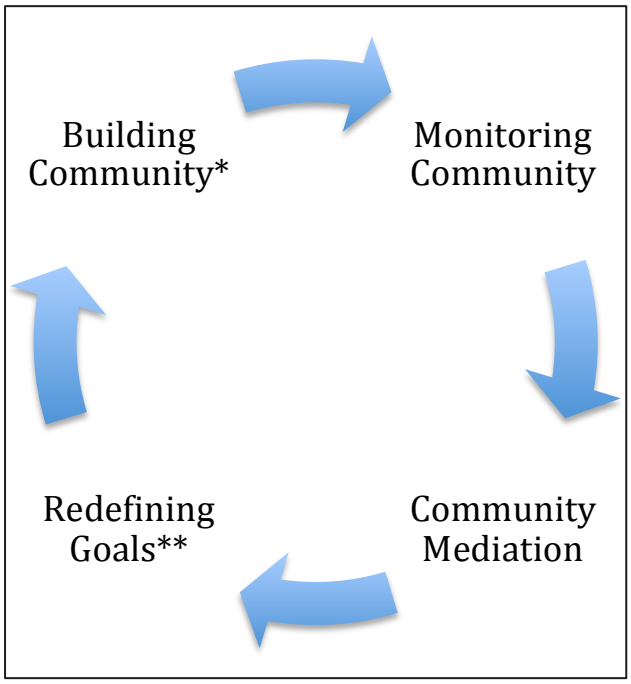

Figure 2.5 *Model of Formative Assessment Cycle Based on Sociocultural Perspective*

*Occurs before the assessment

** Occurs after the assessment

The model cycle length can vary from the shortness of an activity to the length of a lesson or an entire course. A course may have multiple lesson cycles, and a lesson cycle can have multiple activity cycles.

Building Community

In sociocultural perspectives, science learning occurs through interaction with students, and students learn within community by participating in scientific activities. "We need to develop ways to recognize and assess emerging science knowledge in classrooms not only as individual accomplishments, but also as shared processes and communal understandings" (Radinsky, Oliva, & Alamar, 2010, p. 620).

To be able to assess student understanding, classroom norms, which support interaction among students towards creating collective understanding in the community, need to be developed. Classroom norms: (1) encourage students to value other community members' ideas and experiences during interaction, (2) facilitate students creating a communal understanding by reflecting on and challenging other students' ideas and experiences, and (3) sharing authority among students and teacher. These norms may assist students taking responsibility for their learning individually and as a community, which facilitates empowering students and provides opportunities for students to develop identities as science learners (Lemke, 2001; Murakami, 2015; Wenger, 1998; Lave & Wenger, 1991).

Building community occurs before the assessment starts, which makes the teacher more responsible for completing this step than students. Teachers may consider student shyness, due to authority not being shared among all members, may restrict student participation, which limits the outcome of learning for individuals and the community. An example is given regarding how teacher can develop a classroom norm.

For example, a teacher asks students about efficient ways to use iPads in a classroom and how they might benefit from using iPads. The teacher asks students to

discuss it as a class and come up with a list. The list could be implemented in the classroom community. This scenario provides an example of how classroom norms can be implemented and how students can participate in creating them.

Another example could be a teacher introducing whiteboarding to the classroom with an activity. Suppose at the beginning of the semester teacher used whiteboarding as an activity to introduce students to the meaning of safe space and used the whiteboarding to provide a safe space for students to discuss their ideas. In this scenario, students whiteboarded about their favorite ice creams, an activity that has no correct outcome. A whiteboarding activity can be expanded upon by discussing possible rules for the whiteboarding (language, respecting peers) and then having the students come to a consensus on the rules. During the discussions students can gain authority.

Monitoring Community

Building a community is not enough by itself - a teacher must know the community. This could be done through participating in community throughout the assessment. Students, as community members, are enhancing their understanding within the community (Lave &Wenger, 1991; Boreham & Morgan, 2004). Thus the classroom norms might change based on student interactions and their inputs. "It is not possible to assume a direct link between teaching and learning and so teachers need to monitor the sense students are making during, and not just at the end, of an activity" (Cowie et al., 2013, p. 11). This step is involved in monitoring student progress to understand student reasoning while being aware of the students' prior experiences, students' developing identities, and the classroom norms, which includes shared language and sharing authority. Classrooms, as such a community, have their own rules and shared language

that must be considered by teachers and used consistently with students (Leach & Scott, 2003; Lave & Wenger, 1991; Wenger, 1998).

This step occurs during the formative assessment process. Teachers and students have the responsibilities of understanding the community, its norms, and the members' needs. These responsibilities can be fulfilled through interaction and discussion among community members. While a teacher constantly monitors the student interaction, students can self-assess by reflecting on their understanding, can monitor their peers via peer assessment, and can take more responsibility for their own learning.

Teacher can better engage students in the learning process by providing them a scenario related to their lives (e.g., Fong & Siegel, 2005). Suppose the teacher provided students an expert report regarding a traffic accident without identifying the vehicles involved. The report was written based on a police report, information from insurance companies, and analysis of the accident scene. The teacher then asked students to both explain how the accident happened in their own words and the physics behind it. Students discussed within a small group possible ways the accident could have been prevented. During these discussions, the teacher walked around, monitored students' interactions, and asked students questions to challenge them. During the small group discussions the teacher facilitated students' use of the classroom norms and encouraged to make changes to these norms. Then the teacher provided a platform for a whole-class discussion in order to create a communal understanding. This example shows how a teacher could facilitate development of a shared language by making students explain the physics behind the accident and discussing as a whole classroom.

Community Mediation

Mediation is accomplished by encouraging students to help each other and by providing them with feedback. Effective feedback is more than a strategy. It goes beyond giving suggestions or corrections to students after assessment; it includes both parties working through cultural differences and sharing knowledge at all stages (Cowie et al., 2013; Willis, 2015). Unlike cognitive perspectives, which are interested in providing feedback to learner on their knowledge, mediation involves challenging of student understanding, spurring the group to reexamine their performance, and fostering growth within the community (Lave & Wenger, 1991). Mediation, through community discussion and use of tools, supports student learning experiences and identity development (Lave & Wenger, 1991; Crossouard, 2009). Student engagement in learning both assists them in recognizing themselves as science persons and also develops the meaning of being a learner (Cowie et al., 2013; Pryor & Crossouard, 2008).

Giving tasks is not enough for students to achieve their goals; mediation is required among students and between the students and teacher. Since peers have similar difficulties of understanding a topic, and they often share experiences and context, they can provide feedback to each other using "familiar and understandable" language (Cowie et al., 2013 p. 15). Students mediate each other via peer assessments, which include examining, comparing, and contrasting their work. Teachers can mediate students by providing feedback on their learning progress within the community.

Suppose, within a unit teaching 'waves', students explored the behaviors of waves and made connections between force and energy. The teacher used an application (app) on a tablet to record waves that allowed slowing the recording so students could observe

the wave's behaviors. Students were encouraged to discuss with their peers and create a shared understanding of the wave's behaviors by using the collected data. During those discussions, the teacher facilitated interactions among students by encouraging them to mediate their peers' use of the app.

Redefining Goals

In cognitive perspectives, the goal of formative assessment is to assess whether students achieve the predetermined learning goals. Teachers determine these learning goals (Moss, 2008; Ruiz-Primo, 2011). Unlike cognitive perspectives, sociocultural perspectives focus on the impact on students. The aim is not only meeting the teacher-determined goals, but also the community-driven goals that come from the interactions during the learning process (Cowie et al., 2013). This community action will not only improve students individually but also improve community cohesiveness. Since community goals can only be achieved through cohesive collaboration, the identity of individuals develops as they become skilled during community activities (Lave & Wenger, 1991; Cowie et al., 2013). Teachers should still consider students' specific needs (e.g., language difficulties, cultural differences) towards identity development. Redefining goals could mean making adjustments rather than changing the goals altogether. This step has greater impact when the teacher empowers students to redefine goals.

Suppose students were involved in decision-making regarding next steps of their activity. Students watched a video on speed skating in which one skater was speeding faster than other. Then the skater lost her balance, fell, and slid in to the wall. The teacher asked students to discuss what forces were affecting the skater. During this discussion,

students get interested in the possible reasons why the skater lost balance. After students eliminate several reasons, they decide to investigate the relationship between the skater's body angle and speed.

Below I summarized the teacher and students' actions in each step of the formative assessment process. I was influenced by Wiliam and Thompson's (2007) approach and thus categorized students' actions as learner or peer (Figure 2.1).

Table 2.1 *Actions for Formative Assessment by Step*

	Teacher	Student (Learner)	Student (Peer)
Building Community	Develop environment to support classroom norms and create communal understanding.	Understands learning intentions, classroom norms, and assessment criteria for success.	Shares the understanding of learning intentions, classroom norms, and assessment criteria for success.
Monitoring Community	Monitors students' learning progress through interactions within community	Knows weakness and strengths of self.	Is aware of the differences among peers and self while listening to and monitoring peers.
Community Mediation	Mediate and challenge students' ideas Spurs the group to reexamine their performance Deepens group understanding Encourages students to take different roles and take on responsibilities	Self assessment Reflects upon own learning process within community	Peer assessment Scaffolds, assesses, challenges, and monitors peers.

Redefining Goals	Redefines goals within classroom context Adjusts goals based on community needs.	Involves self in redefining goals by being aware of community needs.	Involves self in redefining goals by being aware of community needs.

This model explains the cycle of formative assessment that is embedded in instruction. I believe teaching and emphasizing only content knowledge to students is not enough to prepare them to be active, responsible, and scientifically literate participants in society. With this new cycle I extend attention beyond content knowledge. As in prior models, this model is based upon student-teacher interaction during formative assessment. It additionally emphasizes community, addresses power relationships within the classroom, emphasizes shared goals and mediation, and focuses on identity development within the community.

The model is focused on the formative assessment process. To get the most benefit from implementing this model, the cycle may be used for the whole course (a large cycle) with small cycles within it that can be used for activities or lessons. The beginning of the large cycle will help build community, create classroom norms, monitor students' progress of becoming members of community, and defining goals for the future. Small cycles may focus on the monitoring of students' learning progress, mediation of community related to content, and redefining goals related to student understanding of content. Redefining goals within the small cycle can be useful for the course's next activities or lessons. Though building community is generally accomplished within the large cycle, community building can also occur within small cycles based on context and community needs.

This model may be useful to meet in-service and pre-service teachers' needs. I propose this preliminary model to be used as both an analyzing framework for research, and as a tool for improving teacher's assessment practice – a model that leads teachers to a responsive use of sociocultural perspective, not as theory, but as a dynamic environment to be established and fostered. In the following section, I discuss possible implications for teacher education programs and researchers.

Implications

This study examined formative assessment using the sociocultural perspective. After examining literature on formative assessment and sociocultural views on learning, I proposed a new formative assessment cycle based on sociocultural perspectives. I believe my model will be useful both in the classroom and research arenas. I provided examples from a physics classroom to explain my model and demonstrated the classroom practice. Some examples were extended to match expectations of a teacher's practice in the specific step of the formative assessment cycle.

In order to implement my model, several aspects must be taken into consideration. Curriculum, classroom environment, and teacher practice are pivotal for implementation. Formative assessment practices are embedded in teaching (Furtak et al., 2016; Cowie et al., 2013; Cowie, 2005). Supporting complex thinking, problem solving, and interaction between students are critical for the curriculum. Within this model, a classroom environment in which students reflect upon their own thinking and mediate peers has potential to support student-learning progress (Black & Wiliam, 2009) and identity development within the community (Kelly, Luke, &, Green, 2008; Fusco & Calabrese Barton, 2001; Lave & Wenger, 1991; Murakami, 2015). Creating a safe space for

students may increase engagement interaction among students and the teacher. Community cohesiveness may be increased when members value each other's background, experiences, and ideas (Lemke, 2001). Within this model, the teacher's role is critical in creating the environment and modifying the curriculum. My suggestions for implementing this model follow.

This model can be useful for practicing and prospective teachers. In order for teachers to successfully understand and incorporate this model in their practice, it must be embedded within a context. Therefore teachers need to be supported during their implementation. Professional development programs that enable the teacher to implement the model in the classroom, and then discuss the implementation issues, would be useful. Similarly, prospective teachers that implement this model would benefit from mediation during the implementation process. Researchers could use this model to conduct investigations on understanding teacher formative assessment practices and formative assessment culture within the classroom community.

Conclusion

Cognitive perspectives were widely used in formative assessment research. Researchers were interested in tracking student knowledge and improving it. With the NGSS (NGSS Lead States, 2013) approach learning is conceptualized as a combination of three dimensions (scientific practices, core ideas, and crosscutting concepts). Thus the view of assessment in science education needs to change to meet the objectives of new standards (NRC, 2014). Sociocultural perspectives may be useful for this reconsideration since they focused on participation in practices and social interaction during the participation.

Sociocultural learning theories have been used as an analyzing framework in research to explain relationships in and out of the classroom. Only a few studies focused on how to build a curriculum or classroom environment to support learning from the sociocultural perspective (e.g., Calabrese Barton, Tan, & Rivet, 2008; Cowie et al., 2013).

This paper provides a new perspective on a formative assessment process. This paper introduced an innovative formative assessment cycle with examples of its application, accomplished through examination of sociocultural learning theories and prior formative assessment cycles. Student and teacher expectations were provided.

Future researchers can use this framework in multiple classrooms to gain a general understanding of teachers' formative assessment practices, students' contributions, and teachers' strengths and weaknesses. While my model is focused on the classroom, it did not focus on the influence of external communities (e.g., school, school district) or external factors (e.g., standardized tests, familial expectations) upon the formative assessment process. Future research may examine the influence of these external factors.

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CHAPTER THREE

Technology Enhanced Formative Assessment: Practices of a High School Physics Teacher

Abstract

Formative assessment is essential to student learning. Formative assessment, through interaction with students, has the potential to assist teachers in understanding student needs and creating a shared understanding. Formative assessment can empower students via peer and self-assessment opportunities. Technology has the potential to support the teacher during this process and assist in improving student learning. Yet, there is limited research combining technology and formative assessment that is geared towards fostering learning and empowering students (e.g., Cowie, Moreland, & Otrel-Cass, 2013). The purpose of this study was to examine the influence of technology use on a high school physics teacher's assessment practice. Amy was selected due to her frequent use of iPads in her classroom. I examined her formative assessment practices and how the iPad influenced her practices by using sociocultural learning perspectives. In addition to several secondary data sources, my primary data sources included video-recorded observation of class sections, the researcher's field notes, and teacher interviews. To help explain Amy's formative assessment practices in a technology-enhanced classroom, I described the classroom's formative assessment culture by describing community members (students and teacher), tools, and classroom norms. For exploring the influence of the iPad on teacher's formative assessment, I categorized the influence of the iPad on teacher's formative assessment practices. Three themes emerged: 1) transforming classroom community, 2) empowering students, and 3) facilitating evidence-based

discussions. This study sheds insight into the impact of technology use on teacher's formative assessment practice, how it rebuilds the classroom norms, and how it impacts student identity development. Implications for teacher education programs and professional development programs are discussed.

Keywords: formative assessment, technology in education, sociocultural learning.

Introduction

Assessment is an essential part of quality teaching. Research has shown that formative assessment can enhance student learning (Bell & Cowie, 2001a; 2001b; Black, & Wiliam, 1998; Ruiz-Primo, & Furtak, 2006; 2007; Herman, Osmundson, Dai, Ringstaff & Timms, 2015). In a sociocultural perspective, Cowie (2005) defined assessment as "a meaning making activity embedded in and accomplished through interaction, one that shaped what it means to be a student and how individuals see themselves as knowers and learners of science" (p. 209). Formative assessment enables creating a shared understanding via interaction, helps students improve their own learning experience, and increases academic accountability by empowering students (e.g., Cowie, Moreland, & Otrel-Cass, 2013).

Educational technologies support modifying instruction to meet student needs and improving student knowledge for assessment (Aldon, & Dempsey, 2016; Maeng, 2016; Hickey, Taasoobshirazi, & Cross, 2012; Hickey, Ingram-Goble, & Jameson, 2009). Prior research in technology-enhanced assessment focused on features of particular technologies designed by researchers, how learners interact with these technologies, and teacher and student views on particular technology (e.g., Hickey et al., 2009; Buckley, Gobert, & O'Dwyer, 2010; Gerard, Spitulnik, & Linn, 2010). There is a need for research

on teacher's practice of using technology for assessment purposes within science education (Songer & Ruiz-Primo, 2012). Research on how technology supports a teacher in creating a classroom environment that empowers students and improves their learning is limited (e.g., Cowie et al, 2013).

To help fill this gap the aim of this dissertation study was to understand how technology supports or hinders a teacher's formative assessment practices and the classroom culture. This study differs from prior research by examining the influence of technology upon teacher's assessment practices in regards to transformation of classroom culture, empowerment of students, and assistance towards student identity development.

This study examined a high school physics teacher's formative assessment practice in a technology-enhanced classroom. I first explored the teacher's formative assessment practices in a technology-based classroom and portrayed the classroom community by describing members, tools, and assessment norms. Next, I examined the influence of technology in the teacher's formative assessment practices. This study sheds insight into the impact of technology use on teacher's formative assessment practice, how it rebuilds the classroom norms, and how it impacts student identity development.

Theoretical Background and Literature Review

This section consists of three parts; sociocultural views on learning, formative assessment and technology education. The first part is overview of sociocultural views on learning and explaining main characteristics of it. The second part defines formative assessment and explores it from a sociocultural perspective. The last part discusses technology education and mobile learning and explores technology usage in assessment in science education.

Sociocultural Views on Learning

Sociocultural learning theories are different from earlier theories in terms of emphasizing the social and cultural aspects of learning (Wertsch, 1991; Wenger, 1998; Lemke, 2001). According to these theories, knowledge is constructed socially and is context dependent (Boreham & Morgan, 2004). Culture, historical background, and instructional setting have roles in constructing knowledge (Wertsch, 1991). Learners improve their knowledge by participating in the society in social and cultural contexts and this participation improve the society. Thus they develop mutually (Wells & Claxton, 2002). When a group of people works together the way the people talk and solve problems and the constraints they face create a culture and every individual contributes to creating this culture. The way individuals think and behave change within this culture. Wells and Claxton (2002) emphasized the importance of having different goals in the community which work to strengthen the community mindset.

