

Utah State University

DigitalCommons@USU

All Graduate Theses and Dissertations

Graduate Studies

5-2016

A Mixed-Method Study of Mobile Devices and Student Self-Directed Learning and Achievement During a Middle School STEM Activity

Scott Bartholomew
Utah State University

Follow this and additional works at: <https://digitalcommons.usu.edu/etd>



Part of the [Educational Assessment, Evaluation, and Research Commons](#), and the [Junior High, Intermediate, Middle School Education and Teaching Commons](#)

Recommended Citation

Bartholomew, Scott, "A Mixed-Method Study of Mobile Devices and Student Self-Directed Learning and Achievement During a Middle School STEM Activity" (2016). *All Graduate Theses and Dissertations*. 4748. <https://digitalcommons.usu.edu/etd/4748>

This Dissertation is brought to you for free and open access by the Graduate Studies at DigitalCommons@USU. It has been accepted for inclusion in All Graduate Theses and Dissertations by an authorized administrator of DigitalCommons@USU. For more information, please contact digitalcommons@usu.edu.



A MIXED-METHOD STUDY OF MOBILE DEVICES AND STUDENT
SELF-DIRECTED LEARNING AND ACHIEVEMENT DURING
A MIDDLE SCHOOL STEM ACTIVITY

by

Scott Bartholomew

A dissertation submitted in partial fulfillment
of the requirements for the degree

of

DOCTOR OF PHILOSOPHY

in

Education

Approved:

Edward Reeve, Ph.D.
Major Professor

Raymond Veon, Ph.D.
Committee Member

Gary Stewardson, Ph.D.
Committee Member

Victor Lee, Ph.D.
Committee Member

Wade Goodridge, Ph.D.
Committee Member

Mark R. McLellan, Ph.D.
Vice President for Research and
Dean of the School of Graduate Studies

UTAH STATE UNIVERSITY
Logan, Utah

2016

Copyright © Scott R. Bartholomew 2016

All Rights Reserved

ABSTRACT

A Mixed-Method Study of Mobile Devices and Student Self-Directed Learning and
Achievement During a Middle School STEM Activity

by

Scott R. Bartholomew, Doctor of Philosophy

Utah State University, 2016

Major Professor: Edward Reeve, Ph.D.
Department: Applied Sciences, Technology & Education

The increasingly ubiquitous nature of mobile devices among K-12 students has led many to argue for and against the inclusion of mobile devices in K-12 classrooms. Some have conjectured that access to mobile devices may enable student self-directed learning.

This research used a mixed-method approach to explore the relationships between mobile devices and student achievement and self-directed learning during a Science, Technology, Engineering, & Mathematics (STEM) activity in a middle school Technology and Engineering Education classroom. In this study, 706 students from 18 classes worked in groups of 2-3 to complete an open-ended engineering design challenge. Students completed design portfolios and constructed prototypes. Classes were randomly divided with some receiving access to mobile devices during the study while others did not. Additionally, randomly assigned classes completed the design portfolio

electronically while others completed the portfolio on paper. Final student portfolios and products were assessed using adaptive comparative judgment (ACJ). In ACJ, judges view two artifacts (portfolios or products) electronically and choose the better of the two. Repeating this process, a number of times produced a rank-order for the artifacts. The rank order for student portfolios and products represented student achievement. Statistical analyses of student access, portfolio type, student self-directed learning, and student achievement were conducted.

Thirty student interviews and five teacher interviews were conducted and interviewees were asked questions regarding mobile devices, self-directed learning, and their experience during the study. Responses from the interviews were transcribed and coded using causation and thematic coding techniques. The resulting themes from the interviews helped clarify the quantitative findings.

Findings from both the quantitative and qualitative analyses showed that student access to mobile devices was significantly correlated with higher scores on student design portfolios while student achievement on design products was independent of mobile device access. This suggests that mobile devices may improve student achievement in certain types of scenarios but not in others. Student self-directed learning was independent of mobile device access. Students and teachers both commented that mobile devices may be effective at increasing student self-directed learning or achievement but only through proper instruction and demonstration.

PUBLIC ABSTRACT

A Mixed-Method Study of Mobile devices and Student Self-Directed Learning and Achievement During a Middle School STEM Activity

Scott R. Bartholomew

With the increasingly ubiquitous nature of mobile devices among K-12 students, many argue for and against the inclusion of these devices in K-12 classrooms. Arguments in favor cite instant access to information and collaboration with others as positive affordances made possible through mobile devices. Self-directed learning, a process where individuals take charge of their learning and decide what they will learn, how they learn it, and how they assess their learning, has been identified as an increasingly important trait for K-12 students. The relationship between mobile device access in K-12 education settings and student self-directed learning has not been explored.

This research used a mixed-method approach to learn more about the impacts of mobile devices on student achievement and self-directed learning during a Science, Technology, Engineering, & Mathematics (STEM) activity in a K-12 technology and engineering education classroom. In this study, 706 middle school students from 18 classes worked in groups of 2-3 to complete an open-ended engineering design challenge. Students completed design portfolios and constructed prototypes (products) in response to a provided engineering design challenge. Participating classes were divided with some receiving ubiquitous access to mobile devices during the study while others did not. Additionally, randomly assigned classes completed the design portfolio electronically

while others completed their portfolios on paper. Final student portfolios and products were assessed and assigned a rank order using an innovative method of assessment called adaptive comparative judgment (ACJ). In ACJ judges view two artifacts (portfolios or products) electronically via a computer and choose the better of the two. Repeating this process, a number of times produced a rank-order for the artifacts. The rank order for student portfolios and products was used to represent student achievement. Statistical analyses of student access, portfolio type, student self-directed learning, and student achievement were conducted. In addition to the quantitative approach, 30 student interviews and 5 teacher interviews were conducted by the researcher following qualitative methodology. Interviewees were asked a variety of questions regarding mobile devices, self-directed learning, open-ended engineering design challenges, and their experience during the study. Responses from the interviews were transcribed and coded using causation and thematic coding techniques. The resulting themes from the interviews were compared with the quantitative findings.

Findings from both the quantitative and qualitative analyses showed that student access to mobile devices was significantly correlated with higher scores on student design portfolios while student achievement on design products was independent of mobile device access. These findings suggest that mobile devices may improve student achievement in certain types of scenarios but not in others. Over the course of the study, student self-directed learning was independent of mobile device access. Students and teachers both commented that mobile devices may be effective at increasing student self-directed learning or achievement but only through proper instruction and demonstrations.

DEDICATION

First and foremost, I am grateful to my Father in Heaven for the gifts, blessings, trials, and opportunities He continues to provide. My Savior, Jesus Christ, is my eternal friend, mentor, and the reason for everything good I enjoy.

I want to thank my dear wife and eternal companion, Julie, for her support, love, encouragement, and help through the entire doctoral process. Julie, I will be forever grateful for the way you shape my life for the better. In more ways than I can include here, this was a joint effort—through this entire process you shared the responsibilities and opportunities with a loving smile and a grateful heart. You make me smile.

I am grateful to my dear children who make coming home the best part of every day. Kylie and Dallin I am proud to be your father and I am so happy that you continue to make good choices and grow to become the people our Father in Heaven wants you to be. You inspire me to be a better man through your pure love and goodness.

To my parents, Ron and Kris Bartholomew, your examples, love, and never-failing support have been crucial. Dad, thanks for showing me through your example how to be a man, a father, a husband, and an educator. Mom, thanks for showing me how to be a neighbor, a friend, and a disciple of Christ. Ma and Pa, thank you for raising, teaching, and loving the greatest blessing that has entered my life. Your examples of hard-work, love, kindness, and charity continue to shape and influence me. The importance you place on education is a cherished legacy for all who know you.

ACKNOWLEDGMENTS

I want to acknowledge the assistance of my doctoral committee chair, Dr. Edward M. Reeve. More than just the chair of my committee, you have been a trusted mentor, friend, advisor, and support. Your prompt responsiveness, endless questioning, and thoughtful insights were irreplaceable. Thank you for your direction throughout the process and for pushing me to heights I had not previously imagined.

I am very grateful for the help of Dr. Raymond Veon. Raymond, thank you for your willingness to discuss, collaborate, and review materials, methodologies, and designs. Your expertise, experience, and willingness to assist were invaluable throughout the process.

I am equally grateful to the remaining members of my committee, Dr. Gary Stewardson, Dr. Wade Goodridge, and Dr. Victor Lee. Thank you for the unique talents you shared that enabled this process to go forward. I appreciate your encouragement, insights, and mentoring.

I want to recognize Dr. Louis Nadelson, who, despite not being an official member of the committee, provided countless hours, resources, and expertise to this project.

I also want to thank Dr. Richard Kimbell, Dr. Alastair Pollitt, and Matt Wingfield—all colleagues from across the globe. Your work, expertise, insight, and help made much of this study possible as we pushed together to make this project a reality.

Scott R. Bartholomew

CONTENTS

	Page
ABSTRACT.....	iii
PUBLIC ABSTRACT	v
DEDICATION.....	vii
ACKNOWLEDGMENTS	viii
LIST OF TABLES	xii
LIST OF FIGURES	xiv
DEFINITIONS AND ACRONYMS	xv
CHAPTER	
I. INTRODUCTION	1
Connected	1
Self-Directed.....	2
Mobile.....	3
Purpose.....	4
Research Questions.....	5
Need for the Study	6
Significance.....	8
Assumptions.....	8
Limitations	10
Summary of the Study Timeline	11
II. REVIEW OF LITERATURE	13
Self-Directed Learning.....	15
Mobile Devices	24
Science, Technology, Engineering, and Math Education	38
The Self-Directed Learning with Technology Scale	40
The Digital Natives Assessment Scale	43
LiveAssess	45
Adaptive Comparative Judgment-Based Assessment (CompareAssess)	47
Semistructured Interviews	55

	Page
Engineering Design Process	56
Design Portfolios	59
Summary	60
III. METHODOLOGY	63
Research Design and Research Questions	63
Summary	94
IV. FINDINGS	95
Quantitative Findings	96
Qualitative Findings	116
Summary	125
V. DISCUSSION, RECOMMENDATIONS, AND CONCLUSION	127
Study Overview	127
Discussion	130
Recommendations	141
Conclusion	146
REFERENCES	149
APPENDICES	163
Appendix A: Modified Self-Directed Learning with Technology Scale	164
Appendix B: Digital Natives Assessment Scale	169
Appendix C: Classroom Script	174
Appendix D: District, School, and Teacher Demographic Data	190
Appendix E: Demographic Questions from Pre-Study Questionnaire	195
Appendix F: Healing Collection Supplies	200
Appendix G: List of Modelling Collection Supplies for Each Group	202
Appendix H: Paper-Based Portfolio	204
Appendix I: Electronic Portfolio Screenshots	207
Appendix J: Overview of Classroom Schedule	210
Appendix K: Lesson Plan for Digital Citizenship, Mobile Device Use, Engineering Design, and Teamwork	213
Appendix L: Qualitative Semistructured Interview Questions for Teachers	230
Appendix M: Semistructured Interview Questions for Students	233
Appendix N: Engineering Design Challenge and Scoring Rubric	236

	Page
Appendix O: ACJ Judgment Results	242
Appendix P: Ordinal Rankings for Student Portfolios and Student Products.....	244
Appendix Q: URL Links for Pre- and Post-Questionnaire.....	255
Appendix R: Timeline for Study	257
Appendix S: Questions for Dice Rolls.....	259
Appendix T: Student, Parent, and Teacher Informed Consent	261
Appendix U: Student Worksheet for Digital Citizenship Lesson.....	272
 CURRICULUM VITAE.....	 279

LIST OF TABLES

Table	Page
1. Research Design for the Study.....	71
2. Overview of Statistical Analysis Procedures for Research.....	87
3. Student Age by Teacher.....	99
4. Student Age by Teacher Analysis.....	99
5. Post-Hoc Analyses of Differences in Student Age by Teacher	100
6. Student Grade Breakdown by Teacher	100
7. Average Student Grades in TEE Classes by Teacher	100
8. Average Student Grades Across all Courses by Teacher.....	101
9. Analysis of Average Student Grades Across all Courses by Teacher	101
10. Gender by Teacher and by Participating Class	102
11. Student Access to Computers and Mobile Devices by Teacher	102
12. Post-Hoc Analysis of Differences in Student Access to Computers and Mobile Devices by Teacher	103
13. Student Comfort Level with Mobile Device Technology by Teacher.....	104
14. Post-Hoc Analysis of Differences in Student Comfort Level with Mobile Device Technology by Teacher.....	104
15. Student Scores on the Pre-Study SDLTS by Teacher.....	105
16. Post-Hoc Analysis of Differences in Student on the Pre-Study SDLTS by Teacher.....	106
17. Student Digital Nativeness by Teacher.....	106
18. Post-Hoc Analysis of Differences in Student Digital Nativeness by Teacher...	106

Table	Page
19. Regression Results for Student Demographic Information and Post-Study SDLTS Score	107
20. Correlation for Student DNAS Scores and Student Pre- and Post-Study SDLTS Scores.....	108
21. Student Demographics Measures and Student Portfolio Rank Score.....	111
22. Student Demographics Measures and Student Product Rank Score.....	111
23. Student Portfolio Rank Score and Student Post-Study SDLTS Score.....	114
24. Student Product Rank Score and Student Post-Study SDLTS Score	114
25. Student Portfolio Rank Score by Teacher.....	115
26. Post-Hoc Analysis of Differences in Student Portfolio Rank by Teacher	115
27. Student Product Rank Score by Teacher	116
28. Post-Hoc Analysis of Differences in Student Product Rank by Teacher.....	117
29. Student Overall Achievement Rank Score by Teacher.....	117
30. Post-Hoc Analysis of Differences in Student Overall Achievement by Teacher.....	117
D1. District Demographic Information.....	191
D2. School Demographic Information.....	192
D3. Teacher Classroom Demographic Information.....	194
P1. Student Product Rank	245
P2. Student Portfolio Rank Order	250

LIST OF FIGURES

Figure	Page
1. Engineering design process.....	57

DEFINITIONS AND ACRONYMS

Adaptive comparative judgment (ACJ) - a technique borrowed from psychophysics (Thurstone, 1927), which is able to generate reliable results for educational assessment - as such it is an alternative to traditional marking (Kimbell, 2012a; Kimbell, Wheeler, Miller, & Pollitt, 2007; Pollitt & Crisp, 2004). In this approach, judges are presented with pairs of student work and are then asked to choose which is better. By means of an iterative and adaptive algorithm, a scaled distribution (rank order) of student work can then be obtained.

Engineering design process—this study will use TeachEngineering’s (2016) definition of the engineering design process: “a series of steps that engineering teams use to guide them as they solve problems. The design process is cyclical, meaning that engineers repeat the steps as many times as needed, making improvements along the way” (p.1)

Middle school—Middle school is typically students in grades 6-8 (ages 11-14, Utah State Office of Education [USOE], 2014c). In the state where the study was conducted, middle school is typically grades 7-8 (ages 12-14) but can include grades 6-8 depending on the school, district, location, and community needs.

Mobile devices—“Hand-held technology (e.g., smartphones or tablet PCs) that provides continuous accessibility to users anytime, anywhere without using a wire or cable to connect to networks (like the Internet), and allows them to transmit data or communicate with others” (derived from Kim, Olfman, Ryan, Eryilmaz, 2013, p. 55).

Mobile learning—any educational provision where the sole or dominant

technology is a handheld or palmtop device that provides continuous accessibility to users anytime, anywhere without using a wire or cable to connect to networks (like the Internet), transmit data or communicate with others.

Open-ended design problem—According to Rowe (1987), open-ended problems have constraints that are ill defined—meaning they are designed to have multiple interpretations and thus multiple solutions.

STEM—an acronym coined by the National Science Foundation (Bybee, 2010; Woodruff, 2013) standing for Science, Technology, Engineering, & Mathematics.

Self-directed learning—this study uses the definition provided by Knowles (1975) for self-directed learning:

...a process in which individuals take the initiative, with or without the help of others, in diagnosing their learning needs, formulating learning goals, identifying human and material resources for learning, choosing and implementing appropriate learning strategies, and evaluating learning outcomes. (p. 18)

Self-directed learning with technology scale (SDLTS)—The SDLTS is a measurement developed to assess self-directed learning in younger students with a specific technology component. According to Teo et al. (2010):

The SDLTS offers an alternative to existing measures of self-directed learning which were mostly designed for older students (e.g., adult, university) and do not include the technology element. Comprising two factors, the SDLTS measures respondents' perceptions in terms of their self-management and intentional learning. (p. 1769)

STEM Activity—an activity which incorporates multiple areas of STEM (science, technology, engineering, mathematics) disciplines, often through a hands-on problem-based learning format.

STEM Education—STEM education has many meanings, but typically involves

the integration of one or more of the STEM areas. The promotion of STEM education has seen an increase in recent years with many pushes for integrative STEM education leading the way (International Technology and Engineering Education Association [ITEEA], 2016; Reeve, 2015; Sanders & Wells, 2010). Sanders and Wells defined integrative STEM education as:

technological/engineering design-based learning approaches that intentionally integrate the concepts and practices of science and/or mathematics education with the concepts and practices of technology and/or engineering education. (p. 1)

Technology and Engineering Education (TEE)—a field of study that focuses on developing *Technological literacy* for all students. *Technologically literacy* can be defined as: “the ability to use, manage, assess, and understand technology (ITEEA, 2007, p. 9). TEE represents a hands-on learning environment that promotes problem-solving and facilitates the learning of technological literacy.

CHAPTER I

INTRODUCTION

Today's K-12 students are not the learners of a decade ago (Kaiser Foundation, 2010; Partnership, 2011; Prensky, 2007; Tulagan, 2013; West, 2013). As part of the so-called "Z-Generation" (Tulagan, 2013, p. 6), students who were "born in the 90's and raised in the 2000s" have "never known a world in which one could not be in conversation with anyone anywhere any time" (Tulagan, 2013, p. 6). Generation Z students have been described as learners that feel most comfortable in a world of "continuous connectivity and communication" (Tulagan, 2013, p. 3)." Constant connectivity and communication presents today's students with a different set of circumstances than those encountered by any previous generation (Johnson, Adams, & Cummins, 2013; Prensky, 2007; Tulagan, 2013; West, 2013). Today's learners are expected to be connected, self-directed, and mobile (Tulagan, 2013; Prensky, 2007; West, 2013).

Connected

In a global society, connected through technology, today's students are expected to be aware of events happening around the globe and in their own neighborhood (Prensky, 2007). The evolution of the Internet into today's Web 2.0 and tomorrow's Web 3.0 fosters user connectedness and interactivity (Grabowicz, 2014). In 2005, the average American youth spent less than 6.5 hours a day with electronic devices; today, that number had risen to over 7.5 hours a day (Kaiser Foundation, 2010)—with the largest

increases associated with social media use (CommonSense Media, 2013). A recent study from the Pew Research Center (2015) found that 73% of American teens have access to a smart phone, “92% of teens go online daily and 24% say they are online ‘almost constantly’” (p. 1).

Self-Directed

Learners today, with access to more information than any previous generation, are expected to be self-directed in their learning (Fahnoe & Mishra, 2013; Partnership, 2011; Prensky, 2007). Self-directed learning (SDL) emphasizes learner involvement, choice, and decision making. Self-directed learning, as defined by Knowles (1975) is:

...a process in which individuals take the initiative, with or without the help of others, in diagnosing their learning needs, formulating learning goals, identifying human and material resources for learning, choosing and implementing appropriate learning strategies, and evaluating learning outcomes. (p. 18)

The rise in popularity of YouTube, Lynda.com, Khan Academy, and hundreds of other websites dedicated to providing users with online tutorials and other pertinent information, has helped shape the self-directed learning nature of today’s learners (Mitchell, 2014). These online and other self-directed educational opportunities have increased dramatically in recent years—some have even suggested that 50% of all high school courses will be taken online in a self-directed learning fashion by 2019 (Christensen & Horn, 2011). Increasingly ubiquitous access to the Internet and self-directed learning resources may be contributing to a shift in America’s educational paradigm.

Mobile

One way learners are more self-directed in their learning is through mobile devices. As the learning experience and preferences of today's learners' change, more and more learning is occurring outside of traditional classroom settings (Christensen & Horn, 2011; Cole, 2013; Pew, 2015; Project Tomorrow, 2012b; West, 2013). With the increased availability of computers, computing devices, and the Internet, learning can happen almost anywhere. Often the learners of today take part in this learning on-the-go, away from home, or at other locations via mobile devices (e.g., cellular phones, tablets, and other handheld devices connected to the Internet; West, 2013).

In literature the concept of mobile devices and learning often falls under the larger umbrella of "mobile-learning" although a variety of other terms are also used (e.g., "m-learning," "one-to-one learning," and "handheld learning"). Due to a variety of terms and a myriad of different devices, there is some confusion surrounding the terms "mobile-learning" and "mobile devices" and their utilization in K-12 education. In a meta-analysis of research on mobile learning in K-12 Education from 2007 to 2014 (Liu, Scordino, et al., 2014), the authors chose to use Traxler's (2005) definition of mobile learning as "any educational provision where the sole or dominant technology is a handheld or palmtop device" (p. 325). In conjunction with this definition of mobile-learning, this study will use S. Kim, Holmes, and Mims' (2005) definition for mobile device: "technology that provides continuous accessibility to users anytime, anywhere without using a wire or cable to connect to networks (like the Internet), transmit data or communicate with others" (p. 55). Using a combination of the two identified definitions, mobile learning

with the inclusion of mobile devices can be defined as: any educational provision where the sole or dominant technology is a handheld or palmtop device that provides continuous accessibility to users anytime, anywhere without using a wire or cable to connect to networks (like the Internet), transmit data, or communicate with others.