Key elements of sociocultural views on learning include, according to the literature (e.g., Leach & Scott, 2003; Lemke, 2001; Wenger, 1998):

1. Learning demands social interaction.
2. Individuals cannot be separated from their social environment
3. Individuals improve with society and together develop it.
4. Mediation helps individuals develop learning experience through human and symbolic means.
5. Tools help learning while shaping learners' thinking processes.
6. Sharing authority engages learners to take responsibility for learning and supports their identity development.

I categorized the common characteristics based on the key elements of sociocultural views on learning as: (1) interaction, (2) mediation, (3) power, and (4) identity.

Social interaction is the core of the sociocultural learning perspectives (Lemke, 2001; Wenger, 1998; Wertsch, 1991; Nasir & Hand, 2006). Learning is a social activity and it requires to interact with others to explain their needs and share experiences (Lave & Wenger, 1991; Wenger, 1998). This will lead learners to grow within the society (Boreham & Morgan, 2004) and as members of community they collectively produce learning (Boreham, 2000; Boreham & Morgan, 2004; Nasir & Hand, 2006). In this study, this society is the classroom where teacher use technology and its members. As earlier researchers stated, with participation learners will not only learn new knowledge but also will gain new perspectives (Murakami, 2015; Wenger, 1998). Learners will expand their view of the world and of themselves by merging these new perspectives with their own. Thus interaction and participation are sources for developing the identity of self. In this study it is explored how students were interacting with each other within the society and how it shapes their learning experiences and who they are.

Mediation is another characteristics of sociocultural views on learning. It is defined as is helping less experienced individuals become more capable of doing a task or learning a context. Since learning cannot be separated from social contexts. Learners need to learn the rules and cultures of the community that they are part of it. In this learning stage older members mediate newcomers with their experiences (Lave & Wenger, 1991). Using Lave and Wenger's (1991) terms, in the classroom setting, teacher could be defined as "old- timers" and students can be identified as "newcomers".

However for technology usage these identifications are not necessarily accurate, since students were immersed in technology in their daily lives. This creates an interesting dynamic of changes in the roles of students and teacher in the study.

Power is linked very closely to authority in a classroom environment. In a traditional classroom, teacher has authority and the power to decide classroom activities and norms. Sociocultural perspectives emphasize being part of community, a result of which is the taking and sharing of responsibility and power. Power relationships are important in learning because they affect the learning process (Boreham & Morgan, 2004). Group-learning activities are essential for students because of the roles and responsibilities they provide. During these activities students are becoming a part of community, learning to discuss and critique, using argumentation and analytical skills, taking responsibility, and being respectful towards and helping one another. Thus learners take more responsibility for their learning and share authority with the teacher (Murakami, 2015). Sharing authority will help students to become more critical of what they are learning (Crossouard, 2009). In this study it is explored how technology provided new ways to influence group activities and students' responsibility taking.

Identity is a complex concept. It is a label to describe someone or not predetermined and fixed independent of time and context (Lemke, 2001; Carlone & Johnson, 2007; Tan, Calabrese Barton, Kang, & O'Neill, 2013). Thus it is difficult to study (Carlone & Johnson, 2007). In this study, "Identities-in-practice" (Lave & Wenger, 1991) phrase is used. Researchers emphasized that identities are transformed by participating community and by defining their role in the community. There is an inevitable link between learning and identity formation. In sociocultural perspectives

learning is defined as "becoming" (Lave & Wenger, 1991). Increased participation results in greater learning causing learners to become more confident of their ideas and of themselves. This teaching and learning practices will influence learners' sense of who they are and who they become (Cobb, 2004). This is crucial in science education because of an increasing need for qualified STEM workers. In 2015 STEM's need for qualified workers includes under representation by social minorities (National Science Foundation, 2017). One of the main reasons for this is that some learners see themselves as incapable in science related areas. This self-image is partially a result of social and cultural influence upon certain ethnicities (Nasir & Hand, 2006) and is influenced by gender discrimination (Murakami, 2015; Calabrese Barton et al., 2013). If there are more opportunities for them to participate in classroom activities and use authority while learning it will help them in identity development.

All these aspects were interrelated. A technology enhanced physics classroom can be constructed as a community. In this community, learners need to interact to explain their ideas and concerns. They need to interact to help each other and mediate during the process. This type of mediation, human mediation, frequently happens at group activities where students share their work, responsibilities and power. Having responsibilities helps learners to become more confident of their ideas and of themselves. In this study, one teacher's formative assessment in a technology-enhanced classroom is explored based on these aspects and their interrelation.

Formative Assessment

During the 20th century, associationism and behaviorism were dominant learning paradigms. Shepard (2000) presents this shift from behaviorist and associationist

approaches to social–constructivist theory, where learning is constructed socially and assessment aims to understand student learning rather than only recall. As the view of learning shifted from behaviorist teaching and assessment both shifted and were redefined (Abell & Siegel, 2011; Gipps, 1994; 1999; Shepard, 2000). It is shifted from measuring the knowledge students gathered, student recall and memorization skills to high-order thinking skills and understanding and helping student progress. Formative assessment became popular in the 1990's because the general use of summative assessment did not fit well with the constructivist learning theories (e.g., Bell & Cowie, 2001a; 2001b; Black & Wiliam, 1998; Ruiz-Primo & Furtak, 2006; 2007). In the following decade interest in the United Kingdom shifted to aligning formative assessment with sociocultural perspectives (Cowie, 2005; Crossouard, 2009; 2011; Gipps, 2002).

The purpose of formative assessment is to improve student understanding by providing feedback and modifying the teaching based on the information gathered from students (Black & Wiliam, 1998; Buck & Trauth-Nare, 2009; Furtak & Ruiz-Primo, 2008; Gipps, 1994; Popham, 2006; 2008; Shepard, 2005). It allows instructors to make adjustments to their instruction to better meet students' needs (Buck & Trauth-Nare, 2009) and this improves student learning (Ruiz-Primo, & Furtak, 2006). Formative assessment occurs via interaction between teachers and students (Bell & Cowie, 2001a; Cowie & Bell, 1999; Gipps, 1994; Ruiz-Primo & Furtak, 2006; 2007). This study is based on sociocultural perspectives, according to which assessment is situated within a social setting (Moreland, Jones & Northover, 2001). Hence, in this study formative assessment is seen as a process, not a tool. I define formative assessment as: the process in which students and/or teacher recognize and respond to learning progress while

participating in the learning practices within community. During the process students are expected to interact with each other and/or the teacher, and reflect on, and via mediating each other improve, their work. Formative assessment aims to improve student understanding within community, improve student autonomy, and assists adjusting instruction based on community needs. All characteristics of sociocultural perspectives can be discussed within an assessment context.

Formative assessment requires strong interaction between members. This interaction can be accomplished by participating in discussions and teachers asking clarifying questions. Interactions help community members mediate each other's knowledge, their comprehension, and cultural differences. Cowie (2005) says assessment is "a meaning making activity embedded in and accomplished through interaction, one that shaped what it means to be a student and how individuals see themselves as knowers and learners of science" (p. 209). Interaction also assists in creating shared goals and interests. Having shared goals is important as it helps students improve their learning experience and academic accountability. Through interaction students can understand the aim of the assessment. This experience includes the group learning process. During this a teacher should focus on shifting beliefs and reasoning within the group. Thus individuals need to be assessed for contributions while in a group activity (Gipps, 2002).

In assessment, mediation can be used as scaffolding which "supports the student in dealing with the item and/or learning from the assessment experience" (Siegel, 2007, p. 867). It will help students extend their learning experiences. It is particularly helpful for English Language Learners (ELLs) (Siegel, 2007; Walqui, 2003) and differently-abled learners. Importantly, while using scaffolding the content or the difficulty of the

assessment should not change. Another mediation can be human mediation where group members helping each other to learn a context or content knowledge.

For a successful formative assessment, students need to actively participate, reflect on their experiences, and have some authority in or share the responsibility for their learning. In contrast to traditional assessment, according to a sociocultural approach students need to be involved in the assessment process by negotiating and discussing the outcomes. This produces responsibility for their learning via self-monitoring. It also encourages students to create a classroom culture through shared goals and interpretations of knowledge. Sharing authority provides mutual respect between teachers and students and allows the teacher to better understand the learners' thought process and comprehension. Without it students fail to trust or respect their teachers (Torrance & Pryor, 1998).

Identity can be defined as how learning changes a person within the context of a community (Wenger, 19998). Thus culture plays a tremendous role in identity formation. Pryor and Crossouard (2008) highlighted that an individual has multiple identities that "are shaped by the cultural norms of society, its traditions, and institutions" (p. 7). Identity can be developed by active participation, taking different roles and responsibilities. This permits students to redefine the meaning of learner, of learning science, and of being "competent knowers of science" (p. 199, Cowie 2005). Being able to do these definitions and reflecting on their experience increase students' confidence.

Technology Education

The technology growth over the last decade had a substantial effect on routines of daily life. Technology also has a considerable effect on educational systems (Feltman,

2013). Students today are quite different than previous students (Jahnke, 2016). They are immersed in technology and media. According to the "Generation M2: Media in the Lives of 8-18 year olds" study, young people spend 7 hours and 38 minutes on average daily on one or more forms of media on a computer, tablet and/or phone (Rideout, Foehr, & Roberts, 2010). Most of this time is also spent multi-tasking. This study shows that students' learning styles and preferences have changed as a result of the immersion; teachers need to address this (Jahnke, 2016). To address this issue, The National Education Technology Standards for Teachers (NETST) suggests that teachers should have competency in using technology for teaching so they can support students' use of technology for learning during problem solving, inquiry, knowledge construction, and creative processes (International Society for Technology in Education [ISTE], 2008).

Integrating these technologies into the classroom has "a potential to fundamentally change the ways that learning and teaching are carried out" (Manuguerra & Petocz, 2011, p. 61). Technology can provide opportunities to improve scientific learning, engage in varied scientific practices (e.g., Buckley et al., 2010; Hickey et al., 2012) and increase engagement in those practices (e.g., Hickey et al., 2009). Technology also transformed the assessment. It is commonly used for formative assessments and for several purposes: reaching more students (e.g., Penuel & Yarnall, 2005; Feldman & Capobianco, 2008), motivating and engaging students (e.g., Kay & Knaack, 2009; Hoadley & Linn, 2000; Tan & Towndrow, 2009), modifying lessons (e.g., Gerard et al., 2010; Lee, Feldman, & Beatty, 2011; Maeng, 2016), enabling assessment in new environments and ways (e.g., Buckley et al., 2010; Hickey et al., 2012), providing feedback and scaffolding (e.g., Hickey et al., 2009; Yarnall, Schechtman, & Penuel,

2006; Maeng, 2016), and reviewing student knowledge (e.g., Koch & Sackman, 2004; Penuel & Yarnall, 2005).

One of the many benefits of technology is its ability to change communication. The mobile devices make communication more convenient, faster, and less expensive. Recently, these mobile devices began to be integrated into education systems. Teachers and researchers are looking into ways to use mobile devices to support learning and teaching. Mobile learning (m-learning) is defined as learning without a fixed location or time while taking advantage of using mobile devices (O'Malley et al., 2003; Kukulska-Hulme & Traxler, 2005). Zurita and Nussabaum (2004) found that m-learning can increase motivation, interactive learning, and also promote dialogue and collaboration. The collaboration could be through a network and online environment. Thus students can share their ideas and resources easily to solve problems and discuss ideas (Stead, 2005).

iPads are one of the newest mobile devices that are used for m-learning. iPad is an interactive touch screen tablet that can be used for browsing the Internet, taking pictures, recording video and audio, and using different applications (apps). These apps cover a wide range of subjects for every grade level and learning style (Apple iPad in Education). Since the iPad has raised the expectations of working anytime and anywhere while experiencing and supporting both individualism and working collaboratively, the iPad is getting popular in education and in classrooms. There are a variety of reasons why the iPad is in high demand (Carr, 2012). It is easy to carry (Buckley, et al. 2010; Stevens, 2011), user friendly for varied age groups (Buckley et al., 2010; Price, 2011; Wang, 2010), has wireless Internet access that enables users to do research online (Murray & Olcese, 2011; Price, 2011), and it can access a variety of applications. Specially made

educational game-based applications are used in the classroom to engage students, introduce topics, provide practice, and support students learning (Castelluccio, 2010; Hill, 2011; Murphy, 2011; Murray & Olcese, 2011; Price, 2011; Stevens, 2011).

Though the iPad is fairly new there are already research studies in education about it. The research studies are spread across the K-12 grade levels (e.g., Jahnke & Kumar, 2014; Carr, 2012; Hart & Whalon, 2012; Simpson, Walsh, & Rowsell, 2013) and college levels (e.g., Kinash, Brand,Matthew, & Kordyban, 2011; Drouin, Vartanian, & Birk, 2014; Gill & Burin ,2013; Hargis, Cavanaugh, Kamali, & Soto, 2013; Mang & Warley, 2012). Most of the research to date is about students' perceptions of using the iPad (Kinash et al., 2011; Gill & Burin, 2013; Mayfield, Ohara, & O'Sullivan, 2013; Sloan, 2012) and some on faculty members' perceptions (Drouin et al.,2014; Hargis et al., 2013). Research shows that students and faculty members enjoy using iPad (e.g., Gill & Burin, 2013; Mayfield et al. 2013; Drouin et al., 2014; Hargis et al., 2013). However, the effect on student learning has mixed results. While some researchers found no significant effect on student learning (e.g., Carr, 2012; Kinash, et al., 2011), others found the iPad has a positive effect on learning (e.g., Martin & Ertzberger, 2013). On the other hand, Hall and Smith (2011) argued that while using the iPad does not significantly improve students' learning, it enhances student convenience and flexibility.

Research on the iPad in education widely varies in interest. Murray and Olcese (2011) analyzed iPad applications to identify how using the iPad provides additional possibilities in education for both teachers and students. Jahnke and Kumar (2014) explore teachers' practices with iPad in K-12 classroom settings. Despite this there is only one group focused on using iPads for formative assessment purposes: Isabwee and

Reichert (Isabwee, 2012; Isabwee & Reichert, 2012). Their studies aimed to present what happens when students used iPads for peer-to-peer assessment system. In the first study, students worked collaboratively and gave feedback to each other by using the iPad during a college-level mathematics course. They found that peer-to-peer assessment provided more opportunities to discuss and enhance students' views on approaching problem solving and also that iPads helped give immediate feedback that was also easy to share (Isabwee & Reichert, 2012). In the second study, participants were engineering students at the Kigali Institute of Science and Technology (KIST) in Rwanda. Students had positive views on the peer-to-peer assessment system and they liked using iPads (Isabwee, 2012).

Though research on technology in education is a growing area there is a need for research on the benefits of technology for assessment purposes in science education (Songer, & Ruiz-Primo, 2012). iPads are one of the technological devices used popularly in classrooms and they can support assessment practices. However, there are not enough studies on iPads either in science education or within assessment.

Method

The purpose of this research study is to explore teachers' formative assessment practices in a technology-enhanced classroom. For this reason, a physics teacher who actively uses iPads as m-learning technology devices was selected. The research questions that guide this study are:

What is the nature of formative assessment in the context of using technology based assessment?

(a) What do the formative assessment practices of a teacher using the iPad look like from a sociocultural perspective?

(b) How does iPad use affect the formative assessment process?

Research Design

Case study was employed in this study as a qualitative research method. Case study allows research to understand the real-life context when a researcher has little to no control (Yin, 2009). Case study is used when there is a "bounded system (a case)" and a researcher wants to understand the *case* in-depth (Creswell 2007, p. 73). To obtain this depth a researcher provides perspective, experiences, stories of participants within social context, and some interpretations (Snape & Spencer, 2003). For the purpose of this study, the use of iPad for formative assessment in a physics classroom will be examined within the normal social context of student-teacher interaction in which the meaning of the teacher's formative assessment practice using technology is created. The bounded system (case) was teachers' formative assessment practices while using technology, specifically the iPad, from a sociocultural learning perspective. To better understand the phenomena, multiple data sources and extended period data collection is required. To understand the case in depth I was an observer, did not manipulate the classroom purposefully, and collected data from multiple sources including interviews, classroom observations, and artifacts.

Research Participants

Research participants of this study were a high school physics teacher who actively use iPad in her classroom and her students. The participant teacher of this study was selected by employing purposeful sampling, specifically intensity sampling.

Purposeful sampling is used when a researcher has certain key criteria. One of its aims is covering "the key constituencies of relevance to subject matter" (Ritchie, Lewis & Elam, 2003, p. 79). Intensity sampling is defined as "excellent or rich examples of the phenomenon of interest, but not highly unusual cases... cases that manifest sufficient intensity to illuminate the nature of success or failure, but not at the extreme" (Patton, 2002, p. 234). Therefore to explore and gain insight in depth about the phenomena a researcher needs to select samples from which they can gain the most information (Creswell, 2007; Merriam, 1998).

The participant teacher was selected from teachers who are actively using iPads in their classrooms. The participant teacher was recommended by the district Science Coordinator as an innovative teacher who is actively using iPads in her classrooms. The participant teacher, Amy (pseudonym), has been teaching since 1997. She taught physical science, physics, and honors physics courses. During her career, she has achieved National Board Certification, and named as a Professional Development Classroom Teacher. Amy received several local and statewide awards, and was nationally awarded the prestigious *Presidential Award for Excellence in Mathematics and Science Teaching*. She has a Master's and Bachelor's degree in science education. During her career she attended a professional development program related to content knowledge of physics and then she was participated the program as a trainer. Amy also taught a methods course for pre-service science teachers at a Midwestern University.

Amy taught in a junior high school prior to this high school. Even though she was using some technology, she started to use iPad and technology more intense in this high school. This school's teachers were determined a year before school started to

functionally work and provided teachers iPad in that year, year zero. Amy was accepted as a department chair, so she attended additional workshops and conferences to extend her knowledge of technology usage in classroom.

Students were freshmen that were taking an honors physics course. Students were diverse in terms of gender (46.5% female, 53.5 % male), socioeconomic status (51.9% free/reduced lunch), and racial-ethnic composition (54.90 % Caucasian, 29.7 % African American, 6.4% Hispanic, 6.5 % multi-racial). Within the student population, 11.2% of students have IEP and 5% of students are involved in the ELL program.

Research Site

This study was conducted at a public high school in the Midwest United States with a diverse student population. The student-teacher ratio is 18:1. This school was started as a technology-immersed school. The teachers were trained about using both technology and iPad before the school started to accept students. Teachers met quarterly during this transition year and they were encouraged to use iPads in class.

For this study, I participated with two of Amy's classrooms during spring and fall semesters. Both of the classrooms were honor physics classes. In the first classroom, spring semester, Amy taught Newton's Law and Waves units, and in the second classroom, she taught uniform motion. Classes were representative of school student population in terms of gender ratio, socioeconomic status, and racial-ethnic composition.

Data Sources

Qualitative researchers emphasize the importance of using multiple data sources and having rich data for case study (Creswell, 2007; Yin, 2009). Primary data sources included video recorded observation of class sections, researcher's field notes, and

teacher interviews. Supporting secondary sources included pictures during observations, lesson plans, assessment examples, student-works and student interviews.

As primary data sources eighteen classes were recorded. Normal classes were 85 minutes long and there were two short classes 45 minutes long. Researcher also took pictures and field notes during classroom observations. To understand participants, their behaviors, and context in depth, scholars have recommended capturing a comprehensive picture of classroom observations (Glesne, 2006; Yin, 2009). According to American Educational Research Association (AERA) guidelines for the practice of video research in education, video recording helps the researcher to understand the environment by closely capturing and documenting (Derry, 2007). However, as Stake (2010) highlighted, a person cannot capture everything with their eyes and video. Therefore, field notes helped capture what was not recorded in the video and also to reflect on observations and the study overall, as Stake (2000) emphasized. In this study, classroom observations (video recordings and field notes) provided information about a teacher's formative assessment practices, including: student-teacher interaction, student-student interaction, student-iPad interaction, and teacher-iPad interaction.

Other primary data sources included teacher interviews, which are essential for case studies because they provide insights on events, conversations historical development of them (Stake, 2010; Yin, 2009), and allow researchers to see the socially constructed knowledge, reality, and context from another perspective and to capture multiple realities (Hatch, 2002; Stake, 1995). Informal in-depth interviews for reflective interviews and a semi-structured focused interview for pre-observation were conducted with the teacher (Appendix A & Appendix B). While the pre-observation interview

provided a general understanding of iPad usage in the teacher's classroom and the teacher's views, informal reflective interviews focused on formative assessment activity and iPad usage within that activity. There were nine interviews in total; three of them were pre-interview taking 2 hours total, and six were reflective interviews taking 2 and half hours total.

Secondary data sources were pictures during observations, lesson plans, assessment examples and student works which were categorized as artifacts, and student interviews. Student interviews provided student perspective on the usage of iPad in the classroom (Appendix C). Additionally, the written documents provided me with data that I was not able to capture via classroom observations or interviews.

Data Analysis

As Stake (1995) noted, "There is no particular moment when data analysis begins" (p. 71). The analysis process was synchronous with data collection and writing. First author kept a personal research journal to reflect on her experience. For the formal part of data analysis, Hatch's (2002) interpretive analysis was used. I examined all the data by watching the videos, reading and listening to interviews, and reading assessment examples and student works to have a sense for the case.

Primary data sources. Primary data sources included video recordings of the classroom and teacher interviews.

Video recordings. Eighteen class sessions were recorded. Sixteen of them were 85 minutes long and two of them were 45 minutes long. In addition to whole class recordings I recorded students while they were working on iPad. iPad was embedded in teaching. Generally more than half of the class time was spent on iPad or iPad-related

activities (Appendix D). Initially I watched all videos to get an overview of understand the structure of the classroom and how iPad was situated in it. Then she determined the segments, when and how the iPad was used, and she created an index of them. The index enabled her to easily categorize formative assessment activities (e.g., pair-share) and how iPads were used in each category (e.g., QR code scanning). ATLAS.ti was used to code the video recordings for this initial stage of analysis.

The initial codes helped in the selection of video clips. These clips were selected based on whether iPad was either used directly in assessment or assisted formative assessment practices. Activities involving the iPad that did not include data gathering by the teacher were excluded from detailed analysis. For example, using the iPad to read or watch a video was excluded from data analysis. However, if students answered questions based on either their reading or a video, then these practices were included in data analysis.

The selected video clips were watched again and memos were written. These memos included reflections on how each activity supports the sociocultural views on learning characteristics and assessment relationship. An example clip included a group working in which students had authority and they helped each other. Such a clip allowed me to explore interactions, student roles, identity, power relationships, community aspects, and mediation. During this stage, a coding scheme for examining the use of iPads in a teacher's formative assessment practices was used (Figure 3.1). The scheme was derived from Digital didactical design framework (Jahnke & Kumar, 2014, pp. 82, 83) (Appendix E). For each assessment activity, I used the scheme and created initial interpretations that answered the questions posed by the scheme. This was done in order

to explain how each characteristic occurred and how the iPad played a role in them. This coding scheme helped the authors analyze the teacher's formative assessment practices in a technology-enhanced classroom. This analysis served to understand the assessment culture of the classroom, how it occurred, and how technology supported or hindered it.

	Description	Assessment Activity	iPad influence
Key Characteristics of Sociocultural Views on Learning	**Interaction** ● How is the interaction between student-teacher and/or student-student? ● Are students active participants?		
	Mediation ● Does the activity involve scaffolding (text, graphs, etc.)? ● Is the activity sensitive to different levels and backgrounds of students?		
	Identity ● What are the student's roles? ● How does classroom culture affect the student? ● Does the activity provide opportunities for acting like a scientist?		
	Power ● Are students active participants? ● Does the activity allow for self-assessment? ● Does the activity give responsibility to students?		

Figure 3.1 *Form for Data Analysis.* It is used to analyze teacher's formative assessment practice and iPad's effects on it.

Teacher Interviews. All the interviews were transcribed. Transcriptions were uploaded to ATLAS.ti, read, and then the interviews were coded by: (1) background, (2) views of: learning, teaching, assessment, and technology, (3) teacher's ideas of power relations, mediation, roles, students' identity, and community building, and (4) teacher's reasoning behind her practices. Interviews provided information about teacher's previous experiences with using technology in the classroom and the teacher's assessment practices. Interviews were reviewed to provide enhanced understanding of the selected video clips and teacher's reasoning.

Secondary data sources. Student interviews and artifacts were used as supportive data sources. Student interviews were coded by: background, view of learning, view of assessment and technology, and students' experiences with technology. The interviews were used to present students as being part of the classroom community. Artifacts were used when I needed additional data to better explain the selected formative assessment practices.

I generated themes under the influence of the framework to answer the research questions. Data was revisited to support or challenge the results (Hatch, 2002). Triangulation, peer review, member checking, thick and rich descriptions, and external audits are some of the strategies to meet the criteria of trustworthiness (credibility, transferability, dependability, and confirmability) of a qualitative study (Glesne, 2006; Merriam, 2009). In this study, triangulation of data was achieved by collecting multiple data sources that included video recordings of classroom observations, field notes, interviews, and artifacts (Lincoln & Guba, 1985; Patton, 2002). Multiple data sources assisted in providing thick and rich descriptions of findings to enhance transferability. To

ensure trustworthiness, I peer-debriefed with the second author at every step of analysis for internal consistency.

Results

This section has two parts each addressing a research question. The first part describes teacher's formative assessment practices in a technology-enhanced classroom. The second explores the effects of technology on the formative assessment process.

Results Part One

What do the formative assessment practices of a teacher using the iPad look like from a sociocultural perspective?

Classroom Community

The analysis of the video recordings was used to explore the teacher's formative assessment practices in the classroom. Since teacher's formative assessment practices are context dependent, it is necessary to explore the classroom community where assessment takes place. The classroom community has three main components: members, tools, and norms. These components are interrelated and in this section they and their relation will be explained.

Members. In this technology enhanced classroom Amy and her students were members of the classroom community. Amy was an experienced teacher and taught honors physics. According to her, the aim of education was more than teaching the content knowledge - she wanted her students to have the skills and confidence for real life and to prepare them to be scientifically literate citizens who are active participants in society. In her own words she wants

> "… to prepare them and get them excited about science. But likewise have some of those lifelong skills. […] I want to give them skills of critical thinking, problem-solving. I want them to be scientifically literate too. And I want them to be able to look at things, and ask for claims and evidence because I think that's a lifelong skill regardless of what job you go to through. I use physics as my context though." (Interview)

To give these skills to students, Amy frequently used group-learning activities in which students were engaged, interacted with peers, and participated in discussions. During these activities students reflect on their own learning, recognize peer's ideas, assess each other, and create a shared understanding. Group learning activities also provided opportunities for mediation in which advanced students assisted less experienced students. This environment permitted students to exchange their perspectives and expand their views. She believed these conditions provided the best learning environment and that it would prepare them for the future. During the interview she said

> "And so most of my classes spent with cooperative learning groups. Because again when they go to their job and very few jobs that you're going to work in isolation and not have to communicate or cooperative with other people. And so we need to get our students used to that kind of situation. So they can be effective communicators and problem-solvers in a team." (Interview)

Those group-learning activities provided opportunities for formative assessment. Amy was aware of different types of assessment. Formative assessment, peer, and self-assessment were part of her daily routine. In these assessment practices she was comfortable playing different roles including assessor, facilitator, and listener. During assessment she wanted her students to be reflective, take responsibility for their own learning, help their peers, and share authority with her.

Amy started to use technology intensely in this school. She attended several workshops to extend her technology knowledge and she worked closely with other

teachers at the school to exchange their experiences of using technology in the classroom. She believed that technology opened up variety of doors for students and it affected student-learning experiences in positive way. She was also aware that technology is a tool and it is not the answer for every problem. She used technology to improve the interaction with students and scaffold the teaching and assessment activities.

Two different classrooms were observed during the observation. Students were similar in terms of their demographic and their content knowledge. The only difference was second year (Fall 2016) students were more familiar with using iPads because half of them were coming from a middle school that used iPads.

Even though taking a physics course was a requirement for high school graduation, taking the honors physics course instead of regular physics was each student's choice. Students reported that they enjoy group activities in which they were active, interacted with peers, explored, and applied their knowledge to new context.

Students were using technology every day on their own personal time. They used it to access social media and interact with friends, plus do homework and study. Most students used several devices, including iPad, a personal smart phone, and a laptop. While they employed technology in other courses they reported Amy's class was one in which they used iPad and technology the most. They reported that using iPad was helpful for organizing, opened up opportunities to interact with teacher and other students in different ways, and mediated them by providing easy access to homework and their test results. Students complained that writing with iPad was difficult because iPad did not have an external or hardware keyboard.

Tools. There were three main tools used in the classroom: iPad, Lab notebook,

and whiteboards. Those tools were used to improve teaching and learning and shaped the classroom norms.

***iPad**:* iPads, iPad cases, and chargers were provided to students by the school free of charge. iPads were issued to students. The district covered the first occurrence of stolen, damaged, or lost devices and students covered the cost of remaining occurrences. Students were issued the same iPad for their entire high school career while returning it between academic years. Students used these iPads and personal smartphones for communication, doing homework, working on projects, and playing games.

iPad was an essential part of Amy's teaching and part of the classroom routine. She used iPad in her classroom multiple times per class period. iPad was used for different purposes. She was aware that the iPad was a tool to help her better interact with students and provided them with variety in their learning experiences. To support mediation she was using several apps to provide some structure for students to ease the process. Some were used for simple purposes (i.e. a simple calculator) while others were more complex and related to teaching and assessment such as *Socrative* for gathering students' responses immediately. iPad was also used in classroom for simulations, watching video, taking pictures, recording videos, analyzing videos, scanning QR codes, and playing educational games.

iPad was a resource for students in that they could find all the course documents (e.g., homework and lab sheets). The documents were accessible at any time from within the Schoology app. Schoology is a platform by which teacher and students share and exchange documents. Students were doing the homework provided via the app and using it to send completed documents to teacher. The teacher would then grade or read the

homework with feedback and return it via Schoology.

Lab notebook: Lab notebooks were paper notebooks required for keeping important notes and organizing them. They were specifically used to record vocabulary, store "essentials and extensions" (unit objectives) "framing questions" (pre and post-assessment worksheets), and instruction sheets. Lab notebooks were another mediator to ease the process of accessing core information and served two purposes: simplifying the review process and serving as a resource during tests. This provided students easy access to the information in comparison to the entirety of information available on the iPad. The teacher believed students would check their notebooks more often due to the ease of access and compact form.

The teacher encouraged students to use their lab notebooks believing that students needed to learn to use resources just as they would in real life. These notebooks could be used alongside iPads such as during a *Socrative* quiz or for video analysis during the "car crash challenge". During the car crash activity students used instruction glued in their lab notebook for video analysis.

Whiteboards*:* Small dry erase whiteboards were used frequently in the classroom. A group or a pair of students used whiteboards to aid in discussing a question and showing their work. Students used them to draw graphs, do calculations, and write definitions. They served to provide interaction between teacher and students and also among students. The teacher used them to collect data on students' learning processes. Whiteboarding allowed students to monitor their peers and check their own understanding.

Generally students did an experiment and then answered some lab questions. Next

the teacher divided the students into groups and provided them a whiteboard with a question to be answered. During whiteboarding students were expected to use lab evidence stored on the iPad. The groups were asked to provide responses for discussion and write them on the whiteboard. The groups presented the whiteboards and the teacher encouraged students to ask follow-up questions. She used this as a way of encouraging self-reflection by students and to help them correct their own misconceptions. Students were generally actively correcting their responses but despite encouragement asking questions of peers was rare. With whiteboarding Amy provided opportunities to students to reflect, take responsibility for their learning, and become part of community. These opportunities may help students build their identities.

Classroom norms. Amy's formative assessment practices were embedded in her teaching. Amy had a class routine. The lesson started with an agenda of what they were going to do for the day with objectives followed by reminding students of what they learned in previous lessons, a short lecture, a lab activity and gathering of students results, discussion of their findings, summarizing the main ideas of the lesson, and finishing with explaining the homework and a reminder of the next day's activities. This routine formed a classroom culture in which formative assessment was the center. In each step Amy included formative assessment. For example while reminding students of previous lessons she asked students questions to gauge their understanding of the earlier lessons. Even her lecturing included short formative assessment activities such as pair share or speed dating during which students shared their ideas with peers and with the teacher.

In Amy's classroom students were expected to be active and reflective. She

believed that

> "… in active classroom where students are engaged or students are having conversations or students are making predictions or students are then reflecting back on their learning as well. When they're on the driver seat that is the best. I think that is learning loud and it should be loud. Because that means the students are active and just actively engaged." [Teacher interview 1].

Thus, students were always involved in some sort of group learning activities, asking and answering questions, and discussions as part of an everyday routine. Her formative assessment practices were embedded in her teaching and frequently occurred during group-learning activities. The group learning activities took different formats: pair share activities, brainstorming with a partner, think-pair-share, lab groups, and whiteboarding activities. During these group learning activities students had different responsibilities: collecting and analyzing data, discussing their ideas and results, reflecting on their own work, monitoring peers and providing feedback to them, and making decisions. During lecture the teacher's expectations of students included: answering the teacher's questions related to previous lessons and students' observations from prior experiments, analyzing what students learned using evidence, and application of the analysis to the new context. iPad was used as a mediator in several of these activities. It improved the quality of collecting and analyzing data and recording and sharing results. These improvements led to higher quality discussions. All these practices by students (reflecting, using their data for analyzing, and monitoring each other) showed the value of their work, gave them responsibility, and helped them share authority. Giving the responsibility to students provides them with opportunities to recognize themselves as active participants in society and understand learning is more than listening to the teacher and memorizing facts. She valued students' inputs in the classroom and she believed this helped improve her

teaching. In this community all members had opportunity for input to shape the classroom culture.

Just like students Amy was active throughout the class sections. She was always monitoring students by walking around and asking questions. Her questions varied from checking whether students were on task or not, to clarifying their understanding, to checking if they know content knowledge. iPad assisted Amy for this purpose. There were three different applications (apps) used solely for assessment: Socrative, Kahoot, and NearPod. With them Amy was able to gather students' responses immediately and provide immediate feedback.

Amy valued self and peer assessment. She believed that students needed to take responsibility for their own learning. Though peer assessment occurred during group work Amy also provided opportunities for self-assessment. Amy integrated technology in her teaching and assessment practices to enrich them. A QR code scanning app was used for hastening the process of self-assessment. With QR codes students were accessing answer keys faster than manual lookup. Even though QR codes were stored in Schoology and students could access them at any time, Amy provided specific times for students to check their work and also encouraged them to check their partners' work in group discussions. She explained that having designated time for self-assessment during class increased students' review time and quality.

In each teaching unit, "essentials and extensions" were provided for students to learn. Teachers of the Professional Learning Team (PLT) created "essentials and extensions". This team included three physics teachers and a special education teacher. In general physics classes 80% of the test questions covered "essential" material and 20%

“extensions”. For an honors class Amy changed this ratio to roughly 60%: 40% since students had advanced knowledge. For both class types students were required to meet a “smart goal” to pass the course - to score 80% or higher on essential skills portions of quizzes and also on the end-of-unit exam. It also required 80% of students met the criteria otherwise the unit must be taught again. Teachers within PLT also used this to modify their curriculum in the following years. The goal thus affected the content the teacher taught and assessed. To meet it Amy frequently reminded students the essentials and extensions of each topic.