Purpose

The purpose of this study was to identify what relationship, if any, exists between mobile devices and student self-directed learning and student achievement during a middle school Science, Technology, Engineering, & Mathematics (STEM) activity that took place in a Technology and Engineering Education (TEE) classroom. Such information may prove helpful to school administrators, teachers, parents, and students as the debate over the inclusion of mobile devices in the classroom continues. On a larger scale, the purpose of the study is to inform policy and decision makers as the face of education continues to change and evolve with the rapid advancements in technology.

While some students have access to mobile devices outside of school and others do not, this study focuses on access to mobile devices in school during class. As such, unless specifically noted otherwise, each opportunity for “access to mobile devices” referred to in this study is associated with student access to mobile devices during school hours as part of classroom setting.

Although this study specifically looks at the influence of access to mobile devices and student self-directed learning and achievement, it should be noted that the findings of this study should not be confined to mobile devices alone. Mobile devices most directly

offer access—access to a host of affordances, which enable students to retrieve information real-time, communicate instantly, and function in a different way. With these affordances come opportunities to excel, explore, and direct one’s learning; additional opportunities that come with these devices are opportunities to cheat, distract oneself and others, and otherwise deviate from assigned work. As such, the findings from this study can be used to inform current thinking and questioning regarding the place, use, and implementation of mobile devices, and, on a larger scale these findings can be used as another resource in the debate surrounding personal access to the Internet, communication, and mobile functionalities in public schools.

Research Questions

In this study, middle school students in a TEE classroom, working on a STEM activity, had access to mobile devices during one 2-week unit. Student self-directed learning was assessed prior to and following the completion of the unit. In an effort to provide administrators, teachers, parents, and students with information and tools for decision making about the use of mobile devices in a teaching and learning setting, this research explored the following questions.

1. What relationship, if any, exists between middle school student access to mobile devices and student self-directed learning?
2. What relationship, if any, exists between middle school student access to mobile devices and student achievement on an open-ended engineering design problem?

Need for the Study

Throughout the U.S., school district administrators, teachers, and educational professionals are grappling with the question of whether or not mobile devices should be allowed in the classroom (Elder, 2009; Johnson, Adams, & Haywood, 2011; Lloyd, 2010; O'Bannon & Thomas, 2015; Quillen, 2010; Schenker, 2009; Shuler, 2009). School administrators are bombarded with competing opinions regarding the effectiveness, or lack thereof, of mobile devices and the need for their inclusion or exclusion (Johnson et al., 2011). These important decisions are largely being made with little research to inform the decision-makers (Grant et al., 2015). As Kiger, Herro, and Prunty (2012) remarked, there is a need for more empirical research to “guide implementation decisions” (p. 64).

In a closely related study, Mentzer (2011) found that access to information (i.e., the Internet) did not improve student designs when compared with other students without Internet access in an open-ended engineering design challenge. Common arguments for mobile devices in the classroom cite access to information as a major reason why mobile devices should be allowed (Pew, 2015; Prensky, 2007; Robledo, 2012; Shuler, 2009; West, 2013). This research sought to add additional insight to the question of whether or not access to mobile devices, and in turn information, will be beneficial, harmful, or have no impact on student learning.

Despite unclear consequences related to mobile devices in K-12 classrooms the vast majority of school districts currently have limitations in place for mobile devices in K-12 classroom settings (Pearson, 2013; Raths, 2013; Shuler, 2009). Recently, there have been a few discernable efforts at implementing more “mobile friendly” policies and

incorporating mobile devices in student learning experiences (G. J. Hwang & Tsai, 2011; Quillen, 2010; Liu, Navarrete, & Wivagg, 2014; Lloyd, 2010; Schenker, 2009; Shuler, 2009). Despite these efforts, and the increasingly ubiquitous nature of mobile devices among K-12 students (Pew, 2015), little empirical research has been done in an attempt to identify specific impacts of including mobile devices in the classroom (Cheung & Hew, 2009; G. J. Hwang & Tsai, 2011; Liu, Scordino, et al., 2014; Sutton, 2011; Wan, 2011).

In addition to pushes for mobile devices and SDL) in education, recent emphasis on STEM education has also increased (Becker & Park, 2011; Devlin, Feldhaus, & Bentrem, 2013; Rissanen, 2014). Along with the increased emphasis on STEM education a few notable studies have looked specifically at mobile devices within STEM classrooms (Liu, Scordino, et al., 2014). Despite this research emphasis on STEM, all areas of STEM have not been equally studied and highlighted (Bartholomew, 2015; Liu, Scordino, et al., 2014). For example, in their meta-analysis, Liu, Scordino, et al. reported that natural sciences, mathematics, social studies, language arts, and English as a second-language were the dominant academic areas researched in studies related to mobile learning. Although STEM and mobile devices have been recently emphasized, research in the classroom has focused more extensively on the “S” and the “M” areas of STEM than the “T” and “E.” As Liu, Scordino, et al. pointed out “there is an uneven integration of m-learning across academic disciplines” (p. 363). This study proposed to inform the existing research by looking at mobile devices during a STEM activity in a middle school TEE classroom—a classroom representing the “TE” portion of STEM.

Significance

The findings in this study may be important for all involved in K-12 education, from teachers and administrators to students and parents. Specifically, these findings can inform TEE middle school classrooms, which provide the setting for this study, as well as any classroom involved in a STEM activity. Society is changing and mobile devices are becoming increasingly commonplace (Liu, Navarrete, & Wivagg, 2014; Liu, Scordino, et al., 2014; Pew, 2015; West, 2013). Ubiquitous connectedness to the Internet and each other is changing the face of society and education (Pew, 2015; Prensky, 2007; Robledo, 2012; Shuler, 2009; West, 2013). In a 2006 publication involving professionals from five continents, a specific call was issued for research into mobile devices and the impacts provided through mobile devices in K-12 school settings (Chan et al., 2006). Many of today's adolescents carry a mobile device in their pocket that enables constant connections to the Internet and in turn the world (Pearson, 2013; Pew, 2015). An understanding is needed of the relationship between mobile devices in classroom settings and student self-directed learning and achievement.

Assumptions

The following assumptions apply to this research.

1. Responses to questionnaires will reflect real-life experiences for participants and those who participate in this study will be truthful and thoughtful in their responses to all questions.
2. The information gathered for this study will be reported accurately, without

bias, and all reasonable efforts to maintain validity and reliability will be made.

3. All state, district, and local school protocols will be strictly observed by those participating in the study.

4. Evaluation of student work will be conducted in a truthful, unbiased, and accurate manner.

5. Teachers will accurately and correctly administer all training, tests, and assignments following the provided training and protocols.

6. All students in the experimental group will have access to mobile devices and upon completion of the provided training, will understand how to use the mobile devices appropriately.

7. Students will not be required, forced, or coerced to use mobile devices. Any use by students will derive from intrinsic motivation to do so when given the opportunity.

8. All students will understand how to complete their assigned work.

9. The modified *Self-Directed Learning with Technology Scale* is an accurate measure of student self-directed learning readiness in a technology setting and will be administered properly to the students.

10. The adapted *Digital Natives Assessment Scale* is an accurate measure of student's skills and familiarity with technology and behaviors associated with digital natives.

11. The *Demographic Questionnaire* is an accurate measure of student information and will reflect the experiences, perceptions, and attitudes of students.

12. The *CompareAssess* and *LiveAssess* tools for portfolio creation and adaptive-

comparative judgment will be appropriately and accurately implemented in the study.

13. Students have experience with open-ended problems and will be comfortable working in an open-ended teamwork environment.

14. Teacher, classroom, and school differences will not be statistically significant enough to impact the dependent variable (see threats to validity).

15. The presence of mobile devices in society has become so ubiquitous that the Hawthorne effect on participants in the study will be minimal.

Limitations

The study was limited to the following.

1. The opinions and experiences of students in elective middle school TEE courses in the participating state located in U.S.
2. Students in the seventh or eighth grades enrolled in participating *Exploring Technology* classes.
3. Those items measured by the revised *Self-directed Learning with Technology Scale*.
4. Those items measured by the adapted *Digital Natives Assessment Scale*.
5. Those items measured by the *Demographic Questionnaire*.
6. The mobile devices identified and used in this study.
7. The classroom activities, experiences, and environments of those classrooms chosen for this study.
8. Mobile devices as defined by this study (e.g., smartphones, tablets, or E-

readers).

9. The adaptive comparative judgment instrument called *CompareAssess*.
10. The portfolio creation tool called *LiveAssess*.

Summary of the Study Timeline

Conduct review of literature

- a) Self-directed learning
- b) Mobile-learning & Mobile devices in K-12 education
- c) STEM education
- d) Engineering Design Problems



Formulate research questions

- a) What relationship, if any, exists between middle school student access to mobile devices and student self-directed learning?
- b) What relationship, if any, exists between middle school student access to mobile devices and student achievement on an open-ended engineering design problem?



Formulate research design

- a) Pretest, Posttest
- b) Control - Experimental



- a) Initial pilot study, validity, and reliability check
- b) Participating Middle School



- a) Revisions to research design and documentation



Conduct research study

- a) Participating School District
- b) 5 schools, 6 teachers
- c) 18 classes (*Exploring Technology*)

- a. 5 control (mobile devices not allowed),
- b. 13 experimental (Mobile devices allowed)
- d) *Demographic questionnaire*
- e) *Digital Natives Assessment Scale*
- f) *Self-directed learning with technology scale*
- g) Engineering design challenge
- h) *LiveAssess* portfolio system
- i) *CompareAssess* rating system
- j) *Teamwork & problem-solving familiarity questionnaire*



Statistical analysis of findings

- a) Descriptive statistics
- b) t-test, correlation
- c) ANOVA, ANCOVA
- d) Multiple Regression



Report findings from study

- a) Local and national conferences
- b) Academic journals
- c) District board of education
 - a. Participating School District (pilot)
 - b. Participating School District

CHAPTER II

REVIEW OF LITERATURE

Despite the rapid increases in mobile devices, mobile learning, and educational technology opportunities, research related to mobile devices in K-12 settings is limited (Cheung & Hew, 2009; G. J. Hwang & Tsai, 2011; Liu, Scordino, et al., 2014; Sutton, 2011; Wan, 2011). Additionally, the majority of research related to self-directed learning is associated with adult learners, not K-12 students (Fahnoe & Mishra, 2013). The purpose of this study was to identify what relationship, if any, exists between middle school student access to mobile devices and student self-directed learning and what relationship, if any, exists between middle school student access to mobile devices and student achievement on an open-ended engineering design problem. This review of literature was conducted to inform the study and shape the methodological procedures used. The majority of the literature reviewed came from searches in ERIC, PsychInfo, and GoogleScholar. The following terms were used in the searches:

- self-directed learning + adolescent,
- self-directed learning + middle school,
- self-directed learning + technology,
- self-directed learning + mobile device,
- self-regulated learning + mobile device,
- mobile-learning + K-12,
- mobile-learning + middle school,
- mobile device + middle school + learning,
- mobile device + K-12, hand-held + K-12,
- hand-held devices + K-12,
- engineering design portfolio + K-12,
- engineering design process + K-12, and
- engineering design + K-12.

In addition to the search terms above, specific sources were identified as highly-relevant to this research. The *International Journal of Self-directed Learning* (2004-present), *ESCAPE* publications, and *SpeakUp* publications were reviewed because of their direct connection to this research. As a result of the literature review, the following topics were formed for consolidating the findings from the literature review.

1. Self-directed Learning (SDL)
 - a. Definition
 - b. Self-directed learning in K-12 school settings
 - c. Self-directed learning outside of K-12 school settings
2. Mobile devices
 - a. Presence of mobile devices
 - b. Mobile devices and learning
 - i. Benefits of mobile devices in K-12 classrooms
 - ii. Challenges of mobile devices in K-12 classrooms
 - iii. Current trends and initiatives for mobile-learning in K-12 classrooms
 - iv. Mobile device rules and restrictions
 1. Digital Citizenship
 - v. Perceptions of mobile devices in K-12 settings
 1. Student perceptions
 2. Teacher / Parent / Administrator perceptions
3. STEM education
 - a. Technology & Engineering education
 - i. Middle school students
4. The Self-directed Learning with Technology Scale
 - a. Instrument Development
 - i. Validity and Reliability
 - ii. Instrument in Practice

5. The Digital Native Assessment Scale
 - a. Instrument Development
 - i. Validity and Reliability
 - ii. Instrument in Practice
6. The ACJ assessment
 - a. Instrument Development
 - i. Validity and Reliability
 - ii. Instrument in Practice
7. LiveAssess
 - a. Instrument development
8. ACJ Assessment (CompareAssess)
 - a. CompareAssess & Adaptive Comparative Judgment
 - i. Instrument Development
 - ii. Reliability
 - iii. Quality Control
 - iv. Interrater reliability
 - v. Bias control
 - vi. Validity
9. Semistructured Interviews
10. Engineering Design Process
11. Design Portfolios
12. Summary

Self-Directed Learning

This study focuses on the potential relationship of mobile devices and student SDL of middle school students in a TEE classroom while working on a STEM activity. Therefore, an understanding of SDL in K-12 students, both in and outside school, is

needed. In today's high-tech, fast-paced, and constantly changing world, the ability to direct one's learning has been identified as one of the 21st century skills needed by students (Fahnoe & Mishra, 2013; Partnership, 2011; Zsiga & Webster, 2007). Gureckis and Markant (2012) identified the ability to focus on useful information and enhanced encoding and retention of information as benefits of SDL. However, not all agree that SDL is beneficial to learning; some argue that self-directed learning may be detrimental to learning and have drawn connections to low levels of learning transfer and lower effectiveness and efficiency (Kirschner, Sweller, Clark, 2006; Mayer, 2004).

Definition

While a variety of definitions exist for SDL, this study will use Knowles (1975) definition, which states that self-directed learning is

...a process in which individuals take the initiative, with or without the help of others, in diagnosing their learning needs, formulating learning goals, identifying human and material resources for learning, choosing and implementing appropriate learning strategies, and evaluating learning outcomes. (p. 18)

SDL includes a variety of things including a "students' ability to self-assess their own learning needs in order to carry out activities to inquire and find out about the things they want to know" (Van Deur, 2004, p. 167). SDL combines both an understanding of what is not known, with an understanding of what activities need to be undertaken in order to obtain the needed knowledge and "characterize[s] peak performers in all walks of life" (Costa & Kallick, 2004, p. 57).

The terms "self-directed learning," "self-regulated learning," and "self-determined learning" have been confused or used interchangeably in the literature

(Cosnefroy & Carre, 2014; Saks & Leijen, 2014). Self-regulated learning (SRL) research tends to focus more on the learner's thinking and metacognition (Sungar & Tekkaya, 2006), while self-directed learning focuses more on learner's ability to identify resources and appropriate strategies for their desired outcomes, especially in problem-solving situations (Knowles, 1975). Cosnefroy and Carre provided an illuminating explanation of the difference between SDL and SRL:

The difference lies in the ownership of the learning project, which rests almost by definition with the learner in SDL; while it could be controlled externally in SRL...the self-directed learner controls the learning trajectory as a whole, whereas the self-regulated learner's control is restricted to the learning activity. (p. 4)

This delineation between SDL and SRL is important for this study as the learners will be provided with a task to accomplish but be left to their own to determine what they will learn, how they will learn it, and where they will go to learn what they need. While the two terms of SDL and SRL are often used interchangeably (Cosnefroy & Carre, 2014) SDL is the best term to describe the learning activities in this study.

Self-determined learning (sometimes referred to as heutagogy) is another term similar to self-directed learning. However, in self-determined learning the learner makes most/all of the decisions regarding what they will learn, while in self-directed learning the learner is often given a learning task and makes decisions regarding how they will learn the required material (Hase & Kenyon, 2007). As part of the literature review associated with this research, the literature associated with SDL and SRL was also considered, but recognizing the history of research related to SDL (Blumberg, 2000) and the nature of this study (e.g., learners will be provided with mobile devices and an

engineering design problem, and then allowed to choose resources to help them learn in a problem-solving situations) self-directed learning rather than self-regulated learning, or self-determined learning was determined to be the best term to describe the research in this study. After it was determined that self-directed learning was the most correct term for this research further inquiry into research focused on self-directed learning.

Self-Directed Learning in K-12 School Settings

To date, the majority of SDL research has focused on adults and college/university students (Fahnoe & Mishra, 2013; Liu, Scordino, et al., 2014; Teo et al., 2010). Recently, a few studies have emerged focusing on elementary, primary, and high school students (Agra, Blanchard, & Wehmeyer, 2000; Mok, Leung, & Shan, 2005). Despite these few studies, there has been limited research efforts directed at studying SDL in middle school students (Liu, Scordino, et al., 2014).

In one of the few research studies on SDL in K-12 students, SDL was identified as positively correlated with GPA, openness, conscientiousness, emotional stability, extraversion, optimism, career-decidedness, work drive, life satisfaction, and self-actualization (Lounsbury, Levy, Park, Gibson, & Smith, 2009). In other studies, key characteristics of self-directed learners in K-12 settings were identified. These characteristics were identified in a meta-analysis conducted by the researcher and categorized into the following themes.

1. Strong desire to learn and curiosity (Mok et al., 2005; Saeednia, 2011; Van Deur, 2004; Van Deur & Murray-Harvey, 2005).
2. Self-efficacy (Heller & Sottile, 1999; Van Deur 2004; Van Deur & Harvey,

2005).

3. Learner ability to incorporate learning strategies (Mok et al., 2005; Van Deur & Harvey 2005).
4. Self-motivation (Van Deur, 2004; Van Deur & Harvey, 2005).
5. Time-management (Mok, Leung, & Shan, 2005; Van Deur, 2004; Van Deur & Harvey, 2005).
6. Ability to set learning goals (Mok, Leung, & Shan, 2005; Van Deur, 2004).
7. Creativity (Doering & Henrickson, 2015)

In addition to the learner characteristics identified above, several environmental factors that appear to foster self-directed learning in students at the K-12 level have been identified. These factors were categorized into the following themes.

1. The presence of a problem to be solved (Agra, Blanchard, & Wehmeyer, 2000; Saeednia, 2011; Van Deur & Harvey, 2005).
2. Positive classroom environment (Heller, 1996; Van Deur, 2004; Van Deur & Harvey, 2005).
3. Group work settings (Heller & Sottile, 1996; Mok, Leung, & Shan, 2005; Van Deur, 2004).
4. The presence of technology (Fahnoe & Mishra, 2013).
5. Student media literacy skills (Jolls, 2015)

As part of the literature review, and in an effort to draw from previous findings and methodologies, select studies will be highlighted here.

Heller and Sottile (1996) utilized a qualitative methodology to examine classroom characteristics in a high school history class that seemed to promote self-directed learning in students at the grade 10 level. Heller reports that high student self-esteem, relevant content, and a conducive learning environment were all related to increases in self-

directed learning among students. As this research aims to look at mobile devices in the classroom, Heller's findings of "relevant content" or "a conducive learning environment" being related to self-directed learning in students may prove insightful and related.

Lounsbury et al. (2009) set out to assess the construct validity of self-directed learning as a personality trait as opposed to a result of environmental or personal factors. Their study, which looked at the correlations between answers on the *Self-directed learning readiness scale* (Guglielmino, 1977) and various personality tests, included 398 middle school students and 568 high school students. The analysis revealed that self-directed learning is correlated with

...cumulative GPA at all levels as well as to Big Five personality traits (Openness, Conscientiousness, Emotional Stability, and Extraversion), narrow personality traits (Optimism, Career-decidedness, work drive, and self-actualization), vocational interests, and cognitive aptitudes.... (p. 411)

These results suggest that self-directed learning may be more closely related to personality traits rather than factors of the environment or other external stimuli. This is important as this study aimed to identify if the presence of mobile devices (i.e., an environmental factor) was influential on the self-directed learning of middle school students in a STEM classroom.

In a study conducted by Reio and Davis (2005), the authors employed a variety of statistical techniques (correlations, one-way ANOVAs, and ANCOVAs) to identify age and gender differences in self-directed learning readiness as assessed through the *Self-directed learning readiness scale* (Guglielmino, 1977). The authors found that adult learners (30s-50s) had higher self-directed learning readiness scores than adolescents. The authors also noted that 14- to 20-year-old females had "significantly higher self-

directed learning readiness scales than males.” These findings were informative for this study as girls may be more likely to be self-directed than male students at the middle school level.

In 2006, Hiemstra published an article that specifically addressed the ways the Internet is changing how people learn, gather information, and assimilate knowledge. In addition to providing several key references, Hiemstra looked at the changes in SDL as a result of the ubiquitous nature of the Internet today. These thoughts were important in shaping this study as a major affordance brought about through access to mobile devices was the ability of students to access the Internet and in turn, be self-directed in their learning.

Fahnoe and Mishra (2013) conducted a study with similar goals to this research project. Rather than using the *self-directed learning readiness scale* (Guglielmino, 1977), Fahnoe and Mishra utilized a recently developed scale, the *Self-Directed Learning with Technology Scale* (Teo et al., 2010), also known as the *SDLTS*. The majority of self-directed learning research that has been conducted prior to 2010 (including the research related to middle school students) has utilized the *Self-Directed Learning Readiness Scale* (Fahnoe & Mishra, 2013; Guglielmino, 1977; Teo et al., 2010) as the measurement tool for assessing self-directed learning (Fahnoe & Mishra, 2013; Teo et al., 2010). However, as noted in Teo et al., the *Self-Directed Learning Readiness Scale* (Guglielmino, 1977) was developed with an adult audience in mind and may not be appropriate or applicable for middle school students (Teo et al., 2010). The *SDLTS* was developed in 2010 by researchers at Nan yang Technological University who sought to

develop a scale more suited for K-12 students that also combined technology. Teo et al. described this instrument as

...a self-report instrument to measure self-directed learning with technology among young students.... The *SDLTS* offers an alternative to existing measures of self-directed learning which were mostly designed for older students (e.g., adult, university) and do not include the technology element. Comprising two factors, the *SDLTS* measures respondents' perceptions in terms of their self-management and intentional learning. (p. 1769)

In the study conducted by Fahnoe and Mishra (2013), the *SDLTS* was used in a mixed-method design among sixth graders to assess their self-directed learning as it corresponded with technology use. These students were compared with their classmates in a traditional classroom and each group was surveyed for self-directed learning using the *SDLTS* (Teo et al., 2010). Fahnoe and Mishra reported that students in the traditional-designed technology-rich environment were statistically significantly more self-directed in their learning than their classmates in the traditional classroom suggesting that technology carries with it the possibility of increasing and encouraging self-directed learning in K-12 students.