Amy’s view and knowledge of learning, assessment, and technology shaped her practices. Amy integrated self and peer assessment because she believed students need to both be responsible for their own learning and to learn to be a team member. She believed these provided students opportunities to develop identity and would help them in the future. The aim went beyond teaching content knowledge. Amy knew what she wanted to assess, how she wanted to assess, what type of apps and technology tools were available to her. She created a classroom culture in which the norms of classroom were shaped both by her technology and assessment knowledge. When teachers do not understand the purpose of assessment they will face difficulties when there is a technical problem. During observation Amy experienced an issue with Wi-Fi service and was able to do a similar activity without use of the iPad. Teachers need to be reminded that technology is only one of the tools available to teach a topic. The classroom norms were also shaped by students’ needs and skills. Amy knew how she could use technology to meet her students’ needs. She was aware of her students’ needs in acclimating to technology. In one interview Amy said students increased their iPad expertise annually,

which helped her decrease time spent on technology/app training. This allowed scheduling more time for teaching concepts or improving the quality of activities.

Results Part Two

How does technology (iPad) affect the formative assessment process?

Classroom community includes members, tools, and norms. Interaction, mediation, identity, and power are sociocultural views on learning characteristics and compose the classroom norms. In this section the effect of tool (iPad) use on classroom norms was explored in terms of formative assessment process. As seen in Figure 3.2, all the sociocultural views on learning characteristics are interrelated. This study is interested in the iPad's effect. Thus the relationship among the other characteristics was not explored.

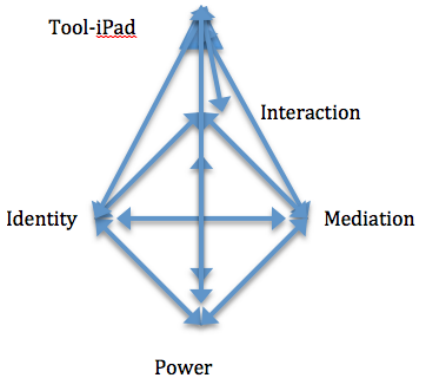

Figure 3.2 *Relationship Among Sociocultural Views on Learning Characteristics.* This figure illustrates the effect of iPad (as a tool) on sociocultural views on learning.

Analysis of data revealed that using the iPad had identifiable effects on the classroom norms. Table 3.1 below describes how iPad influenced each sociocultural views on learning characteristic.

Table 3.1 *iPad's Effects During Formative Assessment on Learning Characteristics from a Sociocultural Perspective*

Characteristics	Effects of iPad
Interaction	iPad enabled faster communication. Provided variety of communication via Schoology (sending messages, homework, and grades, reading the teacher's feedback, taking screen captures during work, improved the number and frequency of students reaching out to teacher) Enabled personalized feedback Assisted collecting and using students' responses immediately <u>Constraints of interaction</u> Students sometimes were texting on the iPad which was an easy distraction. Not having Wi-Fi at home prevented taking online quizzes.
Mediation	Provided varied methods (e.g., video watching, taking pictures, and video analyzing). Enabled customized time frame for completion. Provided flexibility of choosing problem solving methods and strategies Increased organization, distribution, and exchange of course materials Provided enhanced data collection and analysis tools over manual methods QR code scanning used to hasten access to answer keys <u>Constraints of Mediation</u> Typing was hard because iPad only had an on-screen keyboard Plagiarism increased because of the Airdrop feature built into the device
Power	Enables students to engage in different roles Have authority and responsibility within workgroups Involvement beyond answering questions empowers students Peer and self-assessment are improved.

Identity	Reveals all aspects of being a learner Personal engagement in data collection and analysis mimics scientific methods used by scientists Provides realistic examples of materials and challenges applicable to student life and interests Provides a safe space for free exchange of ideas without implicit consequences of judgment

After identifying the relationship between each characteristic and iPad usage during the formative assessment, the analysis of data revealed three themes that impacted formative assessment practices: 1) transforming classroom community, 2) empowering students, and 3) facilitating evidence based discussions.

Transforming classroom community. Findings demonstrated that use of the iPad as a technological tool transformed the classroom norms. Having it in the classroom improved the frequency and quality of communication between members that led to redefining of the meaning of learner and teacher and the way assessment occurs. During an interview, Amy stated that with the iPad students were reaching out to her more frequently than ever. Students were sending her messages using *Schoology* about the questions with which they struggled. They took screenshots of their work and sent it to teacher to show their point of struggle. Being able to use a screenshot improved the communication speed between teacher and students. It made the teacher easily reachable outside of class time and provided opportunities to see incomplete work and give feedback. This improves the relationship between teacher and student and shows students that as a learner one has responsibility and power for his or her own outcomes. This can open doors for students' identity development to see themselves as a part of a community in which their ideas and works are valuable.

iPad also enabled hastening access to the course materials. In Amy's classroom,

this was used to transform the self-assessment process. Amy believed students need to take responsibility for their own learning and to do this they need to reflect on their work. QR codes were frequently used as a tool to mediate and speed up the self-assessment process. Students scanned the QR codes to reach the answer key of the assignment and checked whether they got the answer right or wrong. This immediate feedback made students more aware of the need for communicating with teacher to discuss more than correctness. The use of QR code scanning became a norm of the classroom and was a form of self-assessment that demonstrated student responsibility of their own understanding. It provided more freedom to teacher and students to better manage their time since students could revisit the answer keys whenever they wanted.

iPad use, in fact, enabled students to do things they cannot do without technology. This changed the classroom culture as paper assignments or visual observation were sometimes inferior. Using *SlowPro* helped to slow down the observed movements of waves and assisted students in seeing the waves clearly. *PhET* simulations assisted students in controlling variables of waves. Both apps enabled collecting data from the waves not able to be collected otherwise. This created a new community culture in which students understand and appreciate the affordances of technology and understand the iPad's role in mediation.

Another classroom culture transformation was that iPad opened the possibility of reaching outside the classroom boundaries. In a traditional classroom, students were solving problems within the classroom and used data that was provided to them. Amy provided opportunities to students to collect their own data, to take pictures as demonstration of work and of their collected data, and to carry on investigations outside

of the classroom. iPad assisted these activities. There were different multiple day projects called “challenges”. During these challenges students were introduced to a realistic or hypothetical scenario for which they collected and analyzed data, discussed with peers and then presented their findings.

One of the challenges was “Zombie Bottle challenge”. In this scenario zombies were coming and spreading the “zombie virus”. Students were expected to design a device to keep the water temperature stable to prevent the “zombie virus” from activating and spreading. For this challenge, students were able to reach out of the classroom boundaries through a school partnership with the water and light department of the city’s utility services division. Students had the opportunity to communicate with experts, learn about the necessary materials, and learn how to build a water temperature stabilization device. During the challenge students constantly exchanged their ideas with their peers and teacher, reflected on their own thinking, and made informed decisions based on the evidence. This challenge included making decisions that in the real world would have an impact on society. It highlighted the need for students to think beyond scientific content. This is often not a consideration in a traditional science classroom. In Amy’s own words

> “So they work in their teams and their task is based on the cost of materials. So there is some constraints involved: the cost of materials and the amount of tape and you know those sort of constraints…So part of that process is the build -obviously- in their team because they are making those society decisions.”

However the iPad did not always transform the classroom culture positively. One issue was plagiarism. Students could share their homework using the Airdrop feature built into the device. Another is management of classroom time. Students were distracted by messaging each other, playing games, and listening to music on their iPads. Amy

managed the situation well; she was constantly walking around observing what her students were doing. During the interview she explained:

> "There is always going to be a distraction issue. So it doesn't matter whether it's, as a teacher kids are always going to find something to distract me. So whether it's passing the notes or using their cell phones, or using their iPad. It's important to be able to teach, when it is OK, when it's not OK, what is appropriate use what isn't."

Empowering students. Empowering students is an important phase in formative assessment. From sociocultural perspective students were expected to be active agents during the classroom assessment. In the analysis it was found that iPad provided several forms of opportunity for empowering students. One way was allowing students to collect their own data instead of providing the data to them. Therefore, they exchanged ideas with peers and teachers about how to collect data, reflected on each other ideas, and created a shared understanding of the best way to collect data. This gave opportunities to students to take responsibility for their own learning and to improve their autonomy. These opportunities occurred at the lab stations during the experiments in which students were asked to take pictures of the experiment and base their explanation on this data. Asking students to take pictures forces them to discuss the required attributes for good data collection using photography. This required students to become active and involved which supported empowering them through taking responsibility for their own learning.

Similarly, students own their work by doing and choosing the method of data analysis. Different data analysis apps can be used on the iPad such as *Vernier Video Physics*, *Vernier Graphical Analysis*, the Google Cloud Machine Learning service, *Logger Pro* and *Desmos*. For example, in the car crash challenge students collected velocity data of two different cars from a video by using a video physics app and

analyzed the data using a graphical analysis app. Then as a group they calculated the point of the cars' intersection by choosing their own methods (e.g., a graph, data table, formula, or motion diagram) and tools (e.g., meter sticks, *Logger Pro* graphing template, and analysis apps) for calculation. To choose the methods students discussed which method best fit them. During this discussion they exchanged and reflected on ideas. iPad was used as a mediation tool that helped students collect and analyze data and send the results to the teacher digitally. iPad also helped empower students by both providing options to students for decision ownership and showing their work. This increased their responsibility and power.

Creating presentations based on students' own data empowered them. Students could produce their own ideas, work on data collection, and create their own designs or presentation. While this creation process helps teachers understand student comprehension, struggles, and how student background shapes student thinking, it also helps students share their ideas, show their personal values, and feel valued. Moreover it helps students to understand scientists through this creating process. During "Zombie Bottle Challenge" students not only created devices to keep water temperature steady but also created a video to explain their devices which gave them more power to explain their ideas.

At lab stations, students were expected to respond to questions in different ways: taking a picture, drawing, writing, and calculation. Teacher emphasized these different ways to explain results all of which were valuable. Amy wanted the students to improve their understanding of these methods despite the fact that each student was different. Nonetheless she let students choose the method during whiteboarding and challenges.

Lastly, providing a safe space where students can explain their ideas helped empower students. iPad provided this safe space via apps specific for assessment. For example, when students were using *Kahoot* pseudonyms could be used for answering questions. This anonymity diminished the fear of being wrong. One of the students stated during the interview: "It [using the app] could be an advantage. So people don't feel as judged if they get a question wrong or something. Or if their thoughts are really odd to anyone else... They wouldn't feel as judged about it." (Student Interview)

Facilitating evidence based discussion. Discussions are one of the important methods of assessment that leads to understanding student thinking and reasoning. It is one of the common ways to support student and teacher interaction. A quality discussion comes from students supporting claims with evidence. iPad provides opportunities for better collecting evidence to facilitate evidence based discussions. With the help of technology students can collect data that was previously uncollectable.

The *SlowPro* app was a great example of facilitating evidence- based discussion. The app was used during observation of waves. It allowed students to record their observation and slow down the playback by a factor of a hundred. The app enabled collection and observation of data not possible with human eyes. The app did not assess but helped to improve the quality of discussion by allowing students to collect better evidence in support of their claims. In this way the app provided mediation. This lab had six different stations where students worked in groups for extended discussion to find patterns in wave behavior. Data was collected by students using different materials in each station: water, air vibration, ropes, and springs. This enabled them to work like a scientist. Instead of passively answering questions, students were collecting data,

analyzing it, and applying their knowledge of the energy and force topic to this new context. Data indicated that this mode of iPad use supported the quality of their discussion.

Another way to facilitate evidence-based discussion is to let students collect and analyze their own data. Thus students can see the evidence and understand the patterns. In the car crash challenge, Amy provided videos of two cars -one fast and one slow - and asked students to collect data from video to calculate the cars' velocities. Working with a video analyzing app students were easily able to collect the data; having it on the iPad allowed easy access for further analysis. The data collected from the video was transferred by the students to *Vernier Graphical Analysis*. While the car crash challenge was a group project it had individual work. Students individually analyzed the data by using *Vernier Video Physics* and *Vernier Graphical Analysis* and calculated the speed of each car. Then as a group they calculated the intersection of the cars. During group work students discussed methods of calculation and the best method to use based their collected data.

PhET simulations were used in classroom for data collection. They were used during the waves unit. Similar to *SlowPro* the app enabled data collection. Following collection students were calculating the speed of waves and responding to open-ended questions as a group. During these responses students were able to do peer assessment by monitoring each other and discussing the questions using the evidence they collected.

iPad affected the sociocultural views on learning characteristics in the classroom in different ways. First it transformed the classroom culture by changing how students and teacher communicate which changed the power relationship between them. The

teacher became easily accessible resulting in students not being afraid to ask questions. iPad empowered students by customizing the learning in that students were able to collect and analyze their own data and utilize time based on their needs instead of being attentive to the teacher. iPad not only assisted personal data collection but also enhanced data collection by using different applications and simulations. Thus it improved the quality of discussion through better time management, enhanced data collection, replay analysis, and collaboration than afforded by manual calculation and human visual analysis.

Discussion and Implications

This paper examined a high school teacher's formative assessment practices in a technology-enhanced classroom. During this examination, I adapted a unique perspective by looking at it from a sociocultural lens. In part one, I summarized the teacher's formative assessment practices by looking at the members, tools, and norms. In part two, I focused on the iPad's impact on the formative assessment process. The analysis revealed three impacts of the iPad: 1) transforming classroom community, 2) empowering students, and 3) facilitating evidence based discussions.

The digital didactical design framework focuses on fostering student learning under the influence of technology (Jahnke & Kumar, 2014). It helps explain the relationship among teaching aims, learning activities, and process-based assessment. Based on the framework, researchers developed a data analysis form and analyzed data using the form's five components (teaching objectives, learning activities, feedback, design of social relations, and how iPad use is integrated) (Jahnke & Kumar, 2014). I modified the form to focus specifically on formative assessment process from a sociocultural learning perspective. For this reason, I added specific questions to

understand how assessment aids or hinders key characteristics of sociocultural views on learning (Figure 3.1). Technology use impact was added to the form as an additional attribute to capture the effect of technology on each formative assessment activity. The data analysis form aimed to describe the formative assessment practices, not to evaluate them.

Research has shown that formative assessment improves student learning (Bell & Cowie, 2001a; 2001b; Black, & Wiliam, 1998). Amy created an assessment-centered learning community in which she used formative assessment to support student learning by encouraging students to exchange their ideas with peers, reflect on their own and peer's work, create a shared understanding, and by modifying her instruction. Abell and Siegel (2011) highlighted that "assessment-centered learning environments are critical for supporting learner-centered and knowledge-centered environments to facilitate student learning with understanding" (p. 205). Amy wanted her students to be critical thinkers. She provided opportunities to them to collect data and use it as evidence when answering lab and discussion questions. She benefited from technology during this process.

Amy saw the iPad as a tool for improving her instruction. Using iPad was an assessment strategy (Abell & Siegel, 2011), which eased the process and speed of communication. The teacher's willingness to learn about technology, and keep track of science and technology related news, aided adoption of current technology and discussion topics into the classroom; she desired to use the iPad in different ways to better engage student interaction within real life contexts. The use of video analysis in the car crash challenge was an example as well as using zombies - a popular topic among teens - to teach the physics of energy. She encouraged and assisted students to video record

themselves. The teacher's willingness, combined with her efforts to link real life issues to the class, created an environment in which students were open and willing to try new things. This environment created opportunities for students to develop a new understanding of the meaning of 'learner' and produced opportunity for identity development.

A classroom is one of the many communities within the school community (Jahnke, 2016). Thus assessment in the classroom cannot be isolated. "It informs and is informed by school-wide assessment policy and practices, which in turn are influenced by national standards and curriculum." (Moreland et al., 2001, p. 156). Due to scope of this research, I focused on the classroom community and briefly touched on the school's expectations for assessment in the classroom. Knowing more about a school's view of assessment and technology, and the support system that is available to a teacher, could help a researcher better understand a teacher's formative assessment practices. Future studies should explore the relationships among communities and their effects on each other.

The results showed that iPad impacted and transformed the classroom; it changed, from a traditional classroom, to one that embraced opportunities for integration of external materials and scenarios into lab and exercise activities. Transformation was possible due to the rapid communication capabilities offered by the iPad and teacher-student interactions. Barak (2017) found that more than half of the teachers believe that technology cannot improve the communication between the teacher and students. Opposing that finding, this study showed iPad was used to improve student-student and teacher-student interaction. Amy created a culture in which all student works were

recognized by providing an opportunity for students to share their work with peers, reflect on their work, and take responsibility for their own learning. This interaction between students caused them to learn collectively within their society.

The classroom culture was transformed through hastened access to materials. iPad mediated this by letting students easily access a variety of information during formative assessment activities. As Siegel (2007) suggested, it eased the formative assessment process without impacting either the content or difficulty of assessment.

Jahnke (2016) explained in her book that education needed to transform, from expecting students to sit and passively learn from the teacher, to having enhanced opportunities to apply knowledge in new contexts. This application allows students to participate in the classroom with increased confidence and self-awareness of learning. This generates opportunities for identity development.

Students decided on data collection and analysis methods in these new contexts, which empowered them. To make the decision, students discussed with each other, reflected on ideas, and created a shared understanding. As the analysis in this study revealed, iPad assisted this process by easing and improving data collection and analysis. Collecting data, analyzing it, and being able to choose data collection, analysis, and presentation methods gave students responsibilities and authority. Using these methods gave them opportunity to understand scientists.

Applying knowledge to new contexts, establishing communication, and performing scientific activities are important for students in developing their science identities. Carlone and Johnson's (2007) science identity model consists of three dimensions: performance, competence, and recognition. Performance is relevant to

student scientific practices, competence to students' science content knowledge, and recognition to being recognized as a "science person" by self or others. The analysis within this study showed that iPad played an essential role in improving the performance dimension of science identity.

Amy created a safe space that allowed students to interact with each other respectfully and explain their ideas without fear of judgment. This context gave the message that everybody's ideas were welcomed and valued. As Cowie (2005) highlighted, the interaction provided opportunities for confidence improvement and also for students to recognize themselves as "science person". Combined with teaching the content knowledge that improved student competence, Amy provided opportunities to improve all three dimensions of science identity (Carlone & Johnson, 2007).

The Next Generation Science Standards (NGSS) emphasized the importance of evidence-based argumentation (NGSS Lead States, 2013; National Research Council [NRC], 2012). In Amy's class students used data as evidence to support their arguments during group discussions. The iPad was a mediator towards enhanced data collection and analysis. This facilitated evidence-based discussions.

I cannot claim that iPad is the only mediator in this context. The teacher decides how to utilize the technology. However, we can assume having an iPad in the classroom allowed teacher to seek out opportunities for student learning and think outside of the box. Moreover, the teacher needs to mediate students' app use to increase their confidence and community participation. In the end, their experiences help shape teacher's use of technology.

This study explored teacher's formative assessment practices in a technology-

enhanced classroom. The results showed ways that a teacher, who is experienced with technology used to facilitate student learning, can effectively and creatively include technology in the classroom.

Professional development programs that focus on how to use technology within assessment will be useful to teachers. Technology-based assessment needs to be included in pre-service teacher education to prepare future teachers to be effective users of technology. In-service and pre-service science teachers need to learn how to use technology to give students power, create safe spaces for students so that they can explain their ideas, and improve student interaction. To do those things, teachers need to experience the integration of technology-enhanced formative assessment in science instruction. A community of teachers in which issues are discussed, ideas are exchanged, and teachers support each other may have long-term benefits.

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Appendix A

Teacher Interview Script (Semi-Structured)

Pre-Interview

Thank you for agreeing to be interviewed today. As a reminder, the information you share will help researchers understand your knowledge and perceptions of learning, teaching, assessment, technology, and the purposes for using iPads in your practice. Furthermore, the information will show the challenges and limitations teachers face in terms of the implementation process of the technology. This information will help researchers better understand the needs of teachers who implement technology in their classroom.

Audio taping this interview will help me remember what you share with me today. I will type up our conversation to understand and share your thoughts about implementing the iPad. However, I will not include your name on the transcript. Do I have your permission to audiotape?

Remember that throughout the interview you may also ask questions of me at any time. Do you have any questions before we begin?

Part 1: Instructor's Background

First I would like to learn about your background and interests.

- When did you start to teach?
- Have you ever participated in a PD program related to assessment and/or technology? If so, what did you learn and how did that help you in your teaching?

Part 2: Views of Teaching and Learning

I'd like to know more about your view of teaching and learning [view of learning/knowledge? different purposes?]

- What do you think are the purposes of education?
- How do you describe a good learning environment where students learn best? (Ask about her views of group activity and community.) Follow up: How does learning occur?
- What are teacher's roles and students' roles in education and in your classroom? (Ask about the authority and mediation.)
- How do you help students become better at applying the knowledge learned in class?
- Would you describe a recent class session where you felt like you were effective in achieving your goals for that session?
- Would you describe a recent class session where you felt like you were ineffective in achieving your goals for that session?
- Could you describe an example of one of your students you think is responsible?

Part 3: Views of Assessments

Lets now talk about assessment. I'd like to know more about your views and goals for assessment [view of learning/knowledge? different purposes?]

- In a few words, could you define assessment? How do you use it? Follow up: Ask for formative and summative if not mentioned.
- Can you describe a ritual day of your assessment process: how would you assess students, how do you decide what to assess, and how would you sequence them,

how would you deal with the unexpected things (e.g., what if a student did not understand), and why would you do these in these ways?

- Could you explain the roles of teachers and students in the assessment process?
- How do you prepare students for exams?
- Do you prefer individual exams or group exams? Why?
- Do you use multiple assessments in your teaching sequence? Can you explain it?

Part 4: Assessments Implementation

- How do you use these assessments to inform your instruction/modify the course?
- What methods do you use to get feedback from and provide feedback to students?
- What kinds of things do you do to improve the effectiveness of the feedback?
- How do the results of the assessment influence your teaching?
- How do you promote students to use your feedback?
- What do you see as the two greatest challenges to giving effective written/oral feedback?
- What factors constrain or limit your use of assessment in your teaching?

Part 5: Technology (Views & Implementation)

- How do you use technology in your personal life? How frequently? Can you provide some examples?
- When did you start using technology in your classroom?
- What do you think of technology use in the education?
- What are the advantages and disadvantages of using technology? Can you give an example for each?
- How does using technology change the classroom environment?

- How frequently and in what ways do you use iPads in your teaching? Follow up: How about assessment?
- How do you use iPad apps for providing feedback? Can you give an example?
- Can you describe an example of using the iPad that positively influences your teaching?
- Describe an example of using the iPad that negatively influences your teaching.

Post-Interview

Is there anything else you'd like to say about your experiences with technology, assessment, and technology within assessment?

Thank you again for your participation in this interview.

Appendix B

Teacher Reflective Interview Prompts

- Which assessment from this week do you think was the most effective?
- What were you trying to achieve with this specific assessment?
- Did you achieve your goal?
- What were the student's roles during the assessment?
- What was your role during the assessment?
- How did technology affect your assessment activity?
- Did technology provide any scaffolding/mediation?
- Could you do the same activity without using the technology? If so, how?
- Did this assessment provide information about student learning?
- How did you use the results of the assessment?
- How did the students use the results of the assessment?
- What would you change about this assessment?
- What were the challenges and limitations you encountered during implementation of this assessment?

Appendix C

Student Interview Script (Semi-Structured)

Pre-Interview

Thank you for agreeing to be interviewed today. As a reminder, the information you share will help researchers understand your experiences using the iPad during your learning and improve the quality of teaching in classrooms implementing technology. Audio taping this interview will help me remember what you share with me today. I will type up our conversation to understand and share your thoughts about implementing the iPad. However, I will not include your name on the transcript. Do I have your permission to audiotape?

I am going to be asking you some general questions about your experience learning with the iPad in the course. Remember that throughout the interview you may also ask questions of me at any time. Do you have any questions before we begin?

Part 1: Student's Background

First I would like to learn about your background and interests.

- Do you like science? What makes a science class appealing?
- Why are you taking this course? How will it impact your future (college pathway)?
- What are your career plans? What do you see yourself doing in five years?
- How do you use technology in your personal life? And how frequently? Can you provide some examples?
- What are the difficulties you feel in using technology?

Part 2: Learning

Let's talk about learning;

- Suppose in one class a teacher gives a lecture, solves problems, and provides the right answers and in a different class a different teacher gives projects/problems to students for them to explore and solve. Which represents your view of ideal learning?
- Could you define a teacher's role and students' role in education and your classroom?
- What type of learning activity do you prefer (watching video/ reading/ drawing)?
- Do you prefer working in groups or alone? Explain.

Part 3: Assessment

- Define assessment in a few words.
- How do you study for exams?
- Do you have an opportunity to share your ideas in class? How?
- Suppose in one class a teacher lectures, students read, and in an exam the teacher asks multiple-choice questions. In another classroom a different teacher lets students work in project groups and the exam contains open-ended questions related to the projects. Which method is most similar to the one your teacher uses? Which one do you prefer?
- How does the iPad help you share your ideas?
- How helpful was [assessment tool] in helping you learn? What was most helpful to you? What was least helpful to you? (I will ask about a specific application and specific assessment from the classroom for this question.)

- How could your instructor better use the [assessment tool] to support your learning?
- How could your instructor change the instruction to better support your learning?
- What type of feedback do you get from teacher?
- How does your teacher provide feedback to you? (Writing on assignment paper, orally)?
- How does feedback make you feel? Would you prefer a teacher provide feedback within the classroom or privately?
- How do you use teacher's suggestions (feedback)?

Part 4: Technology

- How do you use technology in the classroom and out of the classroom (for learning purposes)?
- How does using technology change your school experience?
- In what ways and how frequently do you use the iPad? Follow up: How do you use iPads during assessment?
- What are the difficulties and advantages you feel in using technology in the classroom?
- What are the advantages and difficulties of using iPad for feedback?
- How did using technology help you in [specific assessment]?
- Can you describe an example of using the iPad that positively influences your learning?
- Can you describe an example of using the iPad that negatively influences your learning?

Post-Interview

Is there anything else you'd like to tell me about your experiences during the course?

Thank you again for your participation in this interview.

Appendix D

iPad Usage per Class Session

Date	Topic	iPad Use	Time spend on iPad
May 2nd	Newton's 3rd Law	iPad included the lab sheet, students were answering the questions in the lab and drawing on whiteboard	45 minutes
May 4th	Newton's 3rd Law Test day	QR code scanning & iPad used for scanning student response sheet & individual students worked on their iPads	20 minutes (including teacher usage and students individual working time)
May 6th	Exploring Waves	Using SlowPro app- demonstration and scaffolding how to use app, stations of waves- using SlowPro app recording waves and answering questions on lab on iPad	50 Minutes
May 10th	Exploring Waves	Re- visiting Waves stations on iPad and find evidence to come up with big ideas about waves, Speed dating and exchanging ideas, & used to take notes- students draw, take pictures and wrote explanations about wave behaviors	45 Minutes
May 12th	Exploring Waves & Pulse	Kahoot – game for big ideas – formative assessment& PhET simulations on pulse behaviors and factors	50 Minutes

May 16th	Frequency Wave length	PhET simulations-wavelength and frequency	45 Minutes
May 18th	Frequency Wave length	PhET simulations, Physics Website, watching video	50 Minutes
May 20th	Comparing Waves	QR code scanning, Socrative Quiz	55 Minutes
October 17th	Uniform Motion-Making graph and analyzing Graph	Students use to draw graph, input data for graphing and analyzing, teacher used to reflect her iPad to smartboard, NearPod	45 Minutes
*October 19th	Motion diagrams & Change in position	Used iPad as a source for finding evidence for whiteboarding	20 Minutes
October 21st	Motion detector	QR code scanning, making predictions and writing on iPad, drawing graphs, answering questions on lab on iPad	55 Minutes
October 25th	Calculating velocity	Teacher explain criteria of lab, Cornell notes, watching video, calculating velocity on lab on iPad	45 Minutes
October 27th	Calculating velocity and graphing	Checking lab work with a partner (lab work is on iPad), gallery walk-students compare their work with peers and correct their own work, & video analysis	50 Minutes
November 1st	Calculating velocity no graphing Test	QR code scanning for self check of homework	10 Minutes

November 3rd	Calculate final position	Scaffolding students on a calculation on lab on iPad	10 Minutes
*November 7th	Determining the velocity	Working on lab on iPad, taking picture, & video Analysis for velocity on iPad	15 Minutes
November 10th	Calculate velocity and meeting point	Video Analysis for velocity on iPad, working on lab on iPad, & Socrative review	65 Minutes
November 15th	Calculate velocity and meeting point, & Test	Not used-	0 minutes

* Short classes 45 minutes long.

Appendix E

Digital Didactical Design Framework

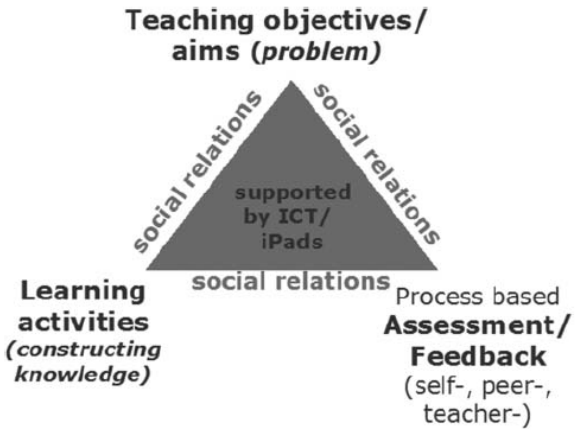

Figure E.1. Digital didactical design. Jahnke & Kumar, 2014 p. 82

Table E.1

Form for Data Analysis. Jahnke & Kumar, 2014 p. 82

Table 1. Form for Data Analysis (derived from DDD)

	Name of the classroom:	Description (keywords)	Element has been addressed? Yes/No	Details of didactical elements in classroom observations/ Quotes from interviews
1	**Teaching objectives** are visible/clear? Are expected learning outcomes visible/ clear?			
2	**Learning activities** are clear and appropriate, and correspond to teaching objectives?			
3	**Feedback**: assessment is process-based or summative or both?			
4	**Design of social relations:** visible in communication & collaboration among peers and teacher-student interaction; degree of collaboration.			
5	**How iPad use is integrated** into the whole learning scenario.			
	Overall analysis per classroom	Brief summary	Number of addressed DDD elements in total (1–5)	Summary and extent of iPad use as high/Medium/Low

Appendix F

IRB Teacher Consent Form

High School Physics Teachers' Technology Based Formative Assessment Practices
TEACHER CONSENT

You are invited to participate in a research study that examines the use of technology for assessment. My name is Nilay Muslu and I am a PhD candidate at the University of Missouri-Columbia, working under the direction of Dr. Marcelle A. Siegel, Associate Professor of Science Education at the College of Education. The goal of the study is to better understand how technology, specifically the iPad, affects teacher assessment practice and the learning environment. The research project will not ask you to change your regular classroom practice in any way.

INFORMATION

Your participation in this study is voluntary; you may choose not to participate and there will be no penalty or consequence. If you decide to participate, you may withdraw from the study at any time without penalty or consequence of any kind.

PARTICIPATION

If you decide to participate in this research study, your participation will involve:

- An interview prior to the classroom observation to gain a general understanding of iPad usage in your classroom and your views (approximately 1 hour)
- Weekly informal reflective interviews on the formative assessment activity and iPad usage within the activity (approximately 20 minutes)
- Being a participant of observation of your class during your teaching
- Student works and assessment examples will be collected

Classroom observations will be videotaped. The video recordings will only be used for research purposes and will only be accessible to researchers. All interviews will be scheduled at your convenience. Audio recordings of the interviews will be made and transcribed. All recordings and transcriptions will be kept in a secure location. Actual names will be replaced by pseudonyms from all data. The research project will not ask you to change your regular classroom practice in any way. This research is not an evaluation of your teaching abilities.

BENEFITS

Your participation in this research study will provide important insights into the understanding of technology use in a high school classroom. The information gained in this study may be published and be useful to professional developers and science educators at other universities and colleges.

CONFIDENTIALITY

All personally identifiable information will be kept strictly confidential. Pseudonyms will be used in all published documents including the name and location of your school/school district. Only the researchers will know your identity. The data collected during the study will be stored in a secure area. You may choose to end your participation at any time during the study, and your data

will be destroyed in the event of early withdrawal from the study. Research data will be stored for seven (7) years beyond the completion of the study within a secure location; after that time it will be destroyed.

RISKS

This project does not involve any risks greater than those encountered in everyday life.

For additional information regarding human subject participation in this research, please contact the University of Missouri-Columbia IRB officer at (573) 882-9585 and email: umcresearchcirb@missouri.edu.

If you have questions, you may also contact the researchers:

- Nilay Muslu, directly at (573) 529-6668 or nilaymuslu@mail.mizzou.edu

Alternately, you can contact my advisor, Dr. Marcelle A. Siegel at SiegelM@missouri.edu

CONSENT

I have read and understand the above information, and I have received a copy of this form. By signing below, I indicate my willingness to participate in the study.

Signed: _____ Date: _____

(Signature of participant)

Printed Name: _____

Investigator's Signature _____

Appendix G

IRB Student Assent Form

High School Physics Teachers' Technology Based Formative Assessment Practices
STUDENT ASSENT

You are invited to participate in a research study that examines the use of technology for assessment. My name is Nilay Muslu and I am a PhD candidate at the University of Missouri-Columbia, working under the direction of Dr. Marcelle A. Siegel, Associate Professor of Science Education at the College of Education. The goal of the study is to better understand how technology, specifically the iPad, affects teacher assessment practice and the learning environment.

INFORMATION

Your experience as a student will help to understand how to use classroom technology better to support your learning. Your permission is being requested to allow you to be involved in this research. The data gathered from this study will be collected during the spring semester of 2016. Participation in this research study is voluntary; you may choose not to participate and there will be no penalty or consequence for non-participation or, if participating, early withdrawal.

PARTICIPATION

If you decide to participate in this research study, your participation will involve:

- Being a participant during the researcher's observation of your class
- An interview after the classroom observation about your views on iPad usage in the classroom. (Once and approximately 45 minutes).
- Student works and assessment examples will be collected.

Classroom observations will be videotaped. The video recordings will only be used for research purposes and will only be accessible to researchers. All interviews will be scheduled at your convenience. Audio recordings of the interviews will be made and transcribed. All recordings and transcriptions will be kept in a secure location. Actual names will be replaced by pseudonyms from all data. The research project will not ask you to change your regular classroom activities in any way. This research is not an evaluation of you and it will not affect your grades.

BENEFITS

Your participation in this research study will provide important insights into the understanding of technology use in a high school classroom. The information gained in this study may be published and may be useful to professional developers and science educators at other universities and colleges.

CONFIDENTIALITY

All personally identifiable information will be kept strictly confidential. Pseudonyms will be used in all published documents including the name and location of your school/school district. Only the researchers will know your identity. The data collected during the study will be stored in a secure area. You may choose to end your participation at any time during the study, and your data will be destroyed in the event of early withdrawal from the study. Research data will be stored

for seven (7) years beyond the completion of the study within a secure location; after that time it will be destroyed.

RISKS

This project does not involve any risks greater than those encountered in everyday life.

For additional information regarding human subject participation in this research, please contact the University of Missouri-Columbia IRB officer at (573) 882-9585 and email: umcresearchcirb@missouri.edu.

If you have questions, you may also contact the researchers:

- Nilay Muslu, directly at (573) 529-6668 or nilaymuslu@mail.mizzou.edu

Alternately, you can contact my advisor, Dr. Marcelle A. Siegel at SiegelM@missouri.edu

CONSENT

Please read the consent statements below and place an "x" next to the statement that describes your desire to participate in this study at this time. Sign and date the form.

I have read the information presented above and have had an opportunity to ask questions and receive answers pertaining to this project.

_____ I hereby agree to participate in this research study. I am aware that participation is voluntary and that I am free to withdraw at any time without any penalties or loss of standing within the program.

_____ I do **not** agree to participate in this research study.

Signed: _____ Date: _____
(Signature of student)

Printed Name: _____

Investigator's Signature _____ Date _____

Appendix H

IRB Parental Consent Form

High School Physics Teachers' Technology Based Formative Assessment Practices
PARENTAL CONSENT

Your child is invited to participate in a research study that examines the use of technology for assessment. My name is Nilay Muslu and I am a PhD candidate at the University of Missouri-Columbia, working under the direction of Dr. Marcelle A. Siegel, Associate Professor of Science Education at the College of Education. The goal of the study is to better understand how technology, specifically the iPad, affects teacher assessment practice and the learning environment.