Conversely, Lee, Tsai, Chait, and Koht (2014) explored students' perceptions of self-directed learning with and without technology and found that students who engaged in self-directed learning in face-to-face contexts without technology also engaged in self-directed learning practices in technology-supported contexts, suggesting that self-directed learning practices may happen independently of the presence of technology. The influence of technology on the self-directed learning practices of students, which this research explored, is unclear.

In addition to the research highlighted here, several large-scale surveys have

sought student, teacher, district, and parental opinions regarding education in general. Results from these surveys have shown that students (and teachers) are increasingly expecting an educational experience that is individual, interactive, and self-directed (Fahnoe & Mishra, 2013; Pearson, 2013; Prensky, 2007). These findings fall in line with 21st century skills expectations for students, which highlight self-directed learning as a key skill for learners today (Partnership, 2011).

Self-Directed Learning Outside of K-12 School Settings

Because mobile devices and SDL are increasingly ubiquitous and commonplace among middle school students and neither mobile device use or SDL is restricted to K-12 classroom settings it is important to also look at other SDL opportunities for middle school students, namely those that occur outside the classroom. Although the literature for SDL outside of school classrooms revolves mainly around adult education and employment-related adult educational experiences (Fahnoe & Mishra, 2013; Guglielmino, 1977), recent changes in mobile technologies and the increasingly prevalent nature of mobile devices have led to increased study and notice of SDL by today's K-12 learners outside of school settings (Project Tomorrow, 2012b).

Another factor contributing to SDL among K-12 students outside of school has been the so-called “maker movement” and the “do-it-yourself” mentality that has seen increasing growth and attention in recent years (Cole, 2013, Moran, 2011). Individuals interested in creating and learning on their own (i.e., “Makers”) have increased dramatically in recent years (Cole, 2013), and “maker-sheds” (places where people

interested in SDL and making can meet and work), conventions, clubs, and movements are springing up across America (Cole, 2013, Moran, 2011). The idea of learners taking control of their learning and becoming self-directed has begun to gain popularity (Martin, 2013; Pearson, 2013, Project Tomorrow, 2012b). A plethora of literature, which is beyond the scope of this study, exists related to the Maker movements, maker-sheds, and other out-of-school SDL opportunities (Cole, 2013; Moran, 2011).

Mobile Devices

This study focused on mobile devices and learning in K-12 education, specifically at the middle school level in a TEE classroom. Therefore, it was important to examine the research that looks at the impacts of mobile devices in K-12 learning environments. This section re-establishes the definition of learning with mobile devices and examines findings from studies associated with mobile devices in K-12 learning environments. In the literature the terms “mobile devices,” “mobile learning,” and “m-learning” are all used to denote situations in which a mobile device is present during a learning situation. On one hand “mobile learning” and “mobile education” are commonly used to refer to distance education and other educational settings where learning occurs outside a classroom (Makoe, 2012; Park, 2011). On the other, “mobile learning” and “mobile education” have been described as classroom settings in which a mobile device is added and an additional quantity or type of learning occurs (Groundar, 2011; Makoe, 2012). In a meta-analysis of research on mobile learning in K-12 Education from 2007 to 2014 (Liu, Scordino, et al., 2014), the authors chose to use Traxler’s (2005) definition of

mobile-learning as “any educational provision where the sole or dominant technology is a handheld or palmtop device” (p. 325). This research used Traxler’s definition of mobile-learning in conjunction with S. Kim et al.’s (2005) definition for mobile devices.

[T]echnology that provides continuous accessibility to users anytime, anywhere without using a wire or cable to connect to networks (like the Internet), transmit data or communicate with others. (p. 55)

This study used the included definitions (Chapter I) of mobile-learning and mobile devices to guide and shape the overall methodology and process.

Presence of Mobile Devices

This study sought to understand what relationship, if any, exists between mobile devices in middle school TEE classroom and student SDL and student achievement. This is especially relevant as more than half of the world’s population now owns a cell phone and children under 12 constitute one of the fastest growing segments of mobile technology users in the U.S. (Shuler, 2009). Mobile device ownership among children ages 4-14 has experienced double-digit growth since 2005 (CommonSense Media, 2013; NPD Group, 2008; Shuler, 2009) and is expected to follow a similar trajectory moving forward. This study will look specifically at youth in this age range; middle school students being between 11 and 14 years old (USOE, 2014c). Pew (2015) recently found that 73% of teens have access to a smart phone and “92% of teens go online daily and 24% say they are online ‘almost constantly’” (p. 1). These recent findings from Pew confirm other research studies from recent years regarding increasing teen mobile device use (Lenhart, 2012; Pearson, 2013; Robledo, 2012).

With so many mobile devices, especially in the hands of today’s students, the way

we approach education and learning may need to be changed (Prensky, 2007). Proponents of including mobile devices in the classroom argue that “cell phones are part of the student’s lives and schools and teachers rather than banning cell phones, should tap into the power of these technologies and use them as educational tools” (Center on Media and Child Health [CMCH], 2010, p. 1).

While smart phones are the most common mobile device (Ericsson, 2012), the presence of mobile devices is not limited to smart phones alone. Using the established definition for mobile devices, tablets, e-readers, and other personal digital assistants fall in the same category (G. J. Hwang & Tsai, 2011; Liu, Scordino, et al., 2014). Experts estimate that by 2017, 85% of the world’s population will be covered by high-speed mobile Internet (Ericsson, 2012) through a variety of mobile devices including phones, tablets, and e-readers.

Mobile Devices and Learning

One goal of this study was to identify the impact of access to mobile devices on SDL among middle school students in a TEE classroom during a STEM activity. Currently access to mobile devices in classrooms varies greatly across the country, state, district, and even school (Project Tomorrow, 2011). Current trends show that mobile devices are becoming increasingly ubiquitous in society but not necessarily in schools (Norris, Hossain, & Soloway, 2011). According to a United Nations Educational, Scientific, and Cultural Organizations (UNESCO) report few state-level initiatives have been developed for mobile devices in K-12 classrooms (Fritschi & Wolf, 2012), and these efforts have revolved mainly around professional development for teachers.

Despite the lack of state-level initiatives, some teachers, schools, and districts have implemented mobile devices in classrooms in a variety of ways ranging from Internet browsing to multimedia creation (Project Tomorrow, 2013). Recently, two key meta-analyses have been conducted related to mobile devices and learning in K-12 settings (G. J. Hwang & Tsai, 2011; Liu, Scordino, et al., 2014). G. J. Hwang and Tsai concluded that “mobile and ubiquitous learning research has greatly advanced in the recent 5 years” and that “students from higher education and elementary schools have remained the major samples of mobile and ubiquitous learning research” (p. 67). Similarly, Liu, Scordino, et al. noted that “literature has shown a significant increase in recent years in terms of publications reporting both projects relating to and studies being conducted on mobile technology use in education” (p. 326).

G. J. Hwang Tsai (2011) identified several themes in their review of research trends in mobile and ubiquitous learning.

1. Mobile and ubiquitous learning research has greatly advanced (32 articles during 2001-2005 versus 122 articles during 2006-2010).
2. The majority of research is being conducted with higher education and elementary school students.
3. The majority of studies were not specific to any specific learning domain, instead they mainly focused on the investigation of motivations, perceptions, and attitudes of students toward mobile and ubiquitous learning.
4. The majority of research conducted related to mobile learning has been conducted outside of the United States—specifically in Taiwan. The authors cite Taiwan’s national program for e-Learning as a likely source for this disparity.

Liu, Scordino, et al. (2014) reported that of the 63 articles reviewed in their meta-analysis on mobile learning in K-12 schools, 21% compared the effectiveness of mobile

learning to traditional learning settings, while 79% represented exploratory investigations of mobile learning in K-12 settings. Over half of the studies cited originated in Taiwan, with only 11% originating in the U.S. Additionally, the majority of studies looked at elementary school students, with studies researching mobile devices and middle school-aged students representing the least amount (14%). Natural sciences, mathematics, social studies, language arts, and English as a second-language were the dominant academic areas researched.

This study sought to inform the research by looking at mobile devices in a middle school TEE classroom in the U.S. As Liu, Scordino, et al. (2014) pointed out “there is an uneven integration of m-learning across academic disciplines” (p. 363). Research related to mobile devices and the technology and engineering portions of STEM is lacking—as such this study sought to fill an apparent gap in the existing literature.

Importantly, Liu, Scordino, et al. (2014) found that only one study (out of 63 reviewed) focused on specific apps related to mobile device use in K-12 classrooms. The vast majority of studies “relied on a Web-based learning object that was accessed through the mobile devices browser...” (p. 354). This study looked at mobile devices in the classroom with students using a particular app to create their portfolios. However, students will not be constrained to this particular app and will be allowed to use their devices however they see fit during the study.

In an earlier review of literature on mobile devices in K-12 settings, Deegan and Rothwell (2010), set forth the following classification system for mobile device activities.

1. Learning Management. Mobile devices are employed in the management of the actual learning process—registering for classes, checking grades,

examining class calendars, and submitting assignments.

2. **Supportive.** Mobile devices are used as supportive *additions* to classroom learning. Acting as a facilitator of communication or an instrument for surveying opinions are two useful examples.
3. **Context-based.** Mobile devices are helpful in connecting learning to real or virtual environments. Applications which help interpret the environment (light, sound, temperature, GPS, and other sensors embedded in mobile devices) can greatly supplement classroom learning.
4. **Content-based.** New content can be delivered to students via their mobile devices.
5. **Collaborative.** Collaboration between students involving interactions and information exchanges can be facilitated through mobile devices.

For this research mobile devices were used in supportive, context-based, content-based, or collaborative ways as students interacted with them to complete their portfolios, access information, and otherwise work on their assignments in groups.

In another review of mobile-learning literature, Cheung and Hew (2009) highlighted the three most frequent uses of mobile devices in the classroom as: communication (21.8%), multimedia access (20.5%), and task management (17.9%). This study aimed to identify the impact of mobile devices on student achievement and SDL; as such, mobile devices were used in all the ways mentioned by Cheung and Hew.

Benefits of mobile devices in K-12 classrooms. Similar to SDL at the middle school level, there is relatively little empirical research related to mobile devices in middle school classrooms (G. J. Hwang & Tsai, 2011; Liu, Scordino, et al., 2014). An Internet search on mobile-learning reveals that the majority of the literature related to mobile devices in K-12 classrooms is comprised of opinion papers and lacks methodological robustness (Liu, Scordino, et al., 2014). Liu, Navarrete, and Wivagg

(2014) conducted a study with mobile devices in a K-12 setting and reported that some benefits of mobile devices in the classroom were support for language and content learning, differentiated instructional support, extended learning time away from the classroom. Seifert (2015) also identified increased motivation, high levels of self-efficacy, high interest in activities, and increased interest in collaboration as positive traits associated with including mobile devices in a middle school classroom.

In the meta-analysis conducted by Liu, Scordino, et al. (2014), research on mobile learning in K-12 education from 2007-2012 was set forth; this meta-analysis provided a solid reference for this research. Liu, Scordino, et al. reviewed 63 studies from 15 refereed journals and found that of the 15 comparison studies, nine showed positive learning gains through quantitative measures. One study highlighted demonstrated improved student achievement ($F = 11.26, p < .001$) with a large effect size of .93. Other research cited better academic achievement and improved learning attitudes (G. J. Hwang, Shi, & Chu, 2011), increased student engagement (Huang, Lin, & Hwang, 2010), improved language acquisition (W. Y. Hwang & Chen, 2012), and greater interaction with peers in problem-solving (Sung, Hou, Liu, & Chang 2010). Five of the studies reviewed found positive learning gains for students learning academic content in a real-world context. Similarly, Liu, Scordino, et al. found that situational learning was supported across numerous studies through the use of mobile devices.

In the noncomparison studies reviewed by Liu, Scordino, et al. (2014), the researchers found increased communication and collaboration as important benefits of mobile devices in the classroom and the authors noted “the ability to access content and

communication with peers and teachers at any time proved to be an important benefit of using mobile devices.” (p. 354). Additionally, they identified mobile use as beneficial for promoting and increasing course-related interaction among students. Liu, Scordino, et al. identified four primary affordances of mobilized learning from the literature:

(a) offering students multiple entry points and learning paths and allowed for differentiated learning, (b) enabling multiple modality via mobile devices by which students have a tool to create a different learning artifact to suit their needs, (c) supporting student improvisation in situ—student may improvise as needed within the context of learning (e.g., take pictures to illustrate learning connections), and (d) supporting learning creation on the move with an ease of creating and sharing artifacts. (p. 356)

Last, Liu, Scordino, et al. (2014) identified the “potential for mobile devices to support self-regulated learning” (p. 357) outside the classroom through guided and independent opportunities. They report that “mobile devices allowed anytime access to support and helped students and instructors monitor progress” (p. 357). These findings are important and helped provide the theoretical starting point for this research which examined the relationship between mobile devices in a K-12 STEM classroom and student SDL.

Challenges of mobile devices in K-12 classrooms. As this study looked at the influence of mobile devices on student SDL in a middle school TEE classroom associated challenges with classroom inclusion of mobile devices were also highlighted. In a meta-analysis conducted by the researcher, covering mobile devices and their use in K-12 classrooms, several challenges associated with the inclusion of mobile devices were identified.

1. Distraction (Alberta Education, 2006, 2012; Project Tomorrow, 2011; Shuler, 2009).

2. Harassment (Lenhart, Ling, Campbell, & Purcell, 2010), privacy (Crichton, Pegler, White, 2012; Project Tomorrow, 2011).
3. Cheating (Shuler, 2009)
4. Student disciplinary problems (Project Tomorrow, 2011; Shuler, 2009; K. M. Thomas & McGee, 2012).
5. Lower academic achievement (Kitchen, 2014).
6. Decreased student engagement (Swan, van't Hooft, Kratcoski, & Unger, 2005).

In the 2014 study by Liu, Scordino, et al. the authors highlighted specific challenges associated with the inclusion of mobile devices in the classroom including significant time demand on the teacher, technical issues, the need for professional training, and a dedicated support staff. In addition to these arguments, other formidable challenges to mobile devices in the classroom might include:

1. The status quo—for the most part, mobile devices are currently prohibited in public K-12 class settings (CommonSense Media, 2009; Project Tomorrow, 2011, 2012a; K. M. Thomas & McGee, 2012). Students are permitted to bring their personal mobile devices to school but must store them in lockers, backpacks, or out of sight.
2. The uniqueness of each class, school, and district. Every school, and even classroom, may have their own unique policy relating to mobile devices. Circumstances of students wishing to retain their phones and teachers wanting to rid their classrooms of the “distraction” have led to what contention and frustration between teachers and students (Raths, 2013).

In the aforementioned meta-analysis conducted by Liu, Scordino, et al. (2014), conflicts with school electronic device use policies were cited as the number one deterrent for mobile device use in K-12 classrooms. Liu, Scordino, et al. also noted that mobile devices were often classified as “interruptions” and for the most part mobile devices were prohibited during instructional hours. Student activities with mobile devices

were commonly seen as “off-task,” and carried negative connotations with them. In an earlier study Clark, Logan, Lukin, Mee, and Olver (2009) found that boundaries between formal and informal learning spaces were blurred when mobile devices were introduced with potentially harmful consequences.

Another commonly cited negative consequence of mobile devices in K-12 classrooms was digital inequity (Liu, Scordino, et al., 2014). Some worried that allowing mobile devices in K-12 classrooms would increase the gap between the “haves” and the “have-nots” (Liu, Scordino, et al., 2014). Interestingly, Ferrer, Belvís, and Pàlmies (2011) reported that access to mobile devices through school sponsored programs contributed toward socio-educational equity.

Current trends and initiatives for mobile learning in K-12 classrooms.

Despite the prevailing policies and rules that restrict mobile devices in school, a limited number of initiatives have been implemented by private companies, local organizations, and select school districts. These initiatives are both informative and illuminating as the findings from these initiatives (as well as the model and implementation) can serve to inform this study, especially in developing the guidelines for use of mobile devices in the classroom as part of this study. Although there are multiple initiatives dealing with mobile devices and K-12 education, only a handful of the most relevant will be discussed here. It is also important to note that the majority of the current initiatives and mobile device research and implementation continue to happen outside the U.S. (Liu, Scordino, et al., 2014).

At a national level, the White House released the *National Broadband Plan* (FCC,

2010). The focus of the *National Broadband Plan* has been fixed Internet access nationwide, but in a chapter devoted to cellular access one of the plan's recommendations was as follows:

The FCC (Federal Communications Commission) should initiate a rulemaking to fund wireless connectivity to portable learning devices. Students and educators should be allowed to take these devices off campus so they can continue learning outside school hours. (FCC, 2010, p. 239)

Another initiative, Project Knect, is a program for at risk ninth graders where students were supplied with smartphones so they could access supplemental math materials. In a follow-up survey almost two thirds of the students reported taking additional math courses and considering a career in a math-related field (Project Tomorrow, 2011) due largely to their experience with smartphones as part of the study.

Project Tomorrow institutes a national survey each year to assess opinions regarding relevant topics related to technology. In the Project Tomorrow *Speak Up* 2012 Survey, a majority (52%) of students in grades 6-12 stated that they believe that having access to a tablet computer is an essential component of their ultimate school, 51% of administrators agreed with these statements as well (Project Tomorrow, 2013).

Mobile device rules and restrictions. Although countless variations occur at state, district, and school levels, mobile device access is currently limited in most classrooms across America (Liu, Scordino, et al., 2014; Project Tomorrow, 2011, 2012a; Shuler, 2009). Rules often prohibit students from bringing mobile devices to class but allow students to keep them in their locker or backpack. Rules and restrictions appear to be in place primarily to ensure a safe and productive learning environment (Project Tomorrow, 2011, 2012a).

Digital citizenship. In an effort to provide a standard for responsible conduct with technology in schools and still allow students to utilize current technologies Ribble and Bailey (2007) published guidelines for “digital citizenship. They identified nine components of “digital citizenship;” or core components of professional development activities for teachers to encourage the appropriate and proper usage of mobile devices and technology in their classroom. Crichton et al. (2012) reflected positive outcomes when teachers and students were specifically trained and instructed on these principles. These principles of digital citizenship were especially relevant to this study because they were taught to the teachers and students participating in the study in an effort to facilitate a positive and productive experience. Ribble (2011) described the nine components as an understanding of:

1. How to access to digital content and technology which enables full electronic participation in society.
2. How to buy and sell good electronically.
3. How to appropriately exchange digital information, including email, cell phone use, instant messaging, etc.
4. Digital literacy which allows one to use technology comfortably and name appropriate choices as to the right tool for the correct task / activity.
5. Standards/manners of digital interactions—digital etiquette.
6. Legal implications of electronic actions and deeds
7. One’s digital rights and responsibilities, including privacy and free speech.
8. Digital health and wellness and how to protect oneself online
9. Digital security and knowing what precautions are appropriate in an electronic environment.

Perceptions of mobile devices in K-12 settings. The perceptions of key

stakeholders (e.g., students, teachers, parents, administrators) are important for any changes that affect K-12 classrooms. As this study proposes to include mobile devices in TEE education classrooms during a STEM activity, some perceptions of each group towards mobile devices and learning are included here.

Student perceptions. In addition to previous surveys (Project Tomorrow, 2011, 2012b) a recent survey initiative commissioned by Pearson (2013) sought to better understand how students use mobile technology for learning currently and how students would like to use this technology in the future. The results from the survey of over 2,300 4th-12th grade students were informative. Nine out of 10 students agreed that tablets will change the way students learn in the future, and that they make learning more fun. Eighty percent of students say that tablets will help them learn better in the classroom. Sixty-nine percent of students reported wanting to use their mobile devices more often in the classroom. Seven out of 10 students would like to see mobile devices used more often in their classrooms. Among students who have used a mobile device for school work this year, 60% have used their device for school work at least a few times a week. The most popular school-related activities on mobile devices were researching, homework, and checking assignments. The majority of students who reported having access to tablets reported using them for school work (small tablets: 58%, full tablets: 60%) and 44% of students have used a smartphone for schoolwork this year (55% H.S., 41% M.S., 29% E.L.).

Teacher, parent, and administrator perceptions. Teachers, parents, and administrators have traditionally been opposed to the inclusion of mobile devices in the

classroom (Project Tomorrow, 2011, 2012b). Recent years, however, have seen a shift in these opinions. In 2010, over 60% of principals said it was unlikely that they would allow students to use their own mobile devices in school. In 2013, however, that number was almost cut in half—down to 32%. Additionally, 41% said they were likely to allow such usage today and 10% said they already do allow students to use their own mobile devices to support schoolwork in class (Project Tomorrow, 2014).

In addition to shifting support among administrators, parental support also appears to be shifting. In a national survey (Project Tomorrow, 2012b), 87% of parents say that the effective implementation of technology within instruction is important to their child's success; 50% label it as "extremely important." However, only 64% say that their child's school is doing a good job of using technology to enhance student achievement, and only 12% strongly agree with that statement.

In the 2013 *Speak Up* survey, completed by more than 400,000 K-12 students, parents, teachers, and administrators (Project Tomorrow, 2014), 60% of all parents surveyed said they would like their children to be in a class where using one's own mobile device was allowed. Furthermore, two thirds said they would purchase a mobile device for their child to use within class, if that was allowed by the school.