INFORMATION

Your child's experience as a student will help to understand how to use classroom technology better to support his or her learning. Your permission is being requested to allow your child to be involved in this research. The data gathered from this study will be collected during the spring semester of 2016. Participation in this research study is voluntary; you may choose not to allow your child to participate and there will be no penalty or consequence for non-participation or, if participating, early withdrawal.

PARTICIPATION

If you decide allow your child to participate in this research study, your child's participation will involve:

- Being a participant during the researcher's observation of your child's class
- An interview after the classroom observation about your child's views on iPad usage in the classroom. (Once and approximately 45 minutes).
- Student works and assessment examples will be collected.

Classroom observations will be videotaped. The video recordings will only be used for research purposes and will only be accessible to researchers. All interviews will be scheduled at your child's convenience. Audio recordings of the interviews will be made and transcribed. All recordings and transcriptions will be kept in a secure location. Actual names will be replaced by pseudonyms from all data. The research project will not ask you to change your child's regular classroom activities in any way. This research is not an evaluation of your child and it will not affect your child's grades.

BENEFITS

Your child's participation in this research study will provide important insights into the understanding of technology use in a high school classroom. The information gained in this study may be published and may be useful to professional developers and science educators at other universities and colleges.

CONFIDENTIALITY

All personally identifiable information will be kept strictly confidential. Pseudonyms will be used in all published documents including the name and location of your child's school/school district. Only the researchers will know your child's identity. The data collected during the study will be

stored in a secure area. You may choose to end your child's participation at any time during the study, and your child's data will be destroyed in the event of early withdrawal from the study. Research data will be stored for seven (7) years beyond the completion of the study within a secure location; after that time it will be destroyed.

RISKS

This project does not involve any risks greater than those encountered in everyday life.

For additional information regarding human subject participation in this research, please contact the University of Missouri-Columbia IRB officer at (573) 882-9585 and email: umcresearchcirb@missouri.edu.

If you have questions, you may also contact the researchers:

- Nilay Muslu, directly at (573) 529-6668 or nilaymuslu@mail.mizzou.edu

Alternately, you can contact my advisor, Dr. Marcelle A. Siegel at SiegelM@missouri.edu

CONSENT

Please read the consent statements below and place an "x" next to the statement that describes your desire to participate in this study at this time. Sign and date the form.

I have read the information presented above and have had an opportunity to ask questions and receive answers pertaining to this project.

_____ I hereby agree to allow my child to participate in this research study. I am aware that participation is voluntary and that I am free to withdraw my child at any time without any penalties or loss of standing for my child within the program.

_____ I do **not** agree to allow my child to participate in this research study.

Signed: _____ Date: _____
(Signature of parent/guardian)

Printed Name: _____

Student Name: _____

Investigator's Signature _____ Date: _____

CHAPTER FOUR

Feedback Through Digital Application Affordances and Teacher Practice

Abstract

Feedback has essential influences that promote student learning (Black & Wiliam, 1998; Clark, 2012; Hattie & Timperley, 2007). Clear student-teacher communication can aid effective feedback. Teacher and students acting upon the feedback has potential to support student learning. Learners and teachers may benefit from educational technologies during the feedback process. The purpose of this study was to identify the feedback dimensions that were fulfilled by iPad applications and compare teacher practice to affordances of apps. I analyzed seven applications (*QR Code Reader, Schoology, Kahoot!, Socrative, ZipGrade,* and *The Physics Classroom*) a high school physics teacher used for feedback purposes in a technology-enhanced classroom. Data sources included classroom video recordings, teacher and student interviews, and application developer's websites. To enable analysis of data, I enhanced Hatzipanagos and Warburton's (2009) feedback dimensions. The analysis revealed app diversity in supporting different feedback dimensions (Dialogue, Visibility, Appropriateness, Community, Power, Learning, Timeliness, Clearness, Complexity, Reflection, and Action). I found that the teacher, through additional discussion and interactions with students, could support dimensions that an app did not. I provide recommendations for teachers, teacher educators, and app designers to support use of apps for effective feedback.

***Keywords*:** feedback, formative assessment, mobile learning, iPad

Introduction

Crisp (2007) stated the importance of feedback is emphasized within policy documents and standards (e.g., Next Generation Science Standards [NGSS]) beyond the emphasis provided in the assessment literature (e.g., Evans, 2013; Evans & Waring, 2011; Hattie & Timperley, 2007; Li & De Luca, 2014; Shute, 2008). Feedback is an essential aspect of formative assessment and has powerful influences on learning and achievement (Black & Wiliam, 1998; Clark, 2012; Hattie & Timperley, 2007; Havnes, Smith, Dysthe, & Ludvigsen, 2012; Ruiz-Primo & Li, 2013). Feedback is the essential step in which students and instructor communicate to determine student needs and to help students improve learning. There is not a general agreement on the definition of effective feedback (Shute, 2008; Evans, 2013). Feedback can be implemented in a variety of ways whose effectiveness changes based on student, context, and purpose of feedback (Hattie & Timperley, 2007; Evans, 2013). However, there are general attributes of feedback that help to match feedback to student needs. In this study, I expanded Hatzipanagos and Warburton's (2009) feedback dimensions to analyze effective feedback.

Research indicates that technology can assist teachers during the feedback process to help meet students' needs (Maeng, 2016). Technology can support feedback in a variety of ways: immediate feedback (e.g., Buckley,Gobert, Horwitz & O'Dwyer, 2010), personalized feedback (e.g., Penuel & Yarnall, 2005), collaborative learning communities (e.g., Lai & Ng, 2011), and feedback to instructor (e.g., Feldman & Capobianco, 2008). An anytime-anywhere approach within technology improves communication between teacher and students (Evans, 2013) promoting the feedback process.

Since feedback is an essential and widely mentioned phenomenon in literature

and standards, this empirical study explored how technology plays a role in providing feedback. Technology-based feedback can be provided through a variety of sources: Internet applications, interactive multimedia, electronic games, and mobile devices (Evans, 2013). In this study, feedback was provided via mobile devices, specifically by different applications (computer programs, also known as 'apps') used on the iPad. I explored the potential of iPad apps to support feedback dimensions within a high school physics course. Specifically, I compared affordances of apps to teacher practice.

Feedback

A major aim of feedback is to improve students' learning (Black & Wiliam, 1998; Jones & Blankenship, 2014; Ruiz-Primo & Li, 2013; Siegel, Hynds, Siciliano & Nagle, 2006). Although researchers agree feedback is an important part of assessment, the definition of feedback varies widely (Shute 2008; Black & Wiliam, 2009; Li & De Luca, 2014; Evans, 2013). On one side, Kepner defined feedback as "any procedure used to inform a learner whether an instructional response is right or wrong" (as cited in Jones & Blankenship, 2014, p. 2). On the other side, Li and De Luca (2014) used the term 'assessment feedback' for instructors' comments or grades used to improve student learning.

Researchers claimed there is a gap between students' current performance and the desired learning goal and that feedback should additionally enable closing this gap (Lizzio & Wilson, 2008; Nicol & Macfarlane-Dick, 2006; Sadler, 1989). Jones and Blankenship (2014) suggested a variety of cognitive processes to improve student learning. Some of these suggestions were "restructuring understandings, confirming to students that they are correct or incorrect, indicating that more information is available or

needed, pointing to directions students could pursue, and/or indicating alternative strategies to understand particular information" (Jones & Blankenship, 2014, p. 2). By incorporating these suggestions feedback focuses on helping students improve their own understanding and learning instead of focusing on pointing out the correct answer. In this line of thought, Winne and Butler's (1994) definition of feedback is a good summary that emphasizes students' progress. " … information with which a learner can confirm, add to, overwrite, tune, or restructure information in memory, whether that information is domain knowledge, meta-cognitive knowledge, beliefs about self and tasks, or cognitive tactics and strategies" (p. 5740).

Cowie, Moreland, and Otrel-Cass (2013) assert "A sociocultural perspective enables teachers to regard feedback as more than a strategy, instead regarding it as a practice that is embodied within the social practices and culture of the classroom" (p. 14). Within this view, feedback occurs through interaction among students and teachers. During this interaction, students will share and challenge their ideas and mediate each other, while the teacher monitors and facilitates. Feedback can be used to support student-learning progress within the community during this interaction.

These views demonstrate agreement among researchers that feedback should improve student learning while also showing the variation in methods used to achieve that improvement. Yet, it is not clear from prior research what feedback should be or how it can be best used. Many teachers have issues while providing feedback (Ruiz-Primo & Furtak, 2006).

In this section, I summarize the definition of feedback. In the next section I explore the attributes of effective feedback. Even though feedback's effectiveness has

been argued Hatzipanagos and Warburton (2009) were able to define common attributes.

Feedback Attributes

Hatzipanagos and Warburton (2009) summarized attributes of feedback based on the feedback literature. In their paper, feedback attributes were grouped into eight categories (Appendix A). I expanded these categories with recent literature on feedback.

Table 4.1 *Dimension of Feedback. Adapted from Hatzipanagos and Warburton (2009)**

Dimension	Identified attributes of feedback
Dialogue	1. Feedback is adequate detail 2. Supports peer/tutor dialogue 3. Teacher allows students to be active and respond to feedback 4. Supports questioning
Visibility	1. Discern student-learning needs/prior knowledge 2. Be able to 'spot' unpredicted achieved outcomes
Appropriateness	Feedback is 1. understandable to students 2. linked to learning outcomes (constructive alignment) 3. linked to the assessment criteria
Community	1. Supports the learning communities 2. Supports peer assessment
Power (autonomy and ownership)	1. Supports management of own learning (self-regulated learning) 2. Improves levels of student confidence 3. Increases responsibility and autonomy
Learning	1. Focuses on learning 2. Does not provide grades or ranking
Timeliness	1. Quantity and timing of feedback 2. Feedback is prompt enough to be useful to students
Clearness	1. Feedback should use simple language so students will understand the context without struggling to understand complex terms 2. Give clear signals about good practices

Complexity	1. Feedback should be complex enough to let student think about the issue 2. Feedback should not provide the correct answer.
Reflection	1. Encourages reflection on student work 2. Compares actual performance with a standard and takes action 3. Develops self-awareness skills
Action (student action-1, teacher action-2&3)	1. Students receive feedback and act upon it 2. Teacher helps students set personal goals 3. Feedback helps teacher modify teaching

*Additional sources: Shute (2008); Evans (2013); Hattie & Timperley, (2007); Nicol & Macfarlane-Dick (2006); Izci, Muslu, Long, Anderson, & Siegel (2013)

Table 4.1 is created based on Hatzipanagos and Warburton (2009)'s view of 'feedback as a dialogue', which is based on feedback being an active and participative process. "In formative feedback, dialogue forms the mechanism by which the learner monitors, identifies, and then is able to 'bridge' the gap in the learning process" (p. 46). In line with their views, I believe learning is a social activity, and that assessment is social, because I believe one cannot separate assessment from learning. Participation is pivotal in social activities. Thus, feedback needs to support communication among students and teacher. Hatzipanagos and Warburton (2009) underlined the importance of communication by stating, "Communication is part of the mechanism by which the learner identifies and then bridges the gap between the current learning achievements and the goals by the tutor" (p 47). Feedback enables students to understand their own learning progress within the community. I believe feedback needs to support learning communities, and spur students to take responsibility for their own learning, by enabling students to reflect on and take action based on feedback.

Although feedback is generally defined in the literature as a teacher giving feedback to students, other directions also exist: students giving feedback to teachers, students giving feedback to other students, and students giving feedback to themselves. The effect of self and peer feedback on students' learning cannot be underestimated (Hatzipanagos & Warburton, 2009); these feedback utilizations allow students to take more responsibility and increase engagement in their learning (McConnell, 2006; Hatzipanagos & Warburton, 2009; Saddler 1989). These utilizations help enable students in the pivotal development of self-assessment. Students that ask each other for feedback will improve their dialogue and promote sharing different views. This empowers students by taking more responsibility and by enabling mediation which is external to the student-teacher relationship.

To reach students with feedback it needs to be appropriate for students to meet their needs. According to Kluger and DeNisi (1996), feedback has the greatest effect when goals are specific and challenging and task complexity is low. However, while emphasizing these attributes related to active participation, one cannot underestimate the importance of timing and visibility dimensions of feedback. Some researchers assert that providing immediate feedback has significant effect on student learning (Black & Wiliam, 1998; Hattie & Timperley, 2007). Yet, Mathan and Koedinger (2002) argue that timing of feedback depends on the nature of the assessment task and students' capacities. Visibility dimension focuses on monitoring students to be able recognize their dynamic understanding and learning progress. Via monitoring, the teacher is enabled to assist creating shared understanding among community members (Radinsky, Oliva, & Alamar, 2010). Thus this dimension is essential for effective feedback and it is a first step during

the communication between student and teacher.

The purpose of this study is to understand the potential of app affordances to promote feedback attributes. In this section I enhanced feedback attributes for effective feedback. I then grouped these attributes within dimensions. Data analysis was based on these feedback dimensions.

Technology and Feedback

Technology can help a teacher during the feedback process in a variety of ways (Maeng, 2016). Research on technology-based feedback (also known as e-assessment feedback) has been increasing (Evans, 2013). It can be provided through a variety of sources including mobile devices and internet platforms. Technology-based feedback is varied. It can be synchronous or asynchronous, generated by teacher or be computer-generated, and support individual or group learning.

Technology-based feedback can provide opportunities otherwise impossible without it due to multiple factors: time constraints, geographical problems, and large number of students (Gilbert, Whitelock & Gale, 2011). The technology enables creating an environment for supporting a learning community (Lai & Ng, 2011), helps teachers collect data (e.g., Feldman & Capobianco, 2008), provides immediate feedback (Buckley, Gobert., Horwitz, & O'Dwyer, 2010), provides personalized feedback (e.g., Penuel & Yarnall, 2005; Buckley et al., 2010), and facilitates self-assessment and peer assessment (Ng & Lai, 2012).

Technology-based feedback impacts student motivation and engagement (De Nisi & Kluger, 2000); the impact varies (Evans, 2013). Gilbert et al. (2011) found in their *Synthesis Report of Assessment and Feedback With Technology Enhancement (SRAFTE)*

that the success of technology is dependent on how the technology is implemented rather than the specific technology. Thus engagement and improving student learning depends on the implementation of the specific technology. Therefore, in this study I explore both affordances of apps and teacher practice.

Method

The aim of this paper is to explore the potential of technology to support feedback. Previous sections discussed feedback, effective feedback, and overall impact of technology on feedback. I am specifically interested in whether iPad applications ('apps') can be used to support feedback attributes. The specific research questions guiding this study are:

Which defined feedback dimensions are fulfilled by iPad applications used in the classroom?

a) To what extent do iPad apps fulfill the feedback dimensions?

b) To what extent does teacher use of iPad fulfill the feedback dimensions?

Research Participants

Data was collected from a high school physics teacher's classroom. The participant teacher was recommended by the district Science Coordinator as an innovative teacher who was actively using iPads in the classrooms. The purposeful sampling was used to cover "the key constituencies of relevance to subject matter" (Ritchie, Lewis, & Elam, 2003, p. 79) and to explore and gain insight in depth about phenomena from which a researcher needs to select samples from which the most information can be gained (Creswell, 2007; Merriam, 1998).

The participant teacher, Amy (a pseudonym), has been teaching since 1997. She

taught physical science, physics, and honors physics courses. During her career she achieved National Board Certification and was named a Professional Development Classroom Teacher. Amy received several local and statewide awards and was awarded a prestigious national award - the Presidential Award for Excellence in Mathematics and Science Teaching. She has both a Master's and Bachelor's degree in science education.

Amy taught in a junior high school prior to the high school in which she was a research participant for this study. Even though she was using some technology she started to use iPad and technology more intensely in this high school. This school's teachers were determined a year before the school was inaugurated so that they could start functional work; the school provided every teacher an iPad in that year, year zero. Amy was accepted as a department chair and so she attended additional workshops and conferences to extend her knowledge of technology's use in classroom.

Research Site

This study was conducted at a public high school in the Midwest United States with a diverse student population. Students were diverse in terms of gender (46.5% female, 53.5 % male), socioeconomic status (51.9% free/reduced lunch), and racial-ethnic composition (54.90 % Caucasian, 29.7 % African American, 6.4% Hispanic, 6.5 % multi-racial). Within the student population, 11.2% of students had IEP and 5% of students were involved in the ELL program. The student-teacher ratio was 18:1. This school began as a technology-immersed school. The teachers were trained about using both technology and iPad before the school started to accept students. Teachers met quarterly during this transition year and they were encouraged to use iPads in class.

For this study, I participated with two of Amy's classrooms during spring and fall

semesters. Both of the classrooms were honors physics classes. In the first classroom, during the spring semester, Amy taught Newton's Law and Waves units, and in the second classroom she taught uniform motion. Classes were representative of the school's student population in terms of gender ratio, socioeconomic status, and racial-ethnic composition.

Data sources

Primary data sources included classroom video recordings and application developer's websites. Supporting secondary sources included teacher and student interviews, pictures taken during observations, pictures of student-works, and pictures of student-teacher interactions on apps.

Applications and their developer's websites were used to understand the affordances of apps. Each application downloaded then used with available data. Each of their associated websites were visited and analyzed.

As primary data sources eighteen classes were recorded. Normal classes were 85 minutes long and there were two short classes 45 minutes long (24 hours total). Researcher took pictures and field notes during classroom observations. To understand participants, their behaviors, and context in depth, scholars have recommended capturing a comprehensive picture of classroom observations (Glesne, 2006; Yin, 2009). In this study, classroom observations (video recordings and field notes) provided information about a teacher's feedback practices.

Other data sources included teacher and student interviews which are essential because they provide insights on events, conversations, and historical development of the events (Stake, 2010; Yin, 2009). Interviews provided an understanding of formative

assessment activity and iPad usage within that activity. Pictures taken during observations, pictures of student-works, and pictures of student-teacher interactions via apps provided me with data not able to be captured via either classroom observations or interviews.

Apps

QR Code Reader: Teacher created QR codes via a QR code generating website, posted them to *Schoology*, and placed a few printed copies in various locations in the classroom. Students used the *QR Code Reader* app on their iPads to scan the QR code to reach a predetermined website or document. While the app was not specifically designed for assessment, the teacher frequently used it for providing students answer keys. In the analysis I used *QR Code Reader* as providing answer key via app.

Schoology: *Schoology* was created as a learning management system having an emphasis on education. It is available as an app or a website and can be used on different computing platforms. It allows enrolling each account (teacher or student) into any number of classes. *Schoology* is a platform from which a teacher can keep all documents and share them with students. Quizzes can be administered electronically using *Schoology*. With its discussion board feature students can communicate and discuss the course topics as a group. Students can use Schoology to exchange private messages with the teacher and each other.

Kahoot!: *Kahoot!* is a website that is used for creating multiple-choice educational games. Teacher either creates or reuses other *Kahoot!* users multiple-choice quizzes then creates a virtual room for students to join. Students join the room using the provided room number then determine their own name. After all students join the teacher

starts the quiz. Students get immediate feedback from the app about answer correctness after submitting quiz answers. *Kahoot!* times the student work and ranks students based on correctness and answer speed. It also breaks down answer choices as percent of student responses for each question.

Nearpod: *Nearpod* is an app that enables teacher to share presentations on students' mobile devices or desktop computers. It can assess students via multiple-choice or open-ended questions. When teacher uses the app for presentation students see what teacher is sharing on their iPad. While students use the app to answer questions teacher can see all student responses. For multiple choice-questions teacher receives both individual student responses and statistics of class responses. After teacher receives all the responses, teacher can use a student response and share it using the app to provide a good or a bad example. *Nearpod* allows teacher to present her own computer screen to students, enabling the response statistics to be shared with students.

Socrative: *Socrative* is an app that enables students to take quizzes on their mobile devices. Similar to *Kahoot!* the teacher either creates or borrows multiple-choice quizzes. For each question the teacher can choose to provide feedback only about correctness or can add his or her own detailed explanation. Based on teacher choice the app can provide immediate feedback to students. The app enables students to work at their own speed. Teacher can see student responses as they submit answers to each question and can see the statistical information for the whole class. Teacher can obtain the results in three different ways: download an Excel document, via email, or save on Google Drive.

ZipGrade: *ZipGrade* is a grading app that helps teacher hasten the grading

process. The *ZipGrade* website provides answer sheets for teachers. These answer sheets includes spaces for students to write their names, date, and mark their responses for multiple-choice questions. Teacher simply adds the answer sheet and then scans students answer sheet. The app gives immediate feedback to teacher for both individual students and for the whole class.

The Physics Classroom: *The Physics Classroom* is a website whose corresponding app is Minds on Physics. The website is designed as a source for teacher that includes simulations, content information, and quizzes. It also enables students to review their knowledge. The participant teacher chose the website for students to use to review knowledge. Thus I only analyzed the *Physics Tutorial* and *The Review Session* portions of the website for app affordances. The teacher only used the *Physics Tutorial*; therefore I used it for analysis for teacher practice. Both portions have a list of all the physics topics included from which students can choose the topic to review. *Physics Tutorial* divided each topic into lessons. *Physics Tutorial* first gives a short review of the lesson and presents questions. Students can see the correct responses by clicking a *"See Answer*" button. *The Review Session* provides an opportunity for learning with review questions with links to related learning material in *Physics Tutorial*.

To summarize characteristics of apps Table 4.2 provides information on type of feedback apps provide, timing of feedback, and the direction of feedback.

Table 4.2 App Characteristics

App Title	Type	Timing	Direction
QR Code Reader	Confirmative Elaborative	Postponed	Self
Schoology	Elaborative	Postponed	S to T & T to S
Kahoot!	Confirmative	Immediate	S to T
NearPod	Elaborative	Immediate	S to T & T to S
Socrative	Confirmative Elaborative	Immediate Postponed	S to T & T to S
ZipGrade	Confirmative	Immediate	S to T
The Physics Classroom (website)	Elaborative	Immediate	Self

S to T: student to teacher

T to S: teacher to student

Immediate: before proceeding to the next question

Postponed: after answering questions

Data Analysis

Typological data analysis was used for this study. This type of analysis is used when a study has a narrow focus. Data was collected for specific purposes and the categories for the data was predetermined (Hatch, 2002).

I used an enhanced version of Hatzipanagos and Warburton's (2009) feedback dimensions for analysis. To determine application affordances, I visited each application developer's website to learn the app's features. I was interested in determining which mobile applications (apps) met the feedback dimensions for effective feedback. I installed and used the app. Then, memos were written by the first author. To determine teacher

practices, classroom video recordings and teacher and student interviews were analyzed. They were categorized by app and then watched and read again using this categorization to understand the extent of teacher use of the app. Memos were written. These memos were used to code each dimension by app. The categorization criteria (Table 4.3) were defined as: not applicable (0), low (1), medium (2), and high (3). While affordances of apps were coded based on whether each app supported attributes of each dimension, teacher practice was coded based on any teacher activity that used an app. For example, because students cannot send questions to teacher (or each other) via *QR Code Reader* the app coded as not supporting the 'questioning' attribute of the Dialogue dimension. As another example when using *Kahoot!,* the teacher asked students to peer-share while using it; thus, teacher practice was coded as supporting peer assessment in the Community dimension.

Table 4.3 *Categorization Criteria for Feedback Dimensions*

	Low	Medium	High	Not applicable
Criteria	No attributes met	Some attributes met	All attributes met	When dimension is not affected by app

Findings

Feedback is an essential part of formative assessment that has pivotal effect on learning development (Abell & Siegel, 2011; Black & Wiliam, 1998; Sadler, 1989; Ruiz-Primo & Li, 2013). Researchers have been engaged in discussions about effective feedback (Shute, 2008; Hattie & Timperley, 2007; Evans, 2013). Below I provide

findings: application affordances, teacher practices with applications, and a comparison of the two.

Figure 4.1 compares eleven feedback dimensions on the affordances of apps. Examination showed variation of apps affordances rated as low, medium, high, and not applicable. Only *The Physics Classroom* was applicable to each dimension; all other apps were not applicable in at least one dimension (Appendix B). Most apps were not applicable to the dimensions of clearness (6 of 7) and appropriateness (5 of 7). Community (5 of 7), dialogue (4 of 7) and complexity (4 of 7) were rated as low. Complexity was the only dimension that did not have a high or medium rating. On the other hand, visibility had the greatest high rating (5 of 7), with timeliness (4 of 7) and learning (4 of 7) following. Action and reflections both had the greatest medium rating (4 of 7).

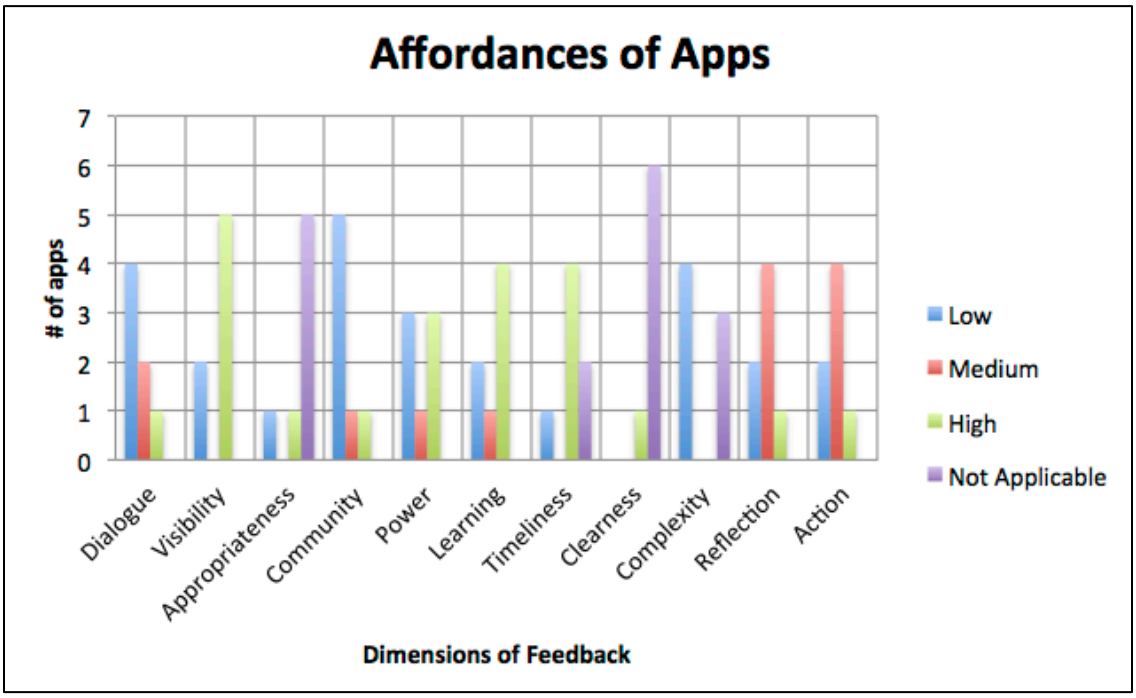

Figure 4.1 *Feedback Dimensions for Affordances of Apps*

Teacher practice of using apps for feedback was also analyzed. Figure 4.2 compares eleven dimensions of feedback on teacher practice. All apps were applicable to every feedback dimension during teacher practice. All apps rated high for appropriateness and clearness dimensions. Action dimension followed having six apps rated high. *Kahoot!* was the only app rated as medium for action dimensions (Appendix A). Complexity had the greatest low rating (5 of 7) and was the only dimension whose low ratings exceeded the high or medium ratings. Complexity had the least high rating followed by Community. Community had the greatest medium rating (3 of 7).

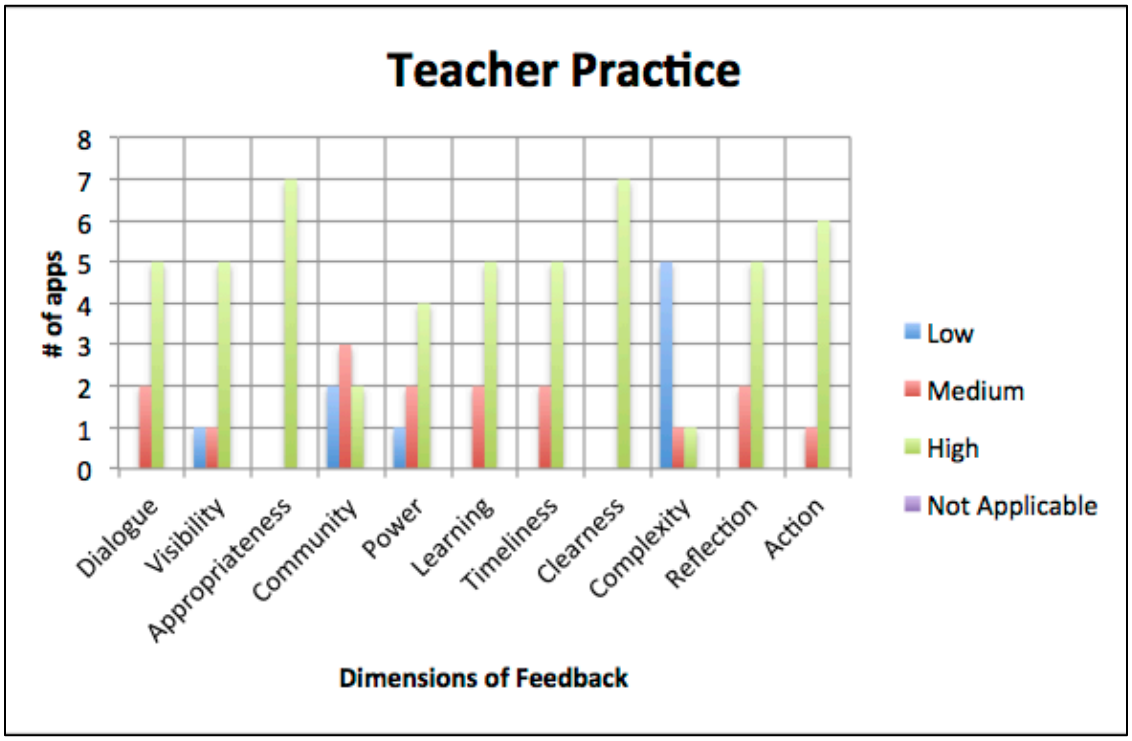

Figure 4.2 *Feedback Dimensions for Teacher Practice*

Using the information on Figure 4.1 and Figure 4.2, affordances of apps and teacher practice were compared. While affordances of apps were diverse the teacher practice predominantly rated as high across all feedback dimensions. While clearness and appropriateness were mostly rated as not applicable for affordances of apps (clearness 6

of 7 and appropriateness 5 of 7), these dimensions were rated as high for all apps for teacher practice. This result is not surprising since both dimensions heavily depend on the teacher, not how feedback is presented. Dialogue was mostly rated as low for app affordances (5 of 7) but mostly rated as medium for teacher practice (5 of 7). Complexity was the dimension mostly rated as low on both teacher practice (5 of 7) and affordances of apps (4 of 7). Action and reaction were mostly rated as medium (4 of 7) for affordances of app but high (5 of 7) for teacher practice. When I compare feedback dimensions for each app separately results showed that teacher practice was almost always better than affordances of any app. The exception is that for *Schoology* the community dimension was rated as high for affordances of app but low for teacher practice (Figure 4.3).

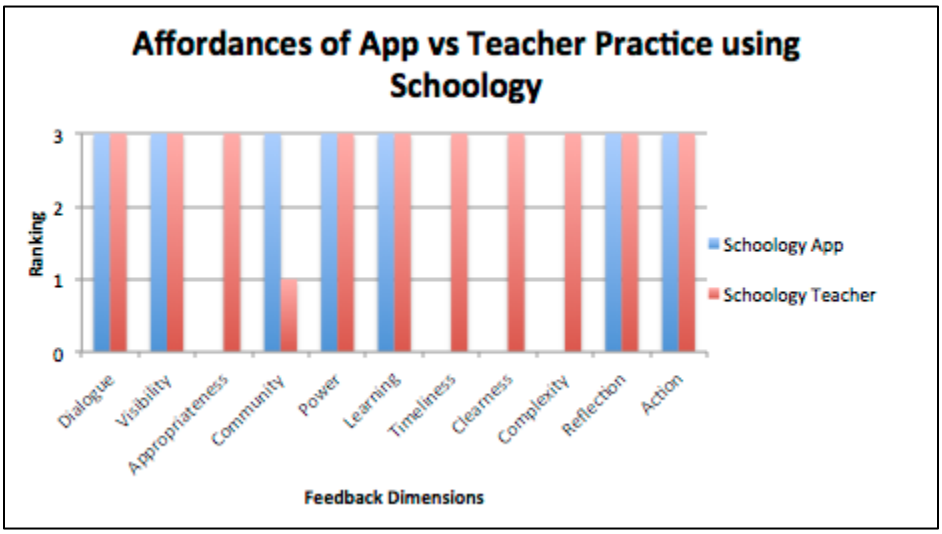

Figure 4.3 *Comparison of Affordances of App and Teacher Practice for Feedback Dimensions using Schoology*

0 = not applicable, 1= low, 2=medium, 3= high

In this section I evaluated how feedback dimensions were met and compared the differences between affordances of apps and teacher practice. The analysis showed that

application affordances applied to most of feedback dimensions with the exception of appropriateness and clearness. Those two dimensions were heavily dependent on the teacher's practice. Data analysis also revealed that teacher practice generally had higher ratings than affordances in each feedback dimension.

Examples of Feedback Dimensions

In the previous section, I quantitatively compared the differences between affordances of apps and teacher practice for meeting the feedback dimensions. In this section, I provide examples with detailed and vivid explanation.

Table 4.4 *Examples of Feedback Dimensions*

	Affordances App	**Teacher Practice**
Dialogue	*Schoology* had a discussion board. In this a question or a comment could be posted. This enabled students to respond to or ask questions of their peers or teacher.	*Socrative* included multiple-choice questions and provided feedback to individual students for each. Teacher asked students to take the *Socrative* exercise until achieving either a perfect score or satisfaction was had. Teacher encouraged students to ask her questions when they are confused about feedback and to re-visit their notes and calculations to correct their mistakes before repeating the exercise. Teacher provided whole-class feedback, explained common quiz mistakes, and demonstrated corrections while allowing students to ask questions during this process.
Visibility	*ZipGrade* scanned student responses and sent all class results to teacher. Thus teacher had statistical information and individual student's responses.	While students were self-assessing using *QR Code Reader* the teacher walked around and gathered information by asking students what they got wrong, how to correct their mistakes, and if they had questions for her.

Appropriateness	*The Physics Classroom* website enabled students to check their responses using the app. A link click provided the correct responses. Some terms were hyperlinked providing an explanation. *The Physics Classroom* provided learning outcomes and assessment criteria.	Teacher embedded *Nearpod* in class lectures. Teacher shared learning outcomes. The provided feedback matched the language used during lecturing.
Community	*Schoology* had has a discussion board part. In this part a question or a comment could be posted. Students and teacher could reply to each other's comments and discuss. This feature assists creating a shared understanding in the classroom.	*Nearpod* helped the teacher see all students' responses, select examples, and then share them with all students. Teacher additionally let students discuss why the response was good or not and how to improve it. This helped create shared understanding in the classroom.
Power	*The Physics Classroom* enabled students to do self-assessment. Thus it increased student responsibility for their own learning which provided opportunities to improve student confidence.	During *Socrative* quiz teacher asked students to revisit their incorrect responses and use different sources to find the correct answer. Teacher encouraged students to ask questions of teacher. This encouraged students to take responsibility for their learning which was not afforded by the app.