In a similar fashion, teachers also appear to be recognizing value in mobile devices in the classroom. Teachers who participated in *Speak Up* surveys seem to agree that the most significant value of incorporating mobile devices within instruction is increased student engagement in school and learning. Despite these findings, many teachers still report feeling unprepared for mobile devices in their classrooms (Project

Tomorrow, 2011). Teacher-training and readiness has been highlighted as a key issue in the successful implementation of mobile devices in the classroom (Project Red, 2011; Project Tomorrow, 2012a, 2013).

The perceptions of students and teachers regarding student SDL and mobile devices were collected as part of this study. The findings were compared with other data regarding perceptions of mobile devices in K-12 classroom settings and reported here.

Science, Technology, Engineering, and Math Education

STEM education has gained momentum in the recent years. Increased emphasis from the National Science Foundation (NSF), federal legislation, federal funding, as well as the creation of ITEEA's *Standards for Technological Literacy*, and the *Next Generation Science Standards* have all combined for a national focus on STEM education (Dugger, 2010, ITEEA, 2007; Next Generation Science Standards [NGSS], 2014). Historically, the term "STEM" was coined by the NSF in the 1990s (Bybee, 2010). Today STEM is an integral part of our education system; President Obama has created numerous departments and committees to specifically oversee STEM education in the U.S. (Executive Office of the President, 2010). The term "STEM Education" has come to mean various things from integrating STEM principles in all classes to teaching each class individual. Dugger (2010) suggested:

A more comprehensive way [to teach STEM] is to infuse all four disciplines into each other and teach them as an integrated subject matter. For example, there is technological, engineering, and mathematical content in science, so the science teacher would integrate the T, E, and M into the S. (p. 5)

With the recent release of the *Next Generation Science Standards* (NGSS, 2014)

and the increasing availability of engineering content in public schools (USOE, 2014a, 2014b), STEM education continues to be at the forefront of the educational conversation. This study took place in a Technology and Engineering Education classroom, which, containing the TE portions of STEM represents a vital part of the STEM education conversation. This study was conducted with the intent to further the literature associated with Technology and Engineering Education, STEM education, mobile devices in K-12 education, and SDL.

Technology and Engineering Education

This study was conducted in a TEE classroom. TEE represents an elective course and is a branch of general education which focuses on increasing students' level of *technological literacy*, defined as: "the ability to use, manage, assess, and understand technology" (ITEEA, 2007). TEE represents a predominantly hands-on environment, where students learn, experience, manage, and assess technology (USOE, 2014a). TEE classes are often easily recognizable because they will have corresponding laboratories, shops, labs, greenhouses, and other areas for use in classroom activities (USOE, 2014b). TEE classes often offer students open-ended engineering design problems (USOE, 2014b), which have been shown to predict self-directed executive functioning (Barker et al., 2014), a key trait in SDL. As the research on TEE has traditionally received less emphasis than the "S" and the "M" of STEM (Bartholomew, 2015; Executive Office of the President, 2010; National Council on Teacher Quality, 2009; Rockland et al., 2010; Roehrig, Moore, Wang, & Park 2012); this study sought to inform the literature and add to the body of knowledge related to TEE and STEM education.

Middle School Students

Middle school students in this study were students in grades 7-8, corresponding to students ages 11-14 (USOE, 2014c). Middle school students are at the developmental stage where they are growing physically and mentally at a rapid pace (Lorain, 2014; J. W. Thomas, 1993). In a review of literature conducted by J. W. Thomas related to middle school students, Thomas concluded that middle school students were capable of sophisticated study techniques and strategic study behavior such as SDL and recommends that teachers employ these practices as a means of helping their students excel. In this study students were allowed access to mobile devices and their SDL was assessed for correlational relationship analysis. Middle School students have been referred to as “free agent learners,” and described as:

...increasingly approaching their education from a DIY (Do It Yourself) perspective, whether that is driven by interests in academic areas that are not covered in classroom curriculum, a desire to leverage peer or expert knowledge, productivity needs, or concerns they have about the quality of their traditional education to adequately prepare them for the future. (Project Tomorrow, 2012b, p. 4)

These descriptions proved important as this research sought to identify what relationships, if any, existed between the inclusion of mobile devices in a middle school TEE classroom doing a STEM activity and student SDL and achievement.

The Self-Directed Learning with Technology Scale

The Self-directed learning with technology scale was developed as an alternative to the *Self-directed learner readiness scale (SDLRS)* with specific application to adolescents and technology use (Teo et al., 2010). The *SDLTS* is significantly shorter

than the *SDLRS* and has been made freely available for use in research, while the *SDLRS* is available only for purchase.

Instrument Development

In research conducted by Teo et al. (2010), the authors reviewed various scales and instruments for measuring SDL, and noted that “few, if any, were developed for use by young students.” Additionally, “no scales with technology as an element for supporting self-directed learning” (p. 1764) were able to be identified. Using a large-scale literature review, Teo et al. generated a list of 21 items related to SDL and technology. A series of focus groups with teachers and students were then employed to determine the appropriateness of each item. Following the feedback from the focus groups the list of items was reduced to seven. A pilot test was utilized among 558 students to test and refine the seven identified items. The pilot test showed that all items were appropriate and “based on the thresholds recommended from the literature, no item was removed and all seven items in the pilot test remained for further analysis” (p. 1767). Utilizing a separate sample of 545 students a confirmatory factor analysis was completed that identified one question for removal from the model—this led to a six-question scale. A fit-indices test for alternative models was performed and resulted in the recommended *SDLTS*. This final scale, consisting of six questions, focused on two components of SDL: self-management (2 questions) and intentional learning (4 questions). Each question was developed to be answered on a Likert scale, ranging from 6 for “All the time” to 1 for “Not at all.” The development of this scale is similar to recent developments of other specific SDL scales in nursing education (Fisher, King, & Tague 2001) and a hybrid

problem-based learning medical program (Hendry & Ginns, 2009).

Validity and Reliability

As part of the initial development of the *SDLTS*, it was validated (Teo et al., 2010). The *SDLTS* has been revalidated (Demir & Yurdugul, 2013) and continues to be included in research on SDL (Demir & Yurdugul, 2013; Fahnoe & Mishra, 2013; Lee et al., 2014; Tan et al., 2013).

Instrument in Practice

The *SDLTS* has been used and cited in a variety of studies including those with K-12 students (Demir & Yurdugul, 2013; Fahnoe & Mishra, 2012; Lee et al., 2014; Tan et al., 2013), and in higher education (Chun, Shum, & Tina, 2014; Francis & Flanigan, 2012; R. Kim et al., 2013; Saks & Leijen, 2014; Tsai & Chung, 2011). Demir and Yurdugul adapted the *SDLTS* (Teo et al., 2010) into Turkish and piloted it among 1,051 primary and secondary students in four locations. An explanatory and confirmatory factorial analysis were used to validate the *SDLTS* for use in Turkish. This validation showed similar promise to the original scale.

Fahnoe and Mishra (2013) conducted a mixed-methods study to examine the SDL of middle school students in an intentionally designed, technology-rich learning environment. Fahnoe and Mishra found that “students in the intentionally designed 21st century learning environment reported a higher perception of self-directedness than their traditional counterparts” (p. 3131).

Lee et al. (2014) explored student perceptions of SDL and collaborative learning

with/without technology in an information and communications technology-supported classroom. Utilizing a pilot study of 219 secondary students and a main survey of 500 secondary students, the authors reported that

The results validated the four-factor structure model and revealed that students who reportedly engaged in SDL and collaborative learning in face-to-face contexts also engaged in these forms of learning in technology-supported contexts. The findings indicate that students' learning without technology support is related to their use of technology for learning. (p. 425)

Tan et al. (2013) identified key findings and insights generated from the mid-term evaluation study of IT Masterplan 3 (MP3) in Singapore in the year 2011. The authors set out to evaluate the outcome measures related to the use of Information and Communication Technologies (ICT) for SDL and collaborative learning (CoL). Surveying 8,217 students and 4,835 teachers, the authors used the *SDLTS* to identify SDL with technology among those surveyed. The authors reported positive improvements “in terms of students' and teachers' perceived engagement in SDL and CoL, but there is room for improvement in terms of their use of ICT to achieve SDL and CoL” (p. 36).

This study used a modified version of the *SDLTS*, which uses slightly reworded questions from the *SDLTS* with the addition of a few additional questions representing principles and ideas covered in the *SDLRS*. This modified version of the *SDLTS* was created in an effort to better convey ideas related to SDL and gather additional information regarding learner self-directedness (Appendix A).

The Digital Natives Assessment Scale

The term “digital natives” was first coined by Prensky (2007) as a term for use in

describing students who are “native speakers” of the digital language of computers, mobile devices, and the Internet. Teo (2013), recognizing the need for an assessment which measured the degree to which today’s students perceive themselves as “digital natives” developed and validated the *Digital Natives Assessment Scale (DNAS)*.

Instrument Development

The instrument is a self-report instrument used to assess students’ perceptions of the degree to which they classify themselves as “digital natives.” Following a literature review of the traits of digital natives and how digital natives learn the instrument was created. Teo (2013) noted that the instrument was both developed and validated:

...with a total sample of 1,018 students from three secondary schools. Results of the principal component and confirmatory factor analyses supported a 21-item, four-factor scale for use by students between 13 and 16 years of age. The four factors are: grow up with technology, comfortable with multitasking, reliant on graphics for communication, and thrive on instant gratifications and rewards. (p. 51)

The instrument originated with 53 Likert-style questions related to “digital nativeness.” These 53 questions were tested using a confirmatory factor analysis which resulted in 30 questions and then finally 21 questions following a second round of the confirmatory factor analysis process.

Validity and Reliability

Following the confirmatory factor analysis for the 21 questions the resulting *DNAS* demonstrated both validity and reliability. As Teo (2013) noted:

The *DNAS* was developed and validated using three separate samples, totaling 1018 students from three secondary schools in Singapore.... All 21 items have good standardized loadings on the each of the four hypothesized factors, which

are significantly but not highly correlated. (p. 56)

Instrument in Practice

The *DNAS*, although very recently developed, has already been used successfully (Yong & Gates, 2014). This scale, which looks at a variety of learner traits associated with “digital nativeness,” aligns well with Prensky’s (2007) definition of digital natives and fits well with this research and the corresponding traits in students. The *DNAS* was adapted for this study and used as part of the pre-study questionnaire to assess students comfort and experience with technology and other skills associated with digital natives (Appendix B).

LiveAssess

The iPad app used by students to complete the design portfolio electronically was developed and commercialized by the company TAG Assessment (also known as DigitalAssess). TAG assessment worked with Richard Kimbell to commercialize and market software based on Kimbell’s (2007) approach to portfolio creation. Later TAG Assessment also worked with Kimbell and Pollitt to commercialize and market software based on their work with adaptive comparative judgment (ACJ).

Richard Kimbell, a professor at Goldsmith’s University of London, founded The Technology Education Research Unit (TERU) in 1990 with the goal of studying learning in and through designing activities. *Project E-scape*, a four phase project, set out develop an approach for assessment in design and technology that encouraged creativity and teamwork (Kimbell, 2007, 2012a). Over the course of the first three phases the project

developed, piloted, refined, and validated digital peripheral tools that enabled learners to create authentic, real-time web-portfolios of their performance. These design portfolios enable learners to build an authentic story of their designing through a combination of drawings, photos, voice files and text (Kimbell et al., 2007). Learners use mobile device apps to record and store their design portfolios and then submit them at the culmination of the unit. The commercial version of the E-scape web-portfolio system was awarded to TAG assessments and is marketed as an iPad-based app called *LiveAssess*.

The tradition of coursework portfolios and summative design problem portfolios has evolved over the years (Bain, Kimbell, Miller, & Stables, 2004; Kimbell, 2007; Kimbell et al., 2007); however, the *LiveAssess* method of creating portfolios carries specific advantages over other traditional methods: performance is tracked in real-time (as opposed to the traditional method of making the portfolio at the end), and the *LiveAssess* portfolio software was specifically designed to be a peripheral technology—one in which students can keep their portfolio in their “back-pocket” and interact with the technology only as they see fit, but also “put it away” when it’s not deemed necessary (Kimbell, 2007).

The *LiveAssess* portfolio approach for open-ended design problems has been used with students in all grade levels and across the world and has shown “radically improved assessment reliability” (Kimbell, 2012b, p. 123). Surprisingly, this portfolio creation software has seen very little implementation in the U.S. Because of the highly beneficial nature of this tool and its relative obscurity in the United States it was determined that this approach to portfolio creation would be used for the open-ended engineering design

challenge in this study.

As part of the research associated with Kimbell's (2012a) implementation of *LiveAssess* into school, Kimbell partnered with Alastair Pollitt in the design, creation, and implementation of a nontraditional form of assessment. This was deemed necessary and beneficial due to the highly creative and open-ended design of the problems used in Kimbell's research (Kimbell, 2012a; Kimbell et al., 2007). This new form of assessment, originally called ACJ assessment, is now marketed through TAG assessment as *CompareAssess*. *CompareAssess* is seen as a vital companion to the *LiveAssess* portfolio creation tool.

Adaptive Comparative Judgment-Based Assessment (CompareAssess)

Recently trends in educational assessment have led to the assigning of scores to student work based on a predetermined rubric (Pollitt, 2004). The score for student work can be holistic or based on micro-judgments that are summated to create a macro-judgment (Pollitt, 2004; Kimbell, 2012a). Working together, Richard Kimbell and Alastair Pollitt developed, piloted, and successfully packaged a very different form of assessment known as *CompareAssess*.

CompareAssess and Adaptive Comparative Judgment

In contrast to traditional test and marking theory, Pollitt suggested a new form of assessment based on Thurstone's law of comparative judgment (Thurstone, 1927). In this form of assessment, judges are presented with two different artifacts of student work (in

the case of this research the judge viewed two design portfolios or two products). The judges were not asked to grade either of the artifacts—rather, they were asked to simply make a holistic judgment about which artifact was better based on a provided rubric and their own professional opinion. While some may contend that the current use of rubrics is sufficient for assessment, Pollitt points out that assessment of *any* kind ultimately involves the comparison of one thing to another (Kimbell, 2012a; Pollitt, 2004). As Pollitt said, “all judgments are relative. When we try to judge a performance against grade descriptors we are imagining or remembering other performances and comparing new performances to them” (Pollitt, 2004, p. 6).

Pollitt and Kimbell provided the example that if a judge were handed a paperweight and a paperclip they could not tell you the exact weight of either one; however, the judge would have little difficulty identifying which object was heavier. This idea, called *The Law of Comparative Judgment* by Thurstone (1927), provided the backbone for *CompareAssess*. Using *CompareAssess*, graders choose the better of two artifacts—a simple comparative judgment, and through a complex algorithm, which has been validated repeatedly and used on thousands of student artifacts, (Pollitt, 2004, 2012) *CompareAssess* uses the judges’ rankings to assign a rank-order to each artifact. In this study using the *CompareAssess* engine each portfolio or product was compared with other portfolios and products by randomly assigned graders until a rank-order was reached which met the reliability requirements.

Instrument Development

Alastair Pollitt (2004, 2012) has been instrumental in the development and

implementation of ACJ assessment, now used electronically in a software known as *CompareAssess*. *CompareAssess* was developed, marketed, and commercialized by TAG assessments similar to *LiveAssess* through help from both Richard Kimbell and Alastair Pollitt. Building on Thurstone's (1927) method of paired comparisons, Pollitt argued for and successfully implemented several ACJ studies (Pollitt, 2004, 2012). Pollitt (2004), proposed

...an alternative method for carrying out summative assessment, one that seems to be intrinsically more valid than the familiar procedure of awarding marks to lots of questions, little or large, and adding them up to get a student's total mark or score. (p. 2)

This method of summative evaluation, while different from traditional methods of assessment, meets the purpose of summative assessment, "to judge the overall quality of students (or their performances) in some educational domain on a standard ordinal scale." (Pollitt, 2004, p. 4) In traditional scoring of assessments a problematic issue has revolved around the low reliability associated with multiple examiners grading tests (Pollitt, 2004, 2012). This reliability weakness is further intensified when the assessment integrates open-ended design problems; Pollitt (2004) specifically identified technology and engineering as an area suffering from this problem: "problems like this seem to occur most prominently in certain less traditional subject areas such as Information and Communications Technology and aspects of Design and Technology" (p. 5).

TEE classrooms, the setting for this research study, are traditionally a home for open-ended engineering design problems (ITEEA, 2007; USOE, 2014a). The reliability issue of grading an open-ended design problem has been connected with technology and design situations repeatedly (Alfrey & Cooney, 2009; Kimbell et al., 2007; Pollitt, 2004,

2012) and is not limited to TEE classrooms alone (Pollitt, 2004, 2012).

The traditional solution to this problem of reliability has been to allow examiners to make many microjudgments and then add up the individual scores for a macrojudgment. While this method tends to improve reliability, this method, in turn, decreases validity. As Pollitt (2004) pointed out:

There is no guarantee that the weighted sum of microjudgments leads to an accurate macrojudgment of a student's performance... Making a reliable direct judgment requires remembering or imagining another performance with which to compare and having a series of internalized standards. There are limitations on how many such categories a person can reliably distinguish. (pp. 5-6)

This rings true with studies in metacognition and cognitive science related to temporary memory and information processing, which suggest that five to seven items are the maximum number of items a person can store in their brain at any given point in time (Miller, 1956; Pollitt, 2004, 2012).

As a solution, Pollitt argues for the method of comparative judgment (Pollitt, 2012; Thurstone, 1927) where raters are shown two pieces of student work (essays, art, pictures, portfolios, etc.) and asked to rate which piece of work is better. This process is repeated until each piece of work has been rated and a rank-order of the student work created. In addition to a simple rank-order of student work, a standardized score of relative quality is produced:

Statistical analysis of a matrix of comparative judgments of 'scripts' can construct a measurement scale expressing the relative value of the performances. The results of comparisons of this kind is objective relative measurement, on a scale with a constant unit. Furthermore, if a few scripts that have already been agreed to represent grade boundaries—perhaps from a previous sitting of the examination—are included in the comparisons, the whole process of marking, grading, and comparability of standards can be replaced by the collection and analysis of paired comparative judgments. (Pollitt, 2006, as cited in Kimbell et al., 2007, p. 2)

Reliability. This method of assessment has shown to be not only more reliable, but also more valid, than traditional methods of assessing student work (Kimbell 2012; Pollitt, 2004, 2006, 2012). Pollitt (2004) pointed out:

Although human judges are likely to have their own internalized standards about what constitutes an item of a certain quality if they compare two things (as in the Thurstone method) then their own standard cancels out. (p. 6)

In another article, Kimbell et al. (2007) argued in favor of this method relating, “I may be a hard marker or a soft one—but I still have to decide which of the two pieces is better. Judges’ personal standards (the greatest source of error in current assessment procedures for 16+ GCSE exams) therefore just cancel out” (p. 21).

When used, the Adaptive Comparative Judgment method has continually produced higher reliability coefficients (Kimbell 2012; Pollitt, 2004, 2012) than traditional marking of exams. The literature identifies reliability coefficients higher than $r = .786$; far higher than reliability coefficients traditionally reached through other methods (Pollitt, 2004).

Pollitt (2004) pointed out that in the past test questions were written in a specific manner so they could be more reliably graded. Test questions were broken into parts and oftentimes worded unnaturally to provide “sections” for graders (i.e., one point for answering each section of the question correctly). In exchange for artificially increasing the reliability, this method of wording has been shown to decrease the validity of the questions being asked (Pollitt, 2004). Pollitt suggested that

...questions could be written in a less restricted way and would hence be likely to be more valid. The method relies on judgments of the comparative quality of responses to construct an ordering of candidates instead of on counting the number of correct points made. (p. 6)

An important principle in the analysis of comparative judgment is that every judgment is statistically independent—this allows for an early analysis of the data that will in turn optimize later data collection (Pollitt, 2004). As each script is compared, producing either a “win” or a “loss” in the comparison, each script will naturally accumulate a “win-loss” record. This ratio of “wins” to “losses” is then used to ensure that similar scripts (i.e., scripts with similar win-loss records) are compared later on; thus strengthening the ordinal ranking process and the efficiency of the overall assessment. The benefits, reliability, and validity of *CompareAssess* and *The Law of Comparative Judgment* have been documented extensively elsewhere (Pollitt, 2004, 2012).

Pollitt (2004) discussed specific benefits related to the reliability of the ACJ method of assessment:

When a judge compares two performances (using their own personal ‘standard’ or internalized criteria) **the judge’s standard cancels out**. In theory the same relative judgment is expected from any well-behaved judge. A similar effect occurs in sport: when two contestants or teams meet the ‘better’ team is likely to win, whatever the absolute standard of competition and irrespective of the expectations of any judge who might be involved. The result of the comparisons of this kind is *objective relative measurement*. (pp. 6-7, emphasis in original)

Quality control. *CompareAssess* places “boundaries” which mark natural breaks between scripts. Inevitable “gray zones” appear in the ordinal ranking of artifacts which consist of artifacts ranked very similar to others or scripts very close to boundary lines. *CompareAssess* automatically accounts for this issue by marking “gray zone” scripts and sending them out for additional ranking. Any script that lies within one standard error of a boundary is identified as a “gray zone” script (Pollitt, 2004) and is marked for additional judgments until the script placement is solidified.

Additionally, it is possible that some artifacts may be misjudged. This naturally results from judge error or other grader mistakes. *CompareAssess* automatically “flags” artifacts that have received significantly different scores between judges (based on the other artifacts they are compared to and their “win-loss” record). Flagged artifacts are automatically sent out for additional ranking until a more reliable score/rank is obtained.

Interrater reliability. Reliability is a measure of repeatability (Gall, Borg, & Gall, 1996); do all the judges agree on the rank/grade obtained by a student artifact? It is possible that one judge may score drastically different than others—thus lowering the reliability of the instrument. In the same way that artifacts are “flagged” a judge that consistently ranks artifacts differently than other judges is “flagged.” At this point in time the judge can either be removed, replaced, or a meeting can be convened where the standard for judgment can be re-established. Use of the *CompareAssess* system has consistently produced reliability coefficients above .9, with some even higher (Kimbell, 2012b).

Although adaptive comparative judgment has been used in many parts of the world it has received little attention in the U.S.—one major reason this method was chosen for inclusion in this study. The *CompareAssess* system, piloted in design and technology education, has been tested, and shown reliable in a variety of subject areas including geography, chemistry, biology, accounting, psychology, sociology, English, math, health, social care, business, foreign language studies, speaking, (Pollitt, 2004, 2012). Pollitt (2004) noted that:

In several of the studies the examiners begin with grave doubts about the feasibility of making consistent holistic judgments about their examinations, but

in every case they agreed to try, and in every case the results from nearly all examiners were satisfactory. After the experience almost all of them accepted that the method could work. (p. 9)

In addition to the reliability discussed, this assessment method has demonstrated stochastic transitivity (if A usually beats B, and B usually beats C, then A will mostly beat C), furthering increasing the reliability of the findings (Pollitt, 2004). It is important to note that strong reliability findings connected with this method of assessment account for possible unreliability between graders *as well* as lack of internal consistency within the assignment itself. This is out of the ordinary as most traditional reliability coefficients only allow for one of these (Kimbell, 2012a; Pollitt, 2004).

Bias control. Pollitt addressed issues of bias (e.g., student handwriting, time of day the script was graded, etc.) and points out that any of these biases can be detected “so long as not all of the judges are equally biased in one direction” (Pollitt, 2004, p. 12). In this study the paper-portfolios created by students were digitized so this issue was not as prevalent as in other studies (Pollitt, 2004). This method of assessment has also been shown to be effective in a variety of situations.

The method manifestly works in many assessment contexts, in that it generates data that are consistent and that all of the researchers involved (from the main English and Welsh Examination Boards) have found credible. (p. 11)

Validity. Validity is the measure of the extent to which the rank obtained by a student artifact represents their actual knowledge and capability. In order to check for validity, the results of ranking done through the adaptive comparative judgment method were compared with ranking results through traditional methods. The value of R^2 was 0.81, corresponding to a correlation of 0.90 (Kimbell et al., 2007), suggesting that the

adaptive comparative judgment method of scoring is valid and will produce highly-correlated results to traditional marking. The strength of the *CompareAssess* adaptive comparative judgment system lies in its reliability, validity, bias control, and quality control. The results from the *CompareAssess* assessment used in this study was a rank order of student portfolios and a rank order of student products for all classes which was then used in the statistical analysis of this study. This study explored open-ended engineering design problem in a TEE during a STEM activity with middle-school students. The *CompareAssess* software for performing ACJ assessment has consistently proved the best (in terms of reliability and validity) for open-ended design problems in Design and Technology classrooms (Kimbell et al., 2007; Pollitt, 2004) and proved a valuable choice for this study.

Semistructured Interviews

This research used semistructured interviews with teachers as a means of further examining the findings from the quantitative portion of the study. Berg (2009) explained that semistructured interviews involve a series of questions around specified topics that are asked of each participant. As part of the semistructured interview process the researcher had the freedom to probe beyond the answers to the prepared questions to further clarify and understand responses. All questions used during the interview were standardized and written in a level of language understood by the interviewees. The researcher focused on asking questions that reflected an awareness and understanding of the phenomenon associated with this study from the interviewee's perspective (Berg,

2009). This form of qualitative research has been used extensively (Berg, 2009) and has been shown as a reasonable method of conducting qualitative research and eliciting themes from responses.

Engineering Design Process

Although it is beyond the scope of this literature review to examine all the literature related to the engineering design process it is important to outline key concepts as this research examined findings related to students working in groups to solve an engineering design challenge. Although varying definitions and models exist representing the engineering design process the majority revolve around similar ideas and concepts (Householder & Hailey, 2012). For this study TeachEngineering's (2015) definition of the engineering design process was used: "a series of steps that engineering teams use to guide them as they solve problems. The design process is cyclical, meaning that engineers repeat the steps as many times as needed, making improvements along the way" (p. 1). In this study students worked in teams to solve a common problem presented as part of the study.

The engineering design process, although sometimes represented graphically in a linear fashion, involves repetition and cyclical movement through the different steps (Householder & Hailey, 2012). Several models depict this process in various ways (Farmer, Allen, Berland, Crawford, & Guerra, 2012; Hynes et al., 2011; ITEEA, 2007; Massachusetts Department of Education, 2006; Sheppard, Macatangay, Colby, & Sullivan, 2009). In a review of engineering design process research, the National Center

for Engineering & Technology Education highlighted different models and chose Hynes et al. as their model of choice (Householder & Hailey, 2012). Similarly, the model proposed by Hynes et al. was the model for the engineering design process used in this research, and taught to the students in class during the study (see Figure 1).

As shown in the figure, although the steps are numbered, teams may start and proceed through the steps in various patterns of progression. Engineering design challenges are beginning to be included more and more frequently in K-12 educational settings (Householder & Hailey, 2012; NGSS, 2014) and with the recent release of *The Next Generation Science Standards* it is likely the number of students participating in engineering design challenges will increase (Ames, 2013 NGSS, 2014).

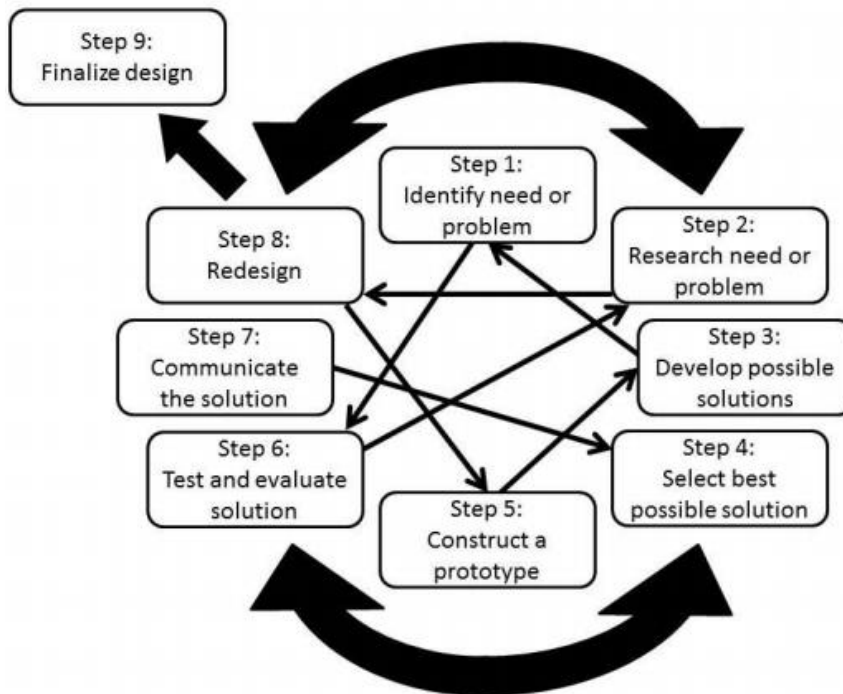


Figure 1. Engineering design process.

It is important to note that although TEE has traditionally been the subject area where engineering is taught in K-12 schools (ITEEA 2007; Loveland & Dunn, 2014; NGSS, 2015); this may not always be the case. With the recent publication of the *Next Generation Science Standards* the arena for engineering may be shifting to other areas outside of TEE (Ames, 2014; Bartholomew, 2015; NGSS, 2014).

Fantz, De Miranda, and Siller (2010) identified differences in the way TEE teachers teach engineering when compared with those with a four-year engineering degree. Most notably, TEE teachers were less likely to use *all* of the steps in the engineering design process and less likely to use the optimization techniques requiring math and analytical reasoning. This study was conducted in TEE classrooms at the middle school level as students worked on an open-ended engineering design problem. These types of problems are a common element in TEE curriculum, a component of STEM education (USOE, 2014a). All teachers were trained on the steps in the engineering design process and provided with a teacher script (Appendix C) which outlined the pattern for guiding their students through that process.

The open-ended engineering design problem used in this study provided the opportunity for the students to progress through the engineering design process in groups. It was anticipated that the TEE teachers would follow precisely the provided script (Appendix C) which encouraged optimization but did not emphasize the mathematical and analytical reasoning approaches tied with engineers. None of the identified teachers had a 4-year degree in engineering; rather, all of the teachers came from traditional TEE preparation programs. The common background for the teachers will assist in the

reliability, fidelity, and validity measures of the study.

The cognitive processes undertaken by students during the design process have been documented in a variety of ways (e.g., Lammi & Becker, 2013); although relevant and interesting, these are beyond the scope of this particular work. It is anticipated that the author and/or others will seek opportunities to evaluate different cognitive processes at each step of the design task and correlate them with other important indicators for each student in the future.

Design Portfolios

Design portfolios have been used as a means for assessing student learning and achievement in open-ended design problems for many years (Bain et al, 2004; Kimbell et al., 2007). Design portfolios take many forms and usually serve as a means for the student to document and “show” their progress through the design process (Kimbell et al., 2007). Notably, design portfolios have been linked with increases in student SDL (Goliath, 2009; Kicken, Brand-Gruwel, Merrienboer, & Slot, 2009). The relationship between student SDL and student achievement was specifically analyzed as part of this study (Chapter IV). Prior to embarking on the project that culminated in the *LiveAssess* and *CompareAssess* software, a team from Goldsmiths University, led by Richard Kimbell, conducted a thorough review of design portfolios and their use in design and technology classes (Bain et al., 2004). Kimbell (2007), noted that:

The best analogy is neither a *container* nor a reported *story*, but it is rather a ***dialogue***. The designer/learner is having a conversation with him/herself through the medium of the portfolio. So it has ideas that pop up but may appear to go nowhere and it has good ideas that emerge from somewhere and grow into part

solutions and it has thoughts arising from others' comments and reflections on the ideas.... Looking in on this form of portfolio is closer to looking inside the head of the learner, revealing more of what they are thinking and feeling and witnessing the live real-time struggles to resolve the issues that surround and make up the task. Importantly, this dynamic version of the portfolio does not place an unreal post-active burden on the learners to reconstruct a sanitized account of the process. (p. 127, emphasis in original)

This study was based on the research and design utilized by Richard Kimbell (Kimbell, 2012a; Kimbell et al., 2004, 2007) with relation to the portfolio creation and implementation in the classroom. The student's portfolios not only served as their "final product" but a "dialogue" (Bain et al., 2004; Kimbell, 2012b; Kimbell et al., 2007) representing their progress through the design process. This study can serve as a valuable resource for comparison with Kimbell's previous work and also sought to answer calls for more research around SDL and design portfolios (Kicken et al., 2009).

Summary

Through an open-ended engineering design problem and access to mobile devices in K-12 classrooms, possible relationships between mobile devices and students SDL and student achievement were studied. Mobile devices, STEM education, SDL, and engineering design problems are all "hot-topic" issues that remain at the forefront of the academic conversation. In the Educational Horizon Report (Johnson et al., 2013) mobile devices in K-12 classrooms were mentioned in all five of the "key trends" for the educational future. Additionally, mobile devices were cited in 5 of the top 10 "Trends Impacting Decisions" and 3 of the top 10 "significant challenges" facing education.

Despite limitations on mobile devices in the majority of school settings, recent

requests for the inclusion of mobile devices into school classrooms and curriculum have significantly increased (Cheung & Hew, 2009; Johnson et al., 2011; S. Kim, Holmes, & Mims, 2005; McCaffrey, 2011; Project Tomorrow, 2011, 2012b; K. M. Thomas & McGee, 2012). Gaskell and Mills (2010) concluded that there is much evidence that mobile technologies are playing an increasing role in education and the use of mobile technologies is increasing in the developed world in a number of areas. Opinion papers, educational theorists, and many districts across the country have been caught up in the mobile device learning frenzy. A quick Internet search reveals the existence of numerous news articles relating to mobile devices and K-12 classrooms. Increasingly, districts, schools, and teachers are becoming comfortable with and open to the idea of including mobile devices in their classrooms (Johnson et al., 2013). Mounting support from parents and administrators (Project Tomorrow, 2011; Johnson et al., 2013) appears to be leading towards a change in the way mobile devices are included in K-12 classrooms.

Limited research has been done to assess the impact of access to mobile devices in the classroom (Liu, Scordino, et al., 2014; Sutton, 2011), with a shortage of rigorous research methodologies being utilized. As Wan (2011) pointed out with relation to the literature on mobile devices in K-12 classrooms, “There is a lack of rigorous research in the field” (p. 5). Today’s pertinent literature consists mainly of descriptive reports, small-scale case studies, pilot studies, and opinion articles (Banister, 2010; Crichton et al., 2012; Daher, 2010; Wan, 2011). Of the relatively few truly reliable experimental studies, many are based on small sample sizes (Cheung & Hew, 2009; Daher, 2010; Swan et al., 2005) and conducted over inadequate time spans (Cheung & Hew, 2009). Several of the

studies rely on self-reported data or surveys (Project Tomorrow, 2011, 2012a, 2012b) or, in some cases, fail to acknowledge research methods at all. Additionally, much of research conducted on mobile device implementation in classroom settings has been conducted externally to K-12 classrooms (Froese et al., 2012; Kuznekoff & Titsworth, 2013; Pfeiffer, Gemballa, Jarodzka, Scheiter, & Gerjets, 2009). This study, conducted in a TEE classroom during a STEM activity, worked through a mixed-method counter-balanced approach to explore the relationship between mobile devices and student SDL and achievement.

CHAPTER III

METHODOLOGY

The purpose of this study was to compare the learning achievement (as demonstrated by the rank-order for student products and portfolios) and self-directedness of students with and without access to mobile devices in an open-ended engineering design challenge presented in a middle school TEE classroom during a STEM activity. The inclusion or exclusion of mobile devices in K-12 classrooms is a divisive issue with competing voices, strategies, and opinions. In an effort to provide administrators, teachers, parents, and students with information and tools for decision-making regarding the inclusion or exclusion of mobile devices in K-12 classrooms this research utilized a counter-balanced research design which will be described here.

Research Design and Research Questions

The guiding research questions for this study were as follows.

1. What relationship, if any, exists between middle school student access to mobile devices and student self-directed learning?
2. What relationship, if any, exists between middle school student access to mobile devices and student achievement on an open-ended engineering design problem?

This study used a mixed-method approach with a primarily quantitative design to answer the research questions. Additional qualitative interviews were utilized to further examine the findings obtained from the quantitative analysis. The qualitative portion focused on exploring the “why” of the findings from the quantitative results. Statistical

methods of t test, ANOVA, ANCOVA, correlation, and multiple regression were used to analyze the data. The following sections describe the research design for this study.

Institutional Review Board

Prior to any data collection approval was obtained through the Utah State University Internal Review Board (IRB) as well as the IRBs for both the participating school districts (pilot and main study). The IRB was initially contacted following study approval from the research committee and all documentation, paperwork, and applications were completed. Following a meeting between the researcher and the director for the Utah State University IRB the IRB application was formally completed and approved. Minor changes, resulting from the IRB processing and approval procedure, were presented to the research committee prior to any research being completed. All data collected as part of this research was stored on a password protected server. The password was only known to the researcher.

Pilot Study

Following IRB approval and the collection of permission forms, an initial pilot study was conducted at a middle school. Working with the TEE teacher at the middle school the researcher implemented the study design using two periods of the *Exploring Technology* class (50 students, 45-minute class periods, Monday-Friday schedule, 2 weeks).

The first class period involved in the study completed the study using the paper portfolios and did not have access to mobile devices during the study. The second class

involved in the study was designated the experimental group and completed the study using iPads; these students also had access to personal mobile devices during the study. The researcher adhered to the classroom protocol (Appendix C) during the study and took copious notes regarding changes that could improve the study. The following changes were made to the study protocol and process as a result of notes and observations recorded by the researcher during the pilot study.

- Several questions on both the pre- and post-questionnaires were reworded following questions by students as to the intent or meaning of the questions
- A teamwork portion was added to the lesson plan for the second day—this was done because several students mentioned that they struggled working in teams or were not accustomed to working in teams. This portion of the lesson presented principles of teamwork and a discussion section for the teacher to answer questions and help students progress in their abilities to work in teams.
- The pills chart was reworked so it showed when each pill was taken (day of the week and time of day). Many students complained about not being able to understand how often each pill was taken just reading the instructions. The number of total pills was also reduced to a more “realistic” number following several student complaints that the engineering design challenge was not realistic.
- Initially several student groups complained that they “couldn’t think of anything.” It was also noticed by the researcher and the teacher that many of the designs were identical. Counseling together it was decided that in the full study students would be shown example pictures of previous student products (from the pilot study) as well as several examples from an internet search for “medicine holder.” This falls in line with research by Bamberger and Cahill (2013) which showed that allowing students to see such pictures can foster creativity and improve overall design concepts.
- Several minor wording changes were made to the paper and electronic portfolio. These changes were almost universally made to the instructions portion of each box following questions by students as to the intent of the box/question.
- The “post-it” note activity wording was updated so students would more easily recognize the four pictures they were supposed to produce. Additionally, the activity wording was updated so students knew which

pictures were to be of other group products and which pictures were to be of their own product.

- In the pilot study students were allowed to use the “handling collection” materials as part of their building with the “modelling collection.” Following discussions with a committee member, who has worked with Kimbell’s model and research previously, this was discontinued for the full study. The rationale was that the “handling collection” was meant to merely spur on ideas but not be actually be used in the building process.
- The students in the pilot study struggled during the handling collection portion of the project. Students got bored easily and struggled to come up with ideas or connections for their final design. Following more discussion with the aforementioned committee member the supplies in the handling collection were revised and additional supplies were provided for the full study. Additionally, a set of questions for the teachers to read while students were working with the handling collection was provided. These questions were meant to encourage creativity and most especially connections between the items in the handling collection and possible design solutions.
- Several minor time-change adjustments were made to the overall lesson plan and design progression. On introspection the researcher felt that the lesson portion of the activity was too rushed in the pilot study and the design portion was too long. Adjustments were made to the schedule which allowed teachers 20 additional minutes for the lesson portion of the activity.
- Small changes were made to the quantities on the supply list to provide more of the supplies that were most commonly requested during the pilot study.
- A Spanish version of the study permission form for students and parents was commissioned for several students that asked for a Spanish copy for their parents.

Following these changes, the appendices and other documentation were updated and prepared for implementation in the full study. Preparation for the full study included: preparation of handling collection and modelling collection kits, and retrieval of signed permission forms for participating students. The permission forms were provided to the teachers one month in advance of the study and collected by the teachers and given to the researcher prior to the study commencing.

Population

The population for this study was chosen from a large suburban school district located in the western U.S. This district is in the top 50 largest districts in the U.S., by number of students served, and had an enrollment of over 72,000 students. This district was selected for participation in this study based on location and willingness to cooperate in this study. Being a very large district, this district provided a representative sample of a large group of students. This suburban district was made up of primarily middle-class families (16% free/reduced lunch) and spanned over 650 square miles of land area. Following expressed interest from teachers to participate in this study, district and school officials and administrators were contacted and an official approval was secured for conducting the study. Six teachers (18 classes, ~700 students) participated in the study. Data for the classrooms, teachers, and schools regarding student socioeconomic status, class size, and enrollment were obtained and compared as part of the study for each school identified and relative comparability was found between school, and classroom student populations (see Appendix D for teacher and school demographic data). Additionally, student GPA and age were collected via self-report measures on the demographic questionnaire (Appendix E); these scores were compared to ensure comparability with regards to SDL readiness across groups. Student responses related to technology and mobile device use (Appendix B) were assessed using the *Digital Natives Assessment Scale* (Teo, 2013) and compared across classes as another means of ensuring relative equivalence across classrooms.

All teachers selected for this study taught at least two sections of the *Exploring*

Technology course (USOE, 2014a); an introductory technology class for seventh and eighth graders that serves as the prerequisite for many other TEE classes (USOE, 2014a). If the teachers taught more than two sections of *Exploring Technology*, teachers were given the option of including their additional sections in the study. This resulted in 18 total classes for the study, with an average of three classes per teacher. As per state education standards (State CIP Code 21.01012, Standard 9, objective 4), one unit of the *Exploring Technology* class consists of activities and lessons surrounding design and open-ended problems (USOE, 2014a). Teachers were asked to set aside two specific weeks of instruction time (five class periods on an A/B, every other day schedule) for the study. These 2 weeks were November 30, 2015 through December 11, 2015.

Recognizing that teacher quality is one of the biggest factors in student success (Darling-Hammond, 2000) every effort was made to ensure comparable teacher quality. This was especially important as some studies have identified instructor traits in problem-based learning situations to be impactful on student SDL (Goh, 2014). Each teacher was purposely selected for this study for a variety of reasons (see Appendix D for teacher and school demographic data). Each teacher was a Level 2 teacher (representing the successful completion of at least 3 years of teaching, recommendation from school administration, and completion of an intensive entry-years teaching enhancement program), was an active participant in local and national organizations, and had demonstrated excellence in teaching (as per recommendations from the district TEE coordinator). Teachers were all trained during a 2-hour training session and all applicable training and classroom materials were provided both electronically and as hard copies to

each teacher. The training sessions were developed by the researcher in cooperation with the research committee and based on research performed by Kimbell (2007) in similar studies. Teachers were compensated (\$100) for their participation in the study in the form of a gift card. Teacher compliance and fidelity to study measures and the teacher script were monitored through daily observations by the researcher and responses to qualitative interviews at the end of the study. As teacher learning facilitation practices have been linked with SDL (Goh, 2014; Wong, 2013), teachers were specifically trained to follow the script in order to improve the study fidelity. Multiple times during the study teachers asked the researcher a question pertaining to the study; these questions were answered via email that was copied to each teacher in the study—thus ensuring that all teachers received the same training and information.

Research Design

Overview. Similar to research conducted by Kimbell (2007, 2012a), students in a TEE class working on a STEM activity received instruction related to the engineering design process and were presented with an open-ended engineering design problem. Additionally, students received one day of instruction regarding appropriate uses of mobile devices and working in groups. This instruction was a minor deviation from Kimbell's (2007, 2012a, 2012b) work but was seen as a necessary addition to the study which allowed the students to be given instruction prior to working in groups and having access to mobile devices. A variation of the open-ended design problem that students responded to has been used in previous studies (Kimbell, 2012a, 2012b; Kimbell et al., 2007) and has shown positive results with relation to student completion, experience, and

reliability (Kimbell, 2012b; Kimbell et al., 2007). Students worked in groups of three or four (teachers assigned students to groups so that each participating class had 10 design groups) to complete the open-ended engineering design challenge in class, which revolved around designing a new container/ dispenser for distributing pills to a client in specified quantities and at prescribed times (see similar examples in Kimbell, 2012a, 2012b; Kimbell et al., 2007). Students designed with a specific user in mind (an elderly individual who enjoys traveling internationally).

Following the research design utilized in Kimbell (2012a) each group of students was initially provided with a “handling collection” from which student’s derived ideas for their final design. After a brief time where students explored the items in the handling collection and brainstormed as a team the handling collections were returned to the teacher. Students were shown pictures of student creations from the pilot-study and asked questions that were specifically formulated to help student draw connections and think creatively (Bamberger & Cahill, 2013). Afterward students were provided with a ‘modelling collection’ which was used to construct a prototype of their design (see Appendices F and G for detailed lists of items in the handling and modelling collections). The handling collection and the modelling collections for student use during the design process have been the subject of considerable research (Kimbell, 2012a) and have been found to be well suited in providing flexibility and feasibility to students during the brainstorming process as well as enhancing creativity (Bamberger & Cahill, 2013).

The handling collection was designed to stimulate student thinking about a wide range of objects, methods, and ideas related to the design task. The handling collection

consisted of several items (see Appendix F) designed to stimulate thought, connections, and creativity.

During the engineering design challenge students completed a portfolio for their group showcasing their journey through the design process. These portfolios followed a prescribed pattern (Appendices H and I) with prompts for inputs and information from students and was intended to be both a prompt and a reflection tool during the design process. Two of the teachers completed portfolios on paper (Appendix H), while the other four teachers completed the portfolios using iPads (Appendix I). Table 1 shows the breakdown by group for the study design.

Table 1

Research Design for the Study

Teacher (class)	Paper portfolio	Electronic portfolio	Mobile devices allowed during unit
Teacher A (1)	X		X
Teacher A (2)	X		X
Teacher A (3)	X		X
Teacher A (4)	X		X
Teacher B (1)	X		
Teacher B (2)	X		
Teacher C (1)		X	X
Teacher C (2)		X	X
Teacher C (3)		X	X
Teacher D (1)		X	X
Teacher D (2)		X	X
Teacher D (3)		X	X
Teacher E (1)		X	X
Teacher E (2)		X	X
Teacher E (3)		X	X
Teacher F (1)		X	
Teacher F (2)		X	
Teacher F (3)		X	

Note. Each row represents one class corresponding with a teacher.

All students in the mobile group were trained as part of the classroom protocol on how to use the school-provided iPad and the iPad app, *LiveAssess* by their teachers. All students in the paper group were trained on how to fill out the paper portfolios by their teachers. The paper portfolios and the electronic portfolios looked similar and covered the same content, questions, prompts, as well as containing the same space for drawings and notes. Students in both the paper groups and the electronic groups were prompted by their teachers at specified time intervals to fill in information on their portfolios.

The overall progression and flow of the research was managed through a script (Appendix C) provided to teachers and checked by the researcher. This script was adapted from research outlined in Kimbell (2007, 2012a, 2012b). There are several reasons for the script including training, ensuring comparable equity across classrooms, validity, and reliability (Kimbell, 2012b). The researcher trained all teachers on the script during the preresearch training and the researcher observed classrooms daily during the research to ensure the script was precisely followed. Any deviations from the script were addressed immediately by the researcher with the teachers and corrected. The majority of these deviations were very minor and consisted of teachers taking more than the allotted time to complete each activity. The researcher worked with each teacher to improve their timing for activities and by the third day of the study there were no additional deviations from the script for the remainder of the study. Overall there were no significant deviations from the script and each teacher and their students completed all activities in the prescribed time.

A full copy of the teacher script and research outline is included (Appendix C)

and a shortened outline of the study is also included (see also Appendix J). The school district, which uses an A/B (every other day) schedule, uses middle school class periods that are approximately 90 minutes long. Five class periods (2 weeks) were used for the study.

Prior to the study. Demographic information for each class/school was collected and teachers and student information was compared to ensure comparability between classes. Students were provided with parental permission forms and information regarding the study. Teachers were also provided with permission forms for participation in the study and the qualitative interview. Teachers passed out and collected the forms during a three-week period prior to the study. Students were given credit by their teachers for returning the form, regardless of whether permission for data collection was granted. Students, parents, and teachers were also informed that they would be creating a unique identifier to use throughout the study—these identifiers were used to match student responses while also helping maintain anonymity of the students.

Day 1. Students turned in parental permission forms for participation in the study (students without returned permission forms still participated in classroom activities however, their survey responses were not included in the study) and completed the first questionnaire on the computer or iPad. The first questionnaire consisted of three parts:

- The adapted *Digital Native Assessment Scale* (Appendix B)
- The modified *Self-directed Learning with Technology Scale* (Appendix A)
- A student demographic questionnaire (Appendix E)

Teachers taught the lesson on digital citizenship and appropriate mobile device use

(Appendix K; Ribble, 2011; Ribble & Bailey, 2007).

Day 2. Teachers taught the students about the engineering design process (Appendix K) and then introduced the unit to students following a script (see Appendix C) provided by the researcher. Students were placed in groups of 3-4 by their teacher so that there was a total of 10 groups in each class. Students relocated to sit with their groups and teachers introduced the students to the engineering design problem. Students in the paper-group received copies of the paper portfolios and instruction regarding filling out the portfolio correctly and completely. Likewise, students in the mobile-group received one iPad per group with the app *LiveAssess* pre-loaded. Students were shown how to navigate the app, how to fill in information, and how to complete the portfolio correctly and completely. Students explored the handling collection and began brainstorming. Student ideas were discussed with partners, criteria for success was outlined, and ideas were revised. Students begin working in groups with the modelling collection.

Day 3. Students continued to develop ideas and follow the script based on similar studies by Kimbell (2007, 2012a, 2012b). Students rolled a dice at prescribed times and responded to corresponding questions regarding their design and brainstorming as they continued to design the product. This process allowed students to roll a die and, depending on the number rolled, respond to a question on their portfolio that pertained to their overall progress. Students conducted the red-pencil review, a process where they switched portfolios with another group and identified weaknesses in red pencil. Students also took their first photo of their product (two Fujifilm Instax Cameras were provided by

the researcher for each paper-based class. Electronic portfolio classes used the iPads to take pictures). Students continued to design, develop, and work in their groups. Midway through class students took their second photo of their product, completed their personal and team reflections, and responded to the question: “what will we do tomorrow?” Students ended class by taking their third photo.

Day 4. Students began by setting target goals for completion. Students worked collaboratively in the “post-it celebration.” The “post-it celebration” was an opportunity for students to walk around the room and look at other group work. Students identified the “wackiest idea,” the “best idea” and areas of weakness in their own design. Students also made plans for what they would do next. Students worked in groups modelling and responding to questions from a third and fourth dice roll. Students took their fourth photo and completed the green-pencil review. Similar to the red-pencil review, students traded portfolios with another group; however, this time groups used a green-pencil to identify strengths of the portfolio and design. Students continued to work modelling in their groups, took their fifth photo, and responded to the question from their fifth dice roll.

Day 5. Students worked in groups, took their sixth photo, completed a team and personal reflection, and finished designing their product. Students took their seventh (final) photo, cleaned up their work areas, and finished their portfolios. Students took the post-questionnaire which consisted of:

- The modified *Self-directed Learning with Technology Scale*
- Open-ended questions regarding their perceptions of the study, mobile devices, and SDL
- Questions regarding their familiarity and comfort with open-ended,

engineering design, and teamwork activities.

The researcher conducted semistructured interviews with five students from each teacher. These students were selected from one class for each teacher. Teachers were instructed to choose students based on the following criteria: (a) students needed a signed permission form granting permission for the interview, (b) two of their “top performing” students were selected, (c) two of their “low-performing” students were selected, and (d) one of their “average-performing” students were selected. The researcher conducted the student interviews outside the classroom in the hallway of the school. The researcher collected all paper portfolios and supplies from each of the teachers. The end of the study coincided with a holiday break so teacher interviews were conducted immediately following the holiday break via telephone. The questions and protocol for the student and teacher interviews can be found in Appendix L and Appendix M.

Data Collection

In an effort to assess the impact of mobile devices on student SDL a counterbalanced quasi-experimental design was used to provide for the removal of possible covariates and lurking variables associated with the differences between mobile and paper portfolios (see Table 1). The paper-based group completed the portfolios on paper while the app-based group completed the same portfolio electronically on the iPads. Students designated as “mobile devices allowed” groups were allowed to use their own personal or school mobile devices during the study. Students in these groups were allowed, but not forced, to use these devices to access the Internet, look up ideas, explore possibilities, communicate or collaborate with others, and otherwise improve their

design.

Pre-study demographic questionnaire. A pre-study demographic questionnaire (Appendix E) was used to collect data for further analysis related to student comparability, self-directedness, and achievement. Questions revolved around possible covariates to achievement and self-directedness identified from the literature review; these included student information related to: age, grades, access to technology, time spent with various technologies, and comfort level with various technologies.

Digital Natives Assessment Scale. In order to assess student's comfort, skill, and awareness of traits associated with a "digital natives" the *Digital Natives Assessment Scale* (DNAS) was adapted and included as part of the pre-study questionnaire. Student responses to the *DNAS* (Appendix B) were collected electronically by the survey instrument Qualtrics. A full description of the *DNAS*, including its development, validity, and reliability is included in chapter 3.

Modified Self-Directed Learning with Technology Scale. Student responses (pre- and post-study) to the *Modified Self-Directed Learning with Technology Scale* (Appendix A) were collected electronically by the survey instrument Qualtrics. This assessment was taken prior to the study and at the conclusion. Student responses were combined to form an overall self-directedness score for each student prior to and immediately following the study. These scores were used to help answer the research question related to students' SDL. A full description of the modified *SDLTS*, its development, validity, and reliability is included in Chapter III.

Student portfolios. All portfolios from the mobile-groups were automatically

collected by the iPads and stored on a server accessible only by the researcher and other graders. All portfolios from the paper groups were collected and digitized by the researcher. This digitization process included scanning in student pictures using a digital scanner and manually entering student responses to an electronic version of their paper-portfolio. In order to ensure the integrity of student responses the spelling, grammar, and structure of student responses was copied identically. The resulting product was 176 electronic portfolios which were used in the judging process.

Student survey responses. All data from student responses to the pre- (721 questionnaires) and post-questionnaires (610 questionnaires) were downloaded as an SPSS file for conditioning. The next step undertaken was the conditioning of the data. Conditioning is a process where the researcher attempts to “clean-up” the data for further analysis (Gall et al., 1996). The researcher worked directly with a seasoned academic advisor who relied on years of statistical research experience to oversee the integrity and validity of the process. The conditioning process of the data involved several steps:

Pre-study questionnaire data conditioning. The pre-study questionnaire was downloaded from *Qualtrics* for statistical analyses. The data were conditioned step by step in an effort to remove potentially harmful outliers and misrepresentative data using the following process.

1. Removed 49 responses to the pre-questionnaire that were recorded on the last day of the study. These responses came from students who inadvertently responded to the pre-questionnaire twice (once on the first day and once on the last).
2. Removed 46 responses that were “doubled-up”—i.e., the student started a

survey, exited, and then started again and completed the survey. Student unique identifiers, timestamps, and IP addresses were used to identify and remove the duplicates.

3. Removed 29 incompletes with many missing values (more than 20 questions not responded to).

4. Removed 46 surveys which were missing more than 10% of the values (7 or more blank responses).

5. One problem with the data collection software (Qualtrics) rose in discussions following the study. Several of the Likert-style questions were displayed using a slider with the initial slider location at the lowest answer possible. If students did not move the slider from that position the software recorded a “no response” value, regardless of whether students meant to answer a “0” or meant to leave the item blank. Following discussions with the identified statistical expert the researcher analyzed the responses for multiple students in an effort to determine whether the students left the responses blank intentionally or meant to record the lowest answer. It was determined that the students meant to answer the lowest possible value as opposed to a no-response. If students did not answer for any of the sliders it was determined that the students meant to leave the question blank, otherwise the lowest value was entered for the no-response items on questions with these sliders.

6. There were four instances of incorrect spelling of teacher’s names that were corrected by the researcher.

7. The same process identified in step 5 was repeated for questions 8, 28, 14, 20, 22, 24, 18, 22, and 23.

8. An average score was computed using each of the student responses on the *Digital Natives Assessment Scale*. This average score was used in data analysis as a representative score of their “digital nativeness,” or their overall comfort and experience with digital technologies.

9. An average score was computer using each of the student responses to the *Modified Self-Directed Learning with Technology Scale*. This average score was used in later data analysis as a representation of their overall self-directedness with relation to learning and technology prior to the study.

Post-study questionnaire data conditioning. The post-study questionnaire was downloaded similarly to the pre-study questionnaire and a combined data set was formed using the student’s pre and post responses. These responses were match by student unique identifier. The following steps were taken to condition the data:

1. One entry with a timestamp from December 3, 2015, was removed. A matched pretest could not be identified using the unique identifiers and the date this survey was taken corresponded to the middle of the study as opposed to the expected dates near the end.

2. Removed 56 responses that were “doubled-up”—i.e., the student started a survey, exited, and then started again and completed the survey. Student unique identifiers, timestamps, and IP addresses were used to identify and remove the duplicates.

3. Removed 16 incomplete surveys with many missing values (more than 20 questions not responded to).

4. Removed surveys which were missing more than 10% of the values (5 or

more blank responses).

5. Following the identified procedure above the lowest values were substituted for slider-style questions with no responses. This was done for questions 3 and 4.

6. Sixty-six surveys were removed as a result of lack of parental or student permission to be involved in the study.

7. A variable was added to the data that corresponded to whether each student was in a paper or electronic portfolio group. Student group numbers and teacher names were used to populate these variables.

8. A variable was added to the data that corresponded to whether each student had access to a mobile device. Student group numbers and teacher names were used to populate these variables.

9. Four variables derived from the ACJ results were added to the post-study questionnaire data set. These included:

- A rank variable for each student group portfolio (1 being the best and 176 being the worst)
- A parameter variable for each student group portfolio representing their overall score (derived from their win-loss record in the during the judgment process). These values ranged from -11.2311 (the worst portfolio) to 10.841 (the best portfolio).
- A rank variable for each student group creation (1 being the best and 176 being the worst)
- A parameter variable for each student group creation representing their overall score (derived from their win-loss record in the during the judgment process). These values ranged from -11.2199 (the worst portfolio) to 10.2957 (the best portfolio).

10. An average score was computed using each of the student responses to the

Modified Self-Directed Learning with Technology Scale. This average score was used in later data analysis as a representation of their overall self-directedness with relation to learning and technology after the study.

Prior to the final data analysis, a panel of graders graded all the portfolios. The software that facilitated the grading process has been described earlier and is called *CompareAssess*. *CompareAssess* is based on the work of Pollitt (2004) and Kimbell (2007, 2012a, 2012b) and an in-depth discussion of the *LiveAssess* and *CompareAssess* tools and their development is included in Chapter II of this work.

Prior to assessment all student portfolios and pictures of final student creations were digitized and transferred to the TAG assessment team. The TAG assessment team prepared all the student portfolios and pictures of their final creations for final judgment. The team of graders consisted of five individuals: three professors with TEE or Design Education background, the researcher, and one licensed K-12 teacher with experience teaching TEE courses. The researcher was trained by TAG assessment and conducted a formal training for the rest of the judges. At the first training for the judges, prior to judging, the judges were introduced to the software and the group graded several pieces of student work according to the rubric (see Appendix N). This exercise was repeated until relative consensus among graders was established. Using several finished portfolios from the pilot study the judging team identified key characteristics that demonstrated SDL or progression through the engineering design process. These traits were used to form a hierarchical sequence that identified key portions in the portfolio that the judges would assess when judging.

1. Boxes 4-6: demonstrated understanding of the criteria, constraints, ability to make plans for designing, and brainstorming
2. Box 14: demonstrates the student's ability to assess their own design and their classmates design
3. Boxes 1-3: demonstrates student's ability to brainstorm and think creatively
4. Other boxes as needed (if a judgment could not be made to as which portfolio was better)

Following the initial meeting each grader was asked to make 20-30 judgments in the following 3-4 days. This initial sweep of judgments allows the ACJ engine to begin the process of ranking the portfolios. Initial judgments were identified as “easy” by most graders because of the wide variability in the quality of the portfolios.

At the beginning of the second week of grading another meeting was convened with the panel of judges. The first judging experiences were discussed and questions answered. Several salient points were addressed as part of the discussion in the meeting including:

1. The importance of looking at the portfolio as a whole rather than just the boxes identified in the initial meeting. This point was discussed at length and it was agreed upon that just because one portfolio was missing boxes 4-6 it did not necessarily mean it should be judged “worse” than another portfolio which did contain information in those boxes. It was agreed upon in the meeting that the entirety of the portfolios would be assessed prior to making “snap-judgments” as to which portfolio was better.
2. Technical errors seemed to be common for certain judges. The technical specifications for judging including browser use, Internet speed, and other suggestions from TAG were discussed.
3. The adaptive nature of the ACJ engine was discussed. This involves the engine showing only one new portfolio or product each judgment round—a feature designed to speed up the grading process which takes place after six complete rounds of judgment have been completed (a round of judgment is considered complete when every piece of work has been graded once) was outlined and demonstrated for the team of judges.

During the second week allotted to grading, each of the graders continued making judgments until a total of 175 judgments per grader were completed. One hundred seventy-five judgments for each grader constituted roughly eight rounds of judgment (each time that every artifact is compared at least once is referred to as a “round of judgment”). This resulted in a reliability coefficients of $r = .943$ for the student products (eight rounds of judgment completed) and $r = .934$ for the student portfolios (seven rounds of judgment completed). Each judge was contacted and asked to complete 20 more rounds of judgment for both the student creations and the portfolios in an effort to increase the reliability and move both comparisons to 10 rounds. At the completion of 10 rounds of judgment, for both comparisons the final rank order was retrieved for both the portfolios and the student products. The final reliability coefficients (see Appendix O) were $r = .959$ for student products (10 rounds of judgment completed) and $r = .972$ for student portfolios (10 rounds of judgment completed). In conversations with the TAG assessment team it was determined that further judgments after this point would result in a “decreasing-returns” situation with little gain for the effort, therefore the judges were told to stop completing judgments after this point. The resulting ordinal ranking of student products and portfolios (see Appendix P) were used in the statistical analysis comparisons discussed in Chapter IV of this work.

Interviews. Semistructured interviews were conducted with each of the teachers from the study as well as five students from each teacher’s classes. Teachers were asked to identify two “top-performing” students, two “bottom-performing students” and one “middle-performing student” for the interviews. Prior to interviews it was confirmed that

student and parental permission for interviews was obtained for each identified interviewee. During the interviews teachers and students were asked several questions (Appendix L and Appendix M) regarding their perceptions and experience with the study. Questions sought to shed further light on mobile devices and student SDL in the study. Interviews were transcribed by the researcher and analyzed using qualitative coding schemes. As explained in Berg (2009), semistructured interviews involve a series of questions and special topics that are asked of each participant, but the interviewer has the freedom to probe beyond the answers to the prepared questions. As part of the semistructured format the researcher can reorder the questions during the interview or probe for additional information (Berg, 2009). Additionally, the researcher can add or delete probes to the interview questions, answer participants' questions, and clarify questions. The semistructured student interviews took place during the last class period allocated for the study. Chosen students were asked to accompany the researcher to the hallway where the interview audio was recorded. Teacher interviews were conducted via telephone a few weeks after the study and the audio was recorded.

Prior to the interviews students and teachers were informed that their responses would be confidential and allowed to ask any questions about the interview. Students and teachers were also read the definition for mobile devices and self-directed learning as outlined in the interview protocol (see Appendix L and Appendix M). During the interviews the researcher loosely followed the set script and sought to understand provided answers through follow-up and probing questions. Students and teachers were given the option to skip any question they did not wish to answer or did not feel

comfortable answering.

Data Analysis

Quantitative. Descriptive statistics were calculated for all the data resulting from the study and potentially anomalous outliers were identified, using standard statistical practices (Gall et al., 2007) and removed. Following this procedure, all quantitative data were analyzed using *t* test, ANOVA, ANCOVA, correlation, and multiple regression analysis. Multiple regression analysis, a statistical tool for understanding the relationships between two or more variables (Cohen, Cohen, West, & Aiken, 2003) was specifically useful for analyzing different types of variables present in this study (ordinal, nominal, rank, ratio) because this research contains rank and continuous variables. By using multiple regression techniques, the researcher was able to remove several possible covariates and lurking variables (e.g., age, technology se) while holding constant the dependent variable (SDL, student grade received on their portfolio). Additionally, multiple regression was well suited for analysis of data in which there are several possible explanations for the relationship among possibly explanatory variables (Cohen et al., 2003), and multiple regression is an effective method of measuring the magnitude of particular effects on outcome variables. Table 2 outlines the statistical analyses used in this study.

Diagnostics. Multiple regression diagnostics were completed as part of the multiple regression analysis to ensure the proper assumptions were met for the research. Regression diagnostics tests were completed to check for linearity, homoscedasticity, normality of residuals, uncorrelated error, mean independence, and normally distributed

Table 2

Overview of Statistical Analysis Procedures for Research

Comparison	Variables	Analysis
Classroom comparability	Age, GPA, <i>DNAS</i> , Pre- <i>SDLTS</i>	ANOVA
Data set comparability	Pre-study <i>SDLTS</i> score, <i>DNAS</i> score, average grades, average time spent with technology, average mobile device use, and average mobile device skill	Independent Samples <i>t</i> test
Demo & Self-directed Learning	Age, GPA, Technology Access, Technology Skill, <i>SDLTS</i> Pre Score (Co-Var), <i>SDLTS</i> (post)	Mult. Regression
SDL (pre) & Self-directed Learning	<i>SDLTS</i> Score (pre), <i>SDLTS</i> (post)	Paired sample <i>t</i> test
<i>DNAS</i> & Self-directed Learning	<i>DNAS</i> , <i>SDLTS</i> , <i>SDLTS</i> (post)	Correlation
Portfolio Type & Self-directed Learning	Portfolio Type, <i>SDLTS</i> Pre Score (Co-Var), <i>SDL</i> (post)	ANCOVA
Access to Mobile devices & Self-directed Learning	Access, <i>SDLTS</i> Pre Score (Co-Var), <i>SDLTS</i> (post)	ANCOVA
Demo & Achievement	Age, GPA, Access to technology, Skill in using Technology, Portfolio Score, Product Score	Correlation
SDL (pre) & Achievement	<i>SDLTS</i> Score (pre), Portfolio Score, Product Score	Correlation
<i>DNAS</i> & Achievement	<i>DNAS</i> , Portfolio Score, Product Score	Correlation
Portfolio Type & Achievement	Portfolio Type, Portfolio Score Portfolio Type, Product Score	Independent Samples <i>t</i> test
Access to Mobile devices & Achievement	Access, Portfolio Score, Product Score	Independent Samples <i>t</i> test
SDL (post) & Achievement	<i>SDLTS</i> Score (post), Portfolio Score, Product Score	Correlation

error. It was determined that each of the regression diagnostic tests were satisfied and the assumptions met for the multiple regression test. Subsequent to these diagnostics tests the following were analyzed.

Demographics data. This data, obtained from the school and district was analyzed using descriptive statistics via *SPSS* software (version 22). Comparability

between schools and classrooms was checked and any major deviations were investigated and reported in Chapter IV of this document.

Digital Natives Assessment Scale. Descriptive statistics were calculated using *SPSS* software and an overall comfort level with technology was obtained for each student and each class. These results were used in later analysis.

Student self-directed learning. The first research question guiding this study was: what relationship, if any, exists between middle school student access to mobile devices and student self-directed learning? The dependent variable used was student score on the modified *Self-directed Learning with Technology Scale*, taken on the concluding day of the study. Data for each student on the following variables was collected and used as potential correlates with student SDL: student demographics, *SDLTS* pretest score, *Digital Natives Assessment Scale* score, portfolio type, access to mobile devices, and student rank (score) received from the *LiveAssess* assessment of portfolios.

A multiple regression analysis was conducted and all variables checked for correlation with the dependent variable: student score on the post-study modified *Self-directed Learning with Technology Scale*. Each of the covariates was analyzed individually and holistically (in combination with other variables) to determine the strongest predictors of high student self-directedness.

Student achievement. The second research question guiding this study was: what relationship, if any, exists between middle school student access to mobile devices and student achievement in an open-ended engineering design problem? The analysis for this

question was very similar to the previous question. The dependent variable was student rank received from the *LiveAssess* adaptive comparative judgment process. Data for each student on the following variables were collected and used as a potential correlate with student score: student demographics, *SDLTS* pre-study score, *Digital Natives Assessment Scale* score, portfolio type, access to mobile devices, and *SDLTS* post-study score.

A multiple regression analysis was conducted and all variables were checked for correlation with the dependent variable: student rank (score) received on the portfolio. Each of the covariates was analyzed individually and holistically (in combination with other variables) to determine the strongest predictors of high student rank (score) on the portfolios. Additionally, in an effort to answer our second research question, partial and semi-partial correlations were conducted to determine the unique contribution of mobile devices to student rank (scores) received. Specific attention was paid to retaining the student score on the pre-study modified *SDLTS* as this had a strong likelihood of being a key covariate (Cohen et al., 2003) to final student scores on the modified *SDLTS* and student score received.

Qualitative interviews. The interview data analysis process followed a standard format of causation and thematic coding (Saldaña, 2013) for themes and relationships. In an effort to triangulate findings from each interview the interviews were compared with findings from the quantitative portion of the study as well as with other interview findings.

Qualitative Interview Analysis Procedures

Initial coding. Data were initially coded by the researcher in a descriptive and

causation manner and then checked for reliability by a member of the committee with extensive experience in qualitative research. Descriptive coding is a process in which a researcher undertakes to identify the “basic topic of a passage” (Saldaña, 2013, p. 88). A single word or short phrase—most often a noun—was used as a descriptor for each sentence, paragraph, or section. Saldaña differentiates that it is important that codes are identifications of the topic, not abbreviations of the content. Saldaña pointed out that “descriptive coding is appropriate for virtually all qualitative studies” (pp. 88-90). Descriptive coding provides the researcher with a categorized inventory of the data’s contents and provides an essential groundwork for further coding.

Each interviewee response was read independently of the question and/or other responses and a single “topic” descriptor word or phrase was assigned. This process was repeated twice for each response for each of the interviewees until each response had two assigned topics (e.g., “decisions” “choices”). Causation coding was next completed for each interviewee response. Causation coding consists of attempting to identify cause and effect relationships, or relationships of one thing leading to another, contained in the interviewee response (Saldaña, 2013). All descriptor words and causation codes were listed in a spreadsheet next to the question topic and the spreadsheet was reviewed with a committee member assigned to check for reliability. Upon approval from the committee member the researcher proceeded to thematic coding.

Thematic coding. The thematic coding method is used by researchers to identify overall themes of interviewee responses (Saldaña, 2013, p. 163). In the initial thematic coding process, the researcher followed the suggested methods by reading through each

response and identifying a key word or phrase that described the content of the response. Additionally, causative relationships were identified and included in the initial coding column. Once the data were initially coded, all codes (descriptive and causation) were placed in one column of a common spreadsheet for each question. This visual representation allowed another venue for the researcher to further examine the data, and identify emerging trends. Additionally, reviewing the themes in the spreadsheet allowed for in-depth review of terminology to be discussed and defined in relation to the themes.

Comparison. Identified themes, and key findings from the interviews, were compared with findings from the quantitative analysis. Relationships were identified and all data from both the quantitative and qualitative portions of the study was used to check for reliability in findings. Any major deviations were noted and reported.

Threats to Validity

This research used a quasi-experimental counter-balanced design. Inherent in this research design are threats to validity and reliability. A quasi-experimental design was used for several reasons including convenience and practicality (students were already grouped in classes with a teacher at a certain location) and prevalence in educational research (Cohen et al., 2003).

Hawthorne effect. The Hawthorne effect refers to the fact that participants tend to act differently when something about their environment changes (i.e., mobile devices are allowed). It was anticipated that because mobile devices are so ubiquitous in society at large (Project Tomorrow, 2013; West, 2013) the affects, if any, from the Hawthorne effect would be minimal.

Selection. Selection deals with the equivalence of groups across research.

Socioeconomic status, *DNAS* scores, and pre-*SDLTS* scores were all compared across groups in an effort to ensure limited impacts from selection bias. Additionally, the counter-balanced design between paper and electronic portfolios, and mobile devices and no-mobile device groups accounted for some of the naturally rising selection issues.

Teacher effect. One of the internal validity concerns with this study relates to teacher effect. Specifically, it was identified that teacher quality could account for the differences in the dependent variables rather than the identified independent variables. To investigate the impact of differences in teachers on the findings of the study homogeneity of variance was calculated using a single-factor ANOVA to determine if the variance between mean scores for each class were greater than a chance occurrence would allow. Additional post-hoc methods of multiple comparison were performed post-ANOVA to check for the significance of the teacher effect. Significant findings related to the Teacher Effect were noted and included in the discussion section.

History. The entire study took place within a 2-week time period. As such, the effects from history were deemed to be minimal.

Maturation. Each teacher performed the study in the same course (*Exploring Technology*), the same grade levels, and the same school district. Because of these similarities, it was anticipated that participants in each of the groups and classrooms matured similarly as a result of the careful selection, suggesting minimal impacts from maturation.

Compensatory rivalry (a.k.a. “John Henry effect”). If the experimental or

control group of participants were aware of the research and the other group, participants may act in a way that will adversely impact the research. When participants believe the other group is receiving goods or services believed to be desirable (i.e., the use of a mobile device in class) social competition may motivate groups to act in abnormal ways. In order to lessen the possibility of a compensatory rivalry affect teachers utilized similar portfolio methods (paper or electronic) and introduced similar mobile device usage requirements in all their classes. The difference was a between-school difference, rather than a between-class differences, thus lessening the likelihood that compensatory rivalry occurred.

Reliability. In research, reliability is the overall consistency of a measure. A measure is said to have a high reliability if it produces similar results under consistent conditions. The reliability for instruments used in this study has previously been covered for the *LiveAssess*, *DNAS*, and modified *SDLTS*. Findings from this study were compared with literature in the fields of SDL, mobile devices, mobile-learning, m-learning, TEE, and STEM education to check for consistency and reliability. Additionally, the results were compared with similar work from design and technology (Kimbell et al., 2007), which informed the research design of this study.

Qualitative Coding

Recommendations from Guba and Lincoln (1989) were used to establish confirmability, dependability, and transferability of the qualitative data. Confirmability addresses the importance of neutrality and unbiased research. The researcher ensured the data collection procedures and interpretation of findings can be confirmed by other

researchers in a similar situation through comparison. An audit trail of materials, including the audio recordings of the interviews, the transcripts of the interviews, and the electronic data files from coding, was used to establish confirmability. Dependability relates to the ability to consistently find a study's findings again (Guba & Lincoln, 1989). This study used the audit trail and identity protection of participants to establish dependability. Transferability refers to the application of the study's findings to other situations. It is anticipated that the rich descriptions of teacher and student experience with the research will be utilized to help with future K-12 efforts in similar situations.

Summary

This study used a mixed-method counter-balanced design to answer the research questions. Quantitative analysis for this study revolved around student responses to several pre- and post-study questionnaires. A variety of statistical tests including t-tests, ANOVA, ANCOVA, correlation, and multiple regression were utilized to analyze the data. The findings from the quantitative analysis were clarified through the descriptive, causative, and thematic coding of 36 qualitative interviews (30 students, 6 teachers). In these semistructured interviews students and teachers were asked about SDL, mobile devices, open-ended engineering design problems, and their experience with the study. The findings from both the quantitative and qualitative portions of the study are included in the next chapter.

CHAPTER IV

FINDINGS

The purpose of this study was to investigate two research questions.

1. What relationship, if any, exists between middle school student access to mobile devices and student self-directed learning?
2. What relationship, if any, exists between middle school student access to mobile devices and student achievement on an open-ended engineering design problem?

This mixed-method study employed both quantitative and qualitative methodologies in an effort to assess possible relationships between access to mobile devices and student self-directed learning and achievement in a middle-school TEE classroom during a STEM activity. This study used a variety of measures to investigate these questions including pre- and post-questionnaires, a 2-week engineering design unit completed by students in small groups, qualitative interviews with teachers and students, and student creations of portfolios and products to satisfy the provided engineering design problem.

This study employed a variety of statistical techniques to analyze the results including t-tests, multiple regression, correlation, ANOVA, and ANCOVA techniques. Each technique provided different insights into answering the research questions and allowed the researcher to parse out important aspects of the data. The findings for this study revolved around the interpretation of each of these statistical techniques as well as noteworthy patterns and other observations. Additionally, qualitative interviews and subsequent analysis were used to support and inform the quantitative findings from this

study. Interpretation and recommendations based on these findings are found in Chapter V.

Quantitative Findings

The quantitative findings from the study are taken from three different sources, the pre-study questionnaire, the post-study questionnaire, and the matched questionnaire containing student pre- and post-questionnaire matched responses. Following data conditioning (see chapter 3) the total number of responses for data sets were: pre-questionnaire ($N = 555$), post-questionnaire ($N = 458$), and matched responses ($N = 221$). The decreasing size of each data set can be attributed to a variety of factors including, but not limited to: student absence, parent or student declining to participate, incomplete questionnaires, and student difficulty in following directions for forming and entering their uniquely assigned identifier. Due to the large decrease in questionnaires from pre-questionnaire to the combined data set ($N = 221$ out of the original $N = 555$) statistical analyses were conducted to ensure the combined data set was representative of the overall N participating in the study. The findings from this study are organized in the following way:

- Comparability of data (combined data set with pre-study data set)
- Demographic information (teachers and schools)
- Demographic information (students)
- Self-directed learning findings
- Achievement findings

Comparability of Data Sets

Due to a variety of factors the overall n -size of the data sets decreased over time. A large part of this decrease resulted from student's failure to correctly enter the same unique identifier on both the pre- and post-study questionnaires, reducing the initial n of 555 to 221 once data sets were combined. Due to the fact that several of the subsequent statistical analyses use the combined data set it was important to test the combined data set for comparability with the pre-study questionnaire. Independent samples t-tests were computed which compared the pre-study data with the combined data set on the following measures to test for significant differences: pre-study *SDLTS* score, *DNAS* score, average grades, average time spent with technology, average mobile device use, and average mobile device skill. The only test that revealed a significant difference between the pre-data set and the combined data set was for average grades, $F(772) = 6.13, p = .023$. A follow-up independent samples t-test, comparing the grades in TEE classes across the groups, did not return significant results ($p = .17$). These tests demonstrate that in all tested cases, with the exception of average grades, the students in the combined data set were not significantly different from the total n contained in the pre-study data set. It was thus concluded that, while not equal, the combined data set is comparable, representative, and suitable for use in further data analyses.

Demographic Information

Teachers. All the teachers in this study were middle school teachers employed in the participating school district. All teachers are male and have obtained a level-2 teacher's license, representing the successful completion of at least 3 years of teaching,

recommendation from school administration, and completion of an intensive entry-years teaching enhancement program. Each teacher in this study is also an active participant in local and national professional organizations, and has demonstrated excellence in teaching (as per recommendations from the district TEE coordinator)

Schools. Each of the schools that participated in this study are part of the participating school district. The participating school district is the largest district in this western state and the 43rd largest in the U.S. The participating school district serves a majority suburban population. Appendix D contains specific demographic information related to each school which participated in the study as well as overall demographic information for the school district which houses all the participating schools. Included information in Appendix D includes: school name, location, grade span, total students, enrollment by grade, gender, and ethnicity, student/teacher ratio, and free/reduced lunch eligibility of students.

Demographic Information (Students)

Age. All of the students who participated in this study were enrolled in one section of the *Exploring Technology* course. This course is defined at the state level as an introductory course in technology and related concepts and is open to both seventh- and eighth-grade students. It was anticipated prior to the study that the ages of students would vary greatly with the inclusion of two grades between the six participating teachers. Table 3 contains student age information separated by teacher. A one-way ANOVA was calculated to assess the significance in difference between student's ages across classrooms (Table 4). The test resulted in a significant value and LSD post-hoc analyses

Table 3

Student Age by Teacher

Teacher	Age 12	Age 13	Age 14	Age 15
Teacher 1	1	64	46	2
Teacher 2	1	57	33	0
Teacher 3	0	59	24	1
Teacher 4	48	18	0	0
Teacher 5	47	26	0	0
Teacher 6	93	35	0	0
Totals	190	259	103	3
%	34.1	46.5	18.5	.5

Table 4

Student Age by Teacher Analysis

Age difference	Sum of squares	<i>df</i>	Mean square	<i>F</i>	Sig.
Between groups	161.61	5	32.33	134.98	.00
Within groups	131.51	549	.24		
Total	293.18	554			

were conducted (Table 5). These results showed that the majority of students with Teachers 1, 2, and 3 were 13-14 years old (typically associated with eighth-grade students), while the majority of students with Teachers 4, 5, and 6 were 12 years old (typically associated with seventh-grade students).

GPA. Students were asked to self-report their grades on average for all their classes and specifically for their TEE classes. Table 6 contains student self-reports totals for student grades overall and Table 7 contains data for students grades specific to TEE

Table 5

Post-Hoc Analyses of Differences in Student Age by Teacher

Teacher	<i>n</i>	<i>m</i>	<i>SD</i>	1	2	3	4	5	6
Teacher 1	113	2.43	.55		.35	.04	.00	.00	.00
Teacher 2	92	2.37	.53			.28	.00	.00	.00
Teacher 3	83	2.29	.46				.00	.00	.00
Teacher 4	66	1.27	.45					.32	.99
Teacher 5	73	1.36	.48						.25
Teacher 6	128	1.27	.45						

Table 6

Student Grade Breakdown by Teacher

Teacher	A's (3.5-4.0 GPA)	B's (2.5-3.4 GPA)	C's (1.5-2.4 GPA)	D's (1.0-1.4 GPA)	F's (below 1.0 GPA)	Refused	Don't know
Teacher 1	59	35	12	4	0	1	2
Teacher 2	54	27	5	1	0	0	4
Teacher 3	54	20	4	1	1	1	3
Teacher 4	43	18	3	0	0	1	1
Teacher 5	43	23	2	2	0	0	3
Teacher 6	84	34	4	0	2	0	4

Table 7

Average Student Grades in TEE Classes by Teacher

Teacher	A's (3.5-4.0 GPA)	B's (2.5-3.4 GPA)	C's (1.5-2.4 GPA)	D's (1.0-1.4 GPA)	F's (below 1.0 GPA)	Refused	Don't know
Teacher 1	90	13	3	3	0	1	3
Teacher 2	75	12	0	0	0	1	2
Teacher 3	73	9	0	0	1	1	0
Teacher 4	56	8	2	0	0	0	0
Teacher 5	54	15	2	1	0	0	1
Teacher 6	101	18	4	2	1	0	2

classes. A one-way ANOVA demonstrated that the average grades in all classes and in TEE classes specifically were not significantly different across teachers (Tables 8 and 9).

Gender. Students were not asked to identify their gender as part of the questionnaires, however, teachers identified the total number of male and female participants in each of their participating classes. Table 10 includes student gender information for each teacher by participating class.

Access to technology. Students were asked about their access to technology at home and at school. Students responded by selecting whether or not they had access to a computer or mobile device at home and at school, and identified how much time they spend on each at home and at school. A one-way ANOVA was used to compare students with different teachers and their overall access to technology through computers and mobile devices. Table 11 shows the results from the one-way ANOVA. The analysis

Table 8

Average Student Grades Across all Courses by Teacher

Grade difference	Sum of squares	df	Mean square	F	Sig.
Between groups	5.37	5	1.07	.72	.61
Within groups	813.15	548	1.48		
Total	818.52	553			

Table 9

Average Student Grades Across TEE Courses by Teacher

Grade difference	Sum of squares	df	Mean square	F	Sig.
Between groups	5.87	5	1.17	1.36	.24
Within groups	470.74	546	.86		
Total	476.60	551			

Table 10

Gender by Teacher and by Participating Class

Teacher	Class period	Male	Female	Total students in each class
Teacher 1	B5	30	7	37
	B7	33	7	40
	B8	31	10	41
Teacher 2	A3	25	9	34
	A4	30	6	36
	B5	26	5	31
Teacher 3	A4	29	1	30
	B5	28	5	33
	B8	23	4	27
Teacher 4	A1/A4	60	14	74
Teacher 5	A1	32	2	34
	A4	27	3	30
	B6	18	3	21
Teacher 6	B5	24	7	31
	B6	28	6	34
	B7	27	6	33
	B8	24	12	36
Total		495	107	602

Table 11

Student Access to Computers and Mobile Devices by Teacher

Access difference	Sum of squares	<i>df</i>	Mean square	<i>F</i>	Sig.
Between groups	18.01	5	3.60	6.21	.00
Within groups	318.46	549	.58		
Total	336.47	554			

showed significant results and a LSD post-hoc test was utilized to identify differences (see Table 12). Post-hoc analyses revealed that students with Teachers 4, 5, and 6 had significantly less access to mobile devices and computers than the students with Teachers 1 and 2. Students with Teacher 3 had more access than students with Teacher's 4 and 6.

Comfort with mobile device technology. Students were asked to respond to several questions regarding their use of mobile devices and their skill level in working with mobile devices to accomplish certain tasks. Questions surveyed students on their use and skill in creating digital content, accessing information, acquiring new skills, communicating with others, and transmitting audio/visual data. Student scores for these questions were totaled and an average score representing each student's comfort with mobile device technology was obtained. These scores were compared across classes (by teacher) in a one-way ANOVA (see Table 13). The results showed a significant relationship between teacher and student comfort with mobile device technology. These findings were further explored using LSD post-hoc analyses (Table 14). Post-hoc

Table 12

Post-Hoc Analysis of Differences in Student Access to Computers and Mobile Devices by Teacher

Teacher	<i>n</i>	<i>m</i>	<i>SD</i>	1	2	3	4	5	6
Teacher 1	113	2.76	.86		.89	.19	.00	.00	.00
Teacher 2	92	2.77	.82			.16	.00	.00	.00
Teacher 3	83	2.61	.74				.04	.10	.02
Teacher 4	66	2.36	.68					.67	.95
Teacher 5	73	2.41	.71						.67
Teacher 6	128	2.36	.78						

Table 13

Student Comfort Level with Mobile Device Technology by Teacher

Comfort difference	Sum of squares	<i>df</i>	Mean square	<i>F</i>	Sig.
Between groups	10.27	5	2.05	2.37	.04
Within groups	475.36	549	.87		
Total	485.63	554			

Table 14

Post-Hoc Analysis of Differences in Student Comfort Level with Mobile Device Technology by Teacher

Teacher	<i>n</i>	<i>m</i>	<i>SD</i>	1	2	3	4	5	6
Teacher 1	113	4.00	0.82		.97	.95	.17	.03	.02
Teacher 2	92	4.00	0.91			.92	.18	.03	.03
Teacher 3	83	3.99	0.92				.22	.04	.04
Teacher 4	66	3.80	1.01					.47	.58
Teacher 5	73	3.69	1.00						.80
Teacher 6	128	3.72	.095						

analyses revealed that students with Teachers 1, 2, and 3 had significantly higher levels of comfort with mobile device technology than students with Teachers 5 and 6.

SDLTS pre-questionnaire. Part of the pre-study questionnaire involved students responding to questions related to their self-directedness with respect to technology and learning. These questions were derived from the *SDLTS* developed by Teo et al. (2010). A copy of the modified *SDLTS* questions can be found in Appendix A. Table 15 outlines the students' results after utilizing a one-way ANOVA in which the teachers were used as factors for separation of data. The results showed a significant relationship between teacher and student responses on the modified *SDLTS* (see Table 15). These results

Table 15

Student Scores on the Pre-Study SDLTS by Teacher

Pre-SDLTS difference	Sum of squares	df	Mean square	F	Sig.
Between groups	3.32	5	.66	2.21	.05
Within groups	164.67	549	.30		
Total	167.98	554			

indicated a need for LSD post-hoc analyses, which demonstrated that the students with Teacher 5 were significantly less self-directed in their learning with technology than their peers in all other classrooms with the other teachers (see Table 16).

Digital Natives Assessment Scale. Part of the study revolved around students performing skills associated with being a “digital native” (Prensky, 2007). As such, students were assessed on their “digital nativeness” on the pre-study questionnaire using the *Digital Natives Assessment Scale* (Teo, 2013). Students were asked to identify the degree to which they agreed with several statements about their ability to perform tasks associated with being a digital native using a Likert scale (Appendix B). Student responses were totaled and an average digital-native score was calculated for each student. These scores were compared across teachers in an effort to evaluate comparability across classrooms and schools. The results of the one-way ANOVA are included below in Table 17. The results were significant and LSD post-hoc analyses were conducted (Table 18). The post-hoc analyses revealed that the students with Teachers 1, 2, and 3 scored higher in relation to their digital nativeness than students with Teachers 4 and 5. Additionally, students with Teacher 2 scored significantly higher than students with Teacher 6.

Table 16

Post-Hoc Analysis of Differences in Student on the Pre-Study SDLTS by Teacher

Teacher	<i>n</i>	<i>m</i>	<i>SD</i>	1	2	3	4	5	6
Teacher 1	113	3.59	.59		.86	.92	.89	.01	.66
Teacher 2	92	3.61	.61			.94	.99	.01	.54
Teacher 3	83	3.60	.57				.96	.01	.61
Teacher 4	66	3.61	.48					.01	.60
Teacher 5	73	3.37	.48						.02
Teacher 6	128	3.56	.50						

Table 17

Student Digital Nativeness by Teacher

<i>DNAS</i> difference	Sum of squares	<i>df</i>	Mean square	<i>F</i>	Sig.
Between groups	5.69	5	1.14	3.16	.01
Within groups	197.95	549	.36		
Total	203.64	554			

Table 18

Post-Hoc Analysis of Differences in Student Digital Nativeness by Teacher

Teacher	<i>n</i>	<i>m</i>	<i>SD</i>	1	2	3	4	5	6
Teacher 1	113	3.36	.58		.39	.82	.02	.01	.23
Teacher 2	92	3.44	.61			.32	.00	.00	.05
Teacher 3	83	3.35	.57				.05	.04	.38
Teacher 4	66	3.15	.57					.92	.19
Teacher 5	73	3.14	.60						.14
Teacher 6	128	3.27	.65						

Student Self-Directed Learning

The first research question asked “What relationship, if any, exists between middle school student access to mobile devices and student self-directed learning?”

Possible relationships between dependent variables and student SDL were explored in an effort to inform this question. The findings from these analyses are shown in this section.

Demographics and student self-directed learning. A simple linear regression was calculated to predict student SDL (post-questionnaire score) based on demographic variables (age, grades in all classes, grades in TEE classes, computer and mobile device access, time spent with technology, and pre-study *SDLTS* score). Upon initial investigation it was shown that not all predictors were significant to student post-study *SDLTS* score. Nonsignificant factors were removed one at a time until only significant factors were contained in the regression. This resulted in a significant regression equation, $F(2, 218) = 26.26, p < .001$, with an adjusted R^2 of .19, and two significant predictors of student score on the post-study *SDLTS* assessment: average mobile device skill level and computer access and use at school (Table 19). Student post-study *SDLTS* score was equal to $2.94 + .40(\text{Average MD Skill level}) - .18(\text{computer access and use at school})$.

Table 19

Regression Results for Student Demographic Information and Post-Study SDLTS Score

Variable	Coefficient <i>B</i>	<i>p</i> value	<i>t</i>	<i>r</i>
Computer access at school	-.07	$p = .003$	-3.02	-.18
Mobile device skill level	.29	$p < .001$	6.61	.40

Student self-directed learning pre and post. A paired-samples t test was used to determine if there was a significant difference in the student pre- and post-*SDLTS* questionnaires. The results showed a significant difference in student pre- ($M = 3.61$, $SD = .54$) and post- ($M = 3.79$, $SD = .57$) scores, $t = 6.521$, $p < .001$, $d = -.44$. These results indicate that students were more self-directed following the study.

Digital Natives Assessment Scale pre-questionnaire. It was also anticipated that student scores on the *DNAS* would be predictive of their post-study *SDLTS* scores. Utilizing correlational techniques tests were run to identify the relationship between student score on the *DNAS* and their post-study *SDLTS* scores. The results showed a significant correlation ($p < .001$) in the positive direction between student *DNAS* and student pre-study *SDLTS* as well as student post-study *SDLTS* scores. This suggests that higher *DNAS* scores corresponded with higher pre- and post-study *SDLTS* scores (see Table 20).

Portfolio type. Different mediums were purposely utilized for student design portfolios as part of the counter-balanced study design: paper and electronic. In order to separate significance based solely off the difference in portfolio medium tests were run to determine the impact of paper or electronic portfolios on student post-study *SDLTS* score.

Table 20

Correlation for Student DNAS Scores and Student Pre- and Post-Study SDLTS Scores

Variable		Pre- <i>SDLTS</i> score	Post- <i>SDLTS</i> score
<i>DNAS</i> score	Pearson correlation	.40	.31
	Sig. (2-tailed)	.00	.00
	N	221	221

Utilizing an ANCOVA, with student pre-study *SDLTS* score as the covariate, portfolio type and student post-study *SDLTS* were analyzed. The resulting p value was not statistically significant ($p = .132$) suggesting that student post-study *SDLTS* score was independent of their assigned portfolio creation medium.

Access to mobile devices. One of the research questions undergirding this study is what relationship, if any, exists between middle school student access to mobile devices and student SDL. Using ANCOVA statistical techniques analyses were conducted looking at the relationship between student access to mobile devices and student post-study *SDLTS* score, using students pre-study *SDLTS* score as a covariate. The resulting value, $p = .82$, was not significant, suggesting that the relationship between student scores on self-directedness in learning with technology and access to mobile devices was not significant.

Familiarity with open-ended engineering design problems. On the post-study questionnaire students were asked about their familiarity, comfort level, and experience with open-ended engineering design problems (problem that do not have a single correct answer which involve an element of design). An average score was computed for each student using their responses to the questions regarding open-ended engineering design problems and a simple bivariate correlation test the relationship between student comfort-level with open-ended engineering design problems and post-study *SDLTS* score showed a significant correlation ($p < .001$) in the positive direction suggesting that higher comfort levels with open-ended engineering design problems corresponded with higher post-study *SDLTS* scores.

Comfort working in groups. Students were asked to identify their experience with and comfort-level in group work settings both in and out of school. Student scores were combined and an average group work comfort score was obtained for each student. This score was compared with student post-study *SDLTS* scores in an effort to determine what relationship, if any, exists between student comfort working in groups and their level of self-directedness. Using a simple correlation test the relationship between student comfort-level in working with groups and student post-study *SDLTS* scores was found to be significant ($p < .001$) and positive, suggesting that higher comfort in working in groups was correlated with higher post-study *SDLTS* scores.

Student Achievement

The second research question asked: “What relationship, if any, exists between middle school student mobile-access and student achievement on an open-ended engineering design problem?” Student achievement was measured in two ways as part of this study: student rank score on their group portfolio and student rank score on their group product (created during the engineering design challenge). Possible relationships between student final scores and other potential predictors were explored using a variety of statistical methods and the results are outlined here.

Student demographics and achievement. Using correlation statistical analyses, the relationships between student group portfolio score (rank) and student group product score (rank) were identified. Table 21 outlines the relationships between student portfolio rank score and demographics. Table 22 outlines the relationship between student product rank score and demographics. These results suggest that student age, average grades,

Table 21

Student Demographics Measures and Student Portfolio Rank Score

Student portfolio rank	Pearson correlation	Sig. (2-tailed)	<i>N</i>
Student age	.16	.02	221
Grades in average (all classes)	.13	.05	220
Grades on average (TEE only)	-.02	.83	221
Average time using technology	.27	.00	214
Average mobile device use	.05	.45	221
Skill level with mobile devices	.15	.02	221
DNAS score	.12	.08	221
Pre-study SDLTS score	-.07	.33	221
Computer access (home) and use	.05	.50	221
Computer access (school) and use	.09	.17	218
Mobile device access (home) and use	.27	.00	219
Mobile device access (school) and use	.24	.00	219

Table 22

Student Demographics Measures and Student Product Rank Score

Student product rank	Pearson correlation	Sig. (2-tailed)	<i>N</i>
Student age	.13	.05	221
Grades in average (all classes)	.06	.40	220
Grades on average (TEE only)	-.04	.56	221
Average time using technology	-.05	.44	214
Average mobile device use	-.08	.25	221
Skill level with mobile devices	-.02	.74	221
DNAS score	-.04	.54	221
Pre-study SDLTS score	-.05	.48	221
Computer access (home) and use	.06	.36	221
Computer access (school) and use	-.02	.79	218
Mobile device access (home) and use	-.01	.89	219
Mobile device access (school) and use	-.05	.48	219

average time using technology, skill level with mobile devices, and mobile devices access at home and school were significantly correlated with student portfolio rank scores, while student age was the only demographic variable that was statistically significantly correlated with student product rank score.

Pre-study SDLTS score and student achievement. Prior to the study students took a pre-study questionnaire and an average score for each student was obtained representing their self-directedness in learning with technology. Student pre-study self-directedness scores were analyzed with reference to their post-study achievement scores in an effort to identify possible correlations. The correlation between student pre-study *SDLTS* score and their portfolio rank score was not significant ($r = -.07, p = .33$). The correlation between student pre-study *SDLTS* score and their product rank score was also not significant ($r = -.05, p = .48$).

DNAS score and student achievement. Students answered questions related to their “digital nativeness” as part of the pre-study questionnaire. It was anticipated that student’s digital native abilities and pre-dispositions may be correlated with their achievement scores on the portfolio and the product. The correlation between student *DNAS* scores and their product rank score was not significant ($r = -.04, p = .54$). The correlation between student *DNAS* scores and their portfolio rank score was also not significant ($r = .12, p = .08$). While neither relationship was significant it is important to note that the relationship between student *DNAS* scores and student portfolio rank score is approaching significance suggesting a possible correlation between *DNAS* scores and portfolios scores.

Portfolio type and student achievement. Using an independent samples t test the impact of portfolio type on student achievement (both portfolio and product rank scores) was analyzed. There was a significant difference in student product scores between paper ($m = 73.93$, $SD = 52.22$) and electronic portfolios ($m = 97.71$, $SD = 49.63$); $t(455) = -4.83$, $p < .001$. There was also a significant difference in student portfolio scores between paper ($m = 68.83$, $SD = 39.46$) and electronic portfolios ($m = 96.58$, $SD = 53.43$); $t(454) = -5.84$, $p < .001$. It is important to note that the scores for the portfolios and the products are ranks scores so a lower number is deemed of higher quality than a higher number. These results suggest that paper portfolios corresponded with higher portfolio rank scores.

Access to mobile devices and student achievement. Using an independent samples t -test the impact of mobile devices on student achievement (both portfolio and product rank scores) was analyzed. This is of direction importance to the research question which asks what relationship, if any, exists between student access to mobile devices and student achievement on an open-ended engineering design problem. Once again, it is important to note that the scores for the portfolios and the products are ranks scores so a lower number is deemed of higher quality than a higher number. There was a significant difference in student portfolio scores between those with access to mobile devices ($m = 81.65$, $SD = 52.07$) and those without access to mobile devices ($m = 101.29$, $SD = 42.52$); $t(454) = -3.62$, $p < .001$. These results suggest that access to mobile devices was related to higher portfolio rank scores.

There was however, not a significant difference in student product scores between

those with access to mobile devices ($m = 90.20$, $SD = 52.82$) and those without access to mobile devices ($m = 85.60$, $sd = 48.60$); $t(455) = .816$, $p = .415$.

Student post-study SDLTS score and student achievement. As this research aimed to identify possible relationships between SDL, mobile devices, and student achievement it was important to look at the correlation, if any exists, between student SDL and their achievement on the assignment. A correlation was computed for student SDL, as measured on the post-study *SDLTS*, and student rank portfolio score (Table 23). A correlation was also computed for student SDL, as measured on the post-study *SDLTS*, and student rank product score (Table 24). Neither relationship returned a significant value.

Table 23

Student Portfolio Rank Score and Student Post-Study SDLTS Score

Variable		Post-study <i>SDLTS</i> score
Student portfolio rank	Pearson correlation	.01
	Sig. (2-tailed)	.91
	<i>N</i>	456

Table 24

Student Product Rank Score and Student Post-Study SDLTS Score

Variable		Post-study <i>SDLTS</i> score
Student product rank	Pearson correlation	-.02
	Sig. (2-tailed)	.65
	<i>N</i>	457

Student achievement by teachers. Research has shown that the biggest factor in student success is the teacher (Darling-Hammond, 2000). This also seemed possible through researcher observations during the study. A one-way ANOVA was computed to assess the impact of the teacher on student achievement scores for the portfolio. The results of the analysis for teacher effect and portfolio score are contained in Table 25. The results were significant suggesting that the effect of teachers on student outcomes was significant. LSD post-hoc analyses were computer to further explore the difference between teacher groups (see Table 26). A separate one-way ANOVA was computed to assess the impact of the teacher on student achievement scores for the product. The results of the analysis for teacher effect and portfolio score are contained in Table 27. The

Table 25

Student Portfolio Rank Score by Teacher

Portfolio rank difference	Sum of squares	<i>df</i>	Mean square	<i>F</i>	Sig.
Between groups	343436.21	5	68687.24	37.70	.00
Within groups	819827.47	450	1821.84		
Total	1163263.68	455			

Table 26

Post-Hoc Analysis of Differences in Student Portfolio Rank by Teacher

Teacher	<i>n</i>	<i>m</i>	<i>SD</i>	1	2	3	4	5	6
Teacher 1	84	64.26	48.95		.00	.00	.00	.00	.12
Teacher 2	84	130.55	44.32			.00	.00	.00	.00
Teacher 3	69	85.20	45.78				.22	.00	.00
Teacher 4	59	94.58	36.23					.08	.00
Teacher 5	53	108.75	47.83						.00
Teacher 6	107	86.47	50.56						

Table 27

Student Product Rank Score by Teacher

Product rank difference	Sum of squares	<i>df</i>	Mean square	<i>F</i>	Sig.
Between groups	108435.85	5	21687.17	8.77	.00
Within groups	1115394.76	451	2473.16		
Total	1223830.62	456			

results were significant and LSD post-hoc analyses were computed to further explore the difference between teacher groups (see Table 28).

As the one-way ANOVA tests looking at teacher impact for both product and portfolio score were significant and the researcher observations had seemed to hint that teacher impact would be highly-influential an additional test was run to see the overall impact of teacher on student achievement. An average rank score was obtained for each student by adding their portfolio and product rank scores and dividing by two. A one-way ANOVA was computed using teacher as the factor (Table 29). The results were significant and LSD post-hoc analyses were also computer to illustrate the difference between teacher groups (Table 30). Students of Teacher 6 scored significantly higher than their peers on both the portfolio and the product aspect of the assignment.

Qualitative Findings

In an effort to enrich and explore the findings obtained through the quantitative data and subsequent analysis qualitative interviews were conducted with students (30 total) and teachers (6 total) immediately following the study. Five students from each

Table 28

Post-Hoc Analysis of Differences in Student Product Rank by Teacher

Teacher	<i>n</i>	<i>m</i>	<i>SD</i>	1	2	3	4	5	6
Teacher 1	85	77.99	47.39		.00	.00	.35	.00	.79
Teacher 2	84	107.17	51.11			.94	.00	.62	.00
Teacher 3	69	106.54	48.26				.00	.69	.00
Teacher 4	59	70.10	47.20					.00	.46
Teacher 5	53	102.85	44.51						.00
Teacher 6	107	76.05	54.89						

Table 29

Student Overall Achievement Rank Score by Teacher

Achievement difference	Sum of squares	<i>df</i>	Mean square	<i>F</i>	Sig.
Between groups	182067.29	5	36413.46	34.25	.00
Within groups	478479.07	450	1063.29		
Total	660546.36	455			

Table 30

Post-Hoc Analysis of Differences in Student Overall Achievement by Teacher

Teacher	<i>n</i>	<i>m</i>	<i>SD</i>	1	2	3	4	5	6
Teacher 1	84	71.03	35.94		.00	.00	.04	.00	.23
Teacher 2	84	118.86	31.33			.00	.00	.02	.00
Teacher 3	69	95.87	34.54				.02	.10	.00
Teacher 4	59	82.34	23.52					.00	.00
Teacher 5	53	105.80	29.12						.00
Teacher 6	107	65.34	35.35						

teacher were interviewed as well as each teacher (see Chapter III for further explanation regarding the selection and interview process). The interviews were transcribed and analyzed using descriptive, causation, and finally thematic coding schemes with several interesting themes emerging. The themes from the student interviews were:

1. choice matters,
2. mobile devices enable, and
3. boundaries and gatekeepers.

The themes from the teacher interviews were:

1. external factors cause self-directed learning,
2. mobile devices need strict monitoring,
3. computers negate the need for mobile devices, and
4. permission doesn't overrule the norm.

Student Interviews

Theme 1 from student interviews: choice matters. Whether discussing SDL or mobile devices in K-12 settings the idea of “student choice” surfaced as a prominent theme. Choice was identified as a thematic code more often than any other item (22 times) with students citing choice as both a cause and effect of SDL and as a key factor in the success or failure of mobile devices in K-12 settings. One student described SDL as “somebody actually choosing what they have to do and what they want to do in their education,” while another gave a more in-depth explanation of SDL:

I would probably describe [self-directed learning] as...it's not something that really...you were assigned to do, it's something that you, like go and do yourself, like you are interested in it, you want to go and figure out what this thing is...or how something works.

Students identified choice as a necessary condition to enable SDL and a value-added benefit arising from SDL situations. Similarly, other's emphasized the “self-

teaching” aspect of SDL:

I think [self-directed learning] is like if you want to learn something and you kind of teach yourself at it instead of like having someone teach you, like, you learn like, on the Internet how to do it and then like teach yourself.

Related to choice, students identified that the most important aspect in the success or failure of mobile devices in the classroom was what students chose to do with them.

When asked about including mobile devices in K-12 classrooms one student responded:

“it all depends on how people use them and like if they trust them with the devices.”

Other students elaborated on the idea of student choice as the determining factor for success.

I think it’s kind of both ways, cuz, um, it’s a good idea because it can be used as a tool and it can help learning and a lot of people want to learn more when there’s mobile devices included but um, a lot of people would abuse that uh, freedom and they would you know, look up bad things and yeah.

Um, well I think it’s good if it helps you learn and I think it’s good because you can look up like anything you want on the Internet, as long as it’s not like, you’re like always on it and always doing stuff.

Student choice was seen as an important and determining factor in the facilitation of SDL and the success or failure of mobile devices.

Theme 2 from student interviews: Mobile devices enable. When talking about mobile devices, themes of how the mobile device enabled different types of behavior emerged from the student responses. Students talked about how mobile devices were “comfortable,” “natural,” and tools for that fit with their particular day and age. One student noted that access to mobile devices would help them “because like, they, oh I feel familiar with this. I know what to do. I know where to go.”

Relatedly, students also described their own learning style as different from other

time periods.

I think [mobile devices] make them better because in our day and age we're learning, um, about the... Well, we know how to use these, like in the fifties, they had, like paper and stuff, and they knew how to use those, but for our day and age, um, it helps us, it helps us, cuz we know how to use it really well.

Students identified the enabling and catalytic power of mobile devices for better or worse. Students recognized the “instant information access” capabilities associated with mobile devices but also recognized the “instant distraction access” capabilities associated with those same devices. One student mentioned that, “[Access to mobile devices would help] some people, because some people are smart and use them for the things they supposed to, some people just, probably play games on it.” Other students echoed similar sentiments.

Well, [access to mobile devices] made it easier because we could look up some ideas which gave us more ideas, so it made that easier for this, to design it, but it made it harder at the same time because some people got distracted using their phones.

[Access to mobile