Learning	*QR Code Reader* enabled reaching an answer sheet which had an explanation of answers to questions. It emphasized explanation not grade marks.	*Kahoot!* simply informed students of answer accuracy. When teacher used *Kahoot!*, the teacher grouped students and then asked the groups to discuss the question separately before the groups provided an answer and discussed it with the whole class. Though the app focused on marks the teacher added value to it by providing more emphasis on learning.
Timeliness	*Kahoot!* provided students immediate feedback on each answer's accuracy.	Via *Schoology* teacher responded to students questions as soon as questions were received. The app hastens the feedback process. Students did not need to wait for face-to-face interaction.
Clearness	*The Physics Classroom* used simple and consistent language within its explanation and assessment portion.	This dimension is very teacher dependent. Teacher used simple, understandable, and consistent language for all feedback.
Complexity	This dimension is completely teacher dependent; no app supported this dimension.	During *Nearpod* teacher asked students to assess their thoughts about the example before she explained it.
Reflection	*Schoology* assisted students to reflect on their work through a discussion board in which the teacher or students could be asked to explain their reasoning. Teacher gathered information about students from the discussion board.	Teacher asked students to reflect on the feedback from *the Physics Classroom* and discuss it with their partners.

Action	In *Schoology* students could respond to feedback using the discussion board. Seeing all the responses assisted the teacher in providing individual and whole-class feedback. Thus teacher helped students set personal goals and modified teaching based on the whole-class needs.	Teacher encouraged students to retake the *Socrative* quiz. Between quizzes teacher asked students to revisit sources and submit questions to the teacher verbally. Teacher used the results to gather information from the whole class which gave opportunities for modifying class instruction.

A Discussion of How Apps were Used for Feedback

Our analysis showed that all feedback dimensions were met. I placed feedback dimensions into five groups below. This helped to more easily explain the dimensions' roles in feedback to support learning, learning communities, and empowerment of students to take responsibility for their own learning.

Deliver Feedback

One of the pivotal aspects of feedback is communication (Shute, 2008; Nicol & Macfarlane-Dick, 2006). Communication is delivering information. Visibility and timeliness are related to feedback delivery.

Most of the apps enabled delivering information to teachers and timely feedback to students. The visibility dimension required the teacher monitor students. Apps enable monitoring individual students and the whole class so the teacher can use the information to assist creating a communal understanding within the classroom. Apps provided this information immediately freeing teacher time to devote to other activities, including verbal communications between students related to learning progress of classroom and provide quicker feedback to students. The timeliness dimension required providing

feedback to students in time for them to be useful. Most apps provide immediate or frequent feedback to individuals or groups. Technology provides opportunities to promote active and continuous formative assessment (Conejo, Garcia-Viñas, Gastón, & Barros, 2016) as students reflect on their work and modify their future work. This improves student self-assessment and reflection skills (Buckley et al., 2010; Hickey, Ingram-Goble, & Jameson, 2009; Yarnall, Shechtman, & Penuel, 2006).

By meeting these dimensions, apps assist the communication between teacher and student that supports student learning, self- assessment, and taking action. When app affordances fell short teacher practice met dimension requirements via modification of instruction such as when adding oral communication alongside using apps.

Matching Students' Needs

For feedback to be effective it needs to be tailored to students (Evans, 2013; Gottheiner & Siegel, 2012; Kluger & DeNisi, 1996). Students need to be able to understand the feedback, which can be achieved by using simple and consistent language created within the classroom. Yet, it still needs to be challenging enough to lead students to thoughtful consideration (Izci et al., 2013). Feedback also should be linked to learning outcomes and assessment criteria, enabling students to have a wider viewpoint (Nicol & Macfarlane-Dick, 2006). Thus appropriateness, clearness, and complexity dimensions are under this category. The dimensions in this category heavily depend on teacher practice. Apps neither support nor inhibit these dimensions. Meeting student needs assists in creating a supportive learning community in which students have shared understanding.

Encourage Teacher and Peer Dialogue

Dialogue is pivotal for feedback. Feedback can be simply seen as communication among teacher and students to improve student understanding (Hatzipanagos & Warburton, 2009). Student-student interaction could be found in a whole-class discussion or as a form of peer assessment. Effective feedback should support responding to the feedback and further questioning (Hatzipanagos & Warburton, 2009; Nicol & Macfarlane-Dick, 2006). This dialogue will create opportunities for shared understanding and will support learning communities. These practices also allow the emphasis on learning instead of grades (Siegel et al., 2006). Dialogue, community, and learning dimensions are categorized as *encourage teacher and peer dialogue*.

Apps were poor at supporting the dialogue and community dimensions; there were not many opportunities for students to interact with each other or with instructor on the app. However, the teacher easily overcame this by providing opportunities for students to interact orally.

Taking Responsibility

For feedback to be effective, students need to take responsibility for their own learning (McConnell, 2006; Sadler, 1989; Evans, 2013). Self-assessment is one way to accomplish that. During self-assessment students reflect on and think of ways to improve it. The teacher needs to encourage reflection; he or she needs to provide guidance to students and help students to set goals. Asking questions, or encouraging students to discuss good and bad examples could help students to create a shared understanding within the community. Power, reflection, and action dimensions are thus placed under this category. Apps have potential to support taking responsibilities. Though they

encourage self-assessment, is not a common for them to enable student reflection on work or taking action based on feedback. Teacher practice overcame this by encouraging students to reflect on their work by discussing it with peers or teacher.

Modifying Instruction

Feedback is not only for students - it helps teacher modify instruction to meet students' needs. *Action dimension (attributes 2 and 3)* explains this category. Modifying instruction cannot be supported by app because it is a decision making process. However, apps help teacher to decide by providing information about students' learning processes (see ***Deliver Feedback***, above).

In this section, I explained how feedback dimensions had a role in the feedback process. I summarized how apps supported the dimensions and how teacher utilization of apps during practice supported meeting feedback dimensions.

Technology provides students flexibility of time use and opportunities to represent their ideas in varied ways (Gilbert et al., 2011). This flexibility impacts student learning and their confidence. Flexibility was not added as an effective feedback dimension to this study because it does not directly impact feedback effectiveness. During analysis I found that *Schoology* and *Socractive* provided opportunities to students to work at their own pace; the teacher encouraged the use of these app affordances during the assessment practice. *Schoology* contained the structure to provide feedback in a variety of ways, such as drawing, voice recording, and writing from teacher to student. The teacher only used the writing option in practice.

Conclusion

In this study, I explored the potential of iPad app affordances for providing effective feedback. Results showed that these apps impacted feedback in a positive way. Gilbert et. al. (2011) asserted within technology-enhanced feedback that technology is only an enabler and that success lies within the pedagogy. Evans (2013) highlighted the role of the teacher is pivotal in designing and implementing feedback. Supporting these researchers' assertions, the results showed that teacher practice extended the affordances of apps. Therefore, teachers should be supported in introducing the applications into teaching and emphasizing proper application use for effective feedback. This study provided data regarding potential of apps to meet effective feedback dimensions along with detailed examples.

Professional development programs and teacher education programs can play an important role in supporting in-service and pre-service teachers. These programs not only provide information but also support teachers during the implementation phase of technology-enhanced feedback. Application designers can benefit from this study towards improving their apps to support effective feedback.

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Appendix A

Table A
Dimension of Feedback. Hatzipanagos and Warburton (2009)

Dimension	Identified attributes of feedback
Power (autonomy and ownership)	Support management of own learning (self-regulated learning) Improves levels of (student) confidence Increase responsibility and autonomy
Dialogue	Ensure feedback is provided often enough and in adequate detail Support peer/tutor dialogue Allow students to be active and respond to feedback Support questioning Share assessment criteria
Timeliness	Quantity and timing of feedback The feedback is prompt (provided quickly enough to be useful to students)
Visibility	Discern student-learning needs/prior knowledge Be able to 'spot' unpredicted achieved outcomes
Appropriateness	Feedback: is understandable to students is linked to learning outcomes (constructive alignment) is linked to the assessment criteria focuses on learning rather than on marks or students themselves.
Action	Feedback is received by students and is acted upon Task-performance-feedback cycles are facilitated Helps students set personal goals
Community	Support the learning communities Support peer assessment
Complexity	Feedback should be complex enough to let student think about the issue; it shouldn't provide the correct answer.
Reflection	Encourage reflection on the work Compare actual performance with a standard and take action Provide information to tutor to help shape teaching (reflection in action/on action) Develop skills in self-awareness

Appendix B

Table B. Analysis for Feedback Dimesions

Source	QR Code Reader		Schoology		Kahoot!		NearPod		Socrative		ZipGrade		The Physics Classroom Website	
Dimensions	**A**	**T**	**A**	**T**	**A**	**T**	**A**	**T**	**A**	**T**	**A**	**T**	**A**	**T**
Dialogue	2	3	3	3	1	2	2	3	1	3	1	2	1	3
Visibility	1	2	3	3	3	3	3	3	3	3	3	3	1	1
Appropriateness	0	3	0	3	0	3	0	3	0	3	1	3	3	3
Community	1	1	3	1	1	3	2	3	1	2	1	2	1	2
Power	3	3	3	3	1	1	2	2	1	3	1	2	3	3
Learning	3	3	3	3	1	2	3	3	2	3	1	2	3	3
Timeliness	0	2	0	3	3	3	3	3	3	3	1	2	3	3
Clearness	0	3	0	3	0	3	0	3	0	3	0	3	3	3
Complexity	1	1	0	3	1	1	0	2	0	1	1	1	1	1
Reflection	2	2	3	3	1	2	2	3	2	3	1	3	2	3
Action	1	3	3	3	1	2	2	3	2	3	2	3	2	3

CHAPTER FIVE

Conclusions

To understand formative assessment in this series of studies, I used sociocultural views on learning, which aim to support student learning, student learning capacities, and empowering students. The goal of this dissertation was to better understand the impact of technology on formative assessment practices in K-12 science classrooms. Towards this, I merged two research strands: research on formative assessment and research on technology education. In Chapter One, I provided an overview of these strands and explained how the dissertation and each manuscript were situated within my research agenda. Three manuscripts were presented in Chapter Two through Chapter Four. In this conclusion chapter, Chapter Five, I summarized and synthesized the conclusions of the manuscripts, discussed possible implications for research and teaching, and concluded with my future research plans.

Sociocultural Views on Learning

In my dissertation, I use sociocultural learning theories to understand and enhance teacher's formative assessment practices. Learning is supported through social interactions when people are engaged in learning activities. Sociocultural perspectives emphasize the impacts on learning within society and culture. Engaged participation, mediation of and by students, the power relationships among community members, and development of identity, are the focuses of sociocultural perspectives (Crossouard, 2009; Kozulin, 2002).

In summary, I reviewed literature in Chapter Two, sociocultural views on learning and generated both key elements and characteristics of these views. These characteristics

were summarized as: interaction, mediation, power, and identity. I defined these characteristics. Using them, I then explained how formative assessment has potential to support each characteristic. Lastly, built on prior formative assessment cycles (Bell & Cowie, 2001; Ruiz-Primo & Furtak, 2006; Wiliam & Black, 1996; Haug & Ødegaard, 2015) and sociocultural views on learning characteristics, I developed a new model of formative assessment that includes four steps: building community, monitoring community, community mediation, and redefining goals. Chapter Two provided examples of implementation of the new model in the classroom. This model presented the potential of using formative assessment to create a community based on student needs, to create a shared understanding, to improve student identity by encouraging students to take responsibility for their own and peer's learning through mediation of each other during the formative assessment process, and to include students in the process of defining learning goals.

In Chapter Three, I presented an empirical research study, one that explores the influence of technology use on a high school physics teacher's assessment practice. In Chapter Four, I presented another empirical research study, one that explores the potential of iPad apps to support feedback dimensions within a high school physics course. Specifically, I compared affordances of apps to teacher practice. I synthesized the three manuscripts findings and developed themes, as discussed below.

Using Sociocultural Perspectives for Formative Assessment can Support Students During the Learning Process

In Chapter Two, I discussed formative assessment being dominated by cognitive perspectives. I explained the need for reconsideration of assessment views to meet the

Next Generation Science Standards [NGSS] objectives (NGSS Lead States, 2013). Learning occurs through participation in practices and social interaction during the participation. I discussed the potential usefulness of sociocultural perspectives. In this view, assessment should include open-ended performance tasks in which students can solve complex problems and apply their knowledge in real-world contexts (Shepard, 2000). During these performance tasks, students can reflect on their work, challenge each other, and create a shared understanding. In Chapter Two, I discussed the need to mediate students during the assessment process; teachers may need to emphasize more than content knowledge alone. Using sociocultural perspectives may help to both understand and assist in supporting the student learning process.

Formative Assessment has Potential to Support Student Learning by Enabling Interactions Among Students and the Teacher; Technology can Support This Process

Formative assessment can support student interaction, during which the teacher can both monitor students and enrich interaction by encouraging students to reflect on their ideas and those of the group, which may result in students to take responsibility for their own learning (Furtak, Thompson, & van Es, 2016). Technology can support the teacher in monitoring. Results in Chapter Four showed that visibility was highest rated among the feedback dimensions, which means that most apps support monitoring students. The results from monitoring were used by the teacher to increase engagement of students through discussion. In Chapter Three, results showed that iPad was used for rapid communications between students and teacher. One example was when students used *Schoology* to ask questions of the teacher and to have a dialogue. Unfortunately, in

Amy's classroom, the interaction through apps was limited to individual students and the teacher.

Technology is a Mediator of Formative Assessment, and It Provides Opportunities for Transforming Classroom Culture

In Chapter Two, I discussed the possibility that classroom norms might change based on student interactions and that the teacher needs to recognize and respond these changes. Technology has a strong impact on how they interact. Utilization of educational technologies in the classroom has the potential of impacting the learning experiences within classroom culture (Manuguerra & Petocz, 2011).

Findings in Chapter Three revealed that iPad utilization could transform the classroom norms. There were three ways in which iPad transformed the classroom culture: increased frequency and quality of communication, opening up opportunities to collect data or conduct observations otherwise impossible, and enabling students to reach outside of the classroom boundaries. As an example, students were responsible for taking pictures and using them to explain phenomenon. In this activity, iPad empowered students to be more responsible for their choices, student work, and learning progress. The transformation of the classroom culture could change the meaning of being a learner and teacher and the way assessment occurs.

However, the iPad did not always support the classroom culture positively. One issue was plagiarism. Students could share their homework using the Airdrop feature built into the device. Another issue is management of classroom time. Students were distracted when messaging each other, playing games, and listening to music on their iPads. However, the teacher used these drawbacks as way of increasing awareness within

the classroom about appropriate uses of technology.

The Teacher's Contributions Had More Weight Than Applications in Creating the Classroom Culture

In Chapter Four, my results showed that teacher practice extended the affordances of apps during the feedback process. Technology is only a mediation tool for feedback, whose success is as a result of teacher practice (Gilbert, Whitelock & Gale, 2011). Similarly, Evans (2013) pointed out that the role of the teacher is pivotal in designing and implementing feedback. In line with these researchers and Chapter Four results, I observed Amy frequently added classroom or small group discussions within her iPad utilization.

Implications

Model

Chapter Two was a beginning step to discuss the use of sociocultural perspectives in a formative assessment cycle. The model, developed in Chapter Two, could be useful for researchers to conduct investigations on understanding teacher formative assessment practices, and formative assessment culture, within the classroom community. Future researchers may benefit from using this model in multiple classrooms to gain a general understanding. They then could expand the model and potentially apply it to other classrooms.

Professional development programs that enable the teacher to implement the model in the classroom, and then discuss the implementation issues, would be useful. Similarly, prospective teachers that implement this model may potentially benefit from mediation during the implementation process.

Technology-Enhanced Assessment

This dissertation study aimed to understand a teacher's formative assessment practices in a technology-enhanced classroom. Based on the results of this study, curriculum could be designed to better support teacher practices for assisting the student-learning process. These new curricula can be used in future research to potentially better understand teacher practices.

Professional development programs that focus on how to use technology within assessment and that focus on specific apps may be useful to teachers. Technology-based assessment needs to be included in pre-service teacher education to prepare future teachers to be effective users of technology. In-service and pre-service science teachers may benefit from learning how to use technology to give students power, to create safe spaces for students so that they can explain their ideas, and to improve student interaction. To do those things, teachers need to experience the integration of technology-enhanced formative assessment in science instruction. A community of teachers in which issues are discussed, ideas are exchanged, and teachers support each other, may have long-term benefits.

Future Research Plans

In the light of this dissertation study, I will continue my research on formative assessment and technology education. First, I will expand the model I developed based on classroom research. I will continue to expand my knowledge on sociocultural perspectives.

In this study, I explored a high school physics teacher's technology-enhanced formative assessment practices. In the future, I would like to investigate the effect of the

interaction between school culture and the teacher within the classroom. I would like to investigate the effect of technology use within a context-specific study.

Lastly, to support student participation in learning practices via technology-enhanced assessment, I want to be involved in curriculum and application design.

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VITA

Nilay Muslu was born in and completed her K-12 education in Soma-Manisa, Turkey. She attended Dokuz Eylul University in 2002 and received a combined Bachelor's and Master's of Education degree in physics education in 2007. Following this Nilay took a position as administrative assistant at Izmir Institute of High Technology, Izmir, Turkey. In the same year, Nilay was awarded a full scholarship by the Turkish Ministry of National Education to pursue a masters and PhD in science education in the United States.

Nilay enrolled at the University of Missouri in the Fall of 2009, to pursue a masters degree in Learning, Teaching, and Curriculum with an emphasis in science education. She completed the master's degree in 2011 and continued pursuing a PhD in the same program. At the University of Missouri, Nilay was a graduate research assistant in several research projects and in professional development programs. Her responsibilities included data collection, management, and analysis, designing a game-based augmented-learning expedition, mentoring undergraduate students, and planning and working within professional development programs. Within these research projects and professional development programs, Nilay studied and developed an interest in both secondary science teacher assessment literacy and practice, and technology education. She completed her PhD dissertation research on the examination of a high school physics teacher's assessment practice in a technology-enhanced course in 2017.

Nilay will take a faculty position in the Department of Primary Science Education within a to-be assigned university in Turkey. Her future plans include teaching science methods courses and conducting research on assessment and technology education.

Together she will use these to enhance the quality of science education in K-12 classrooms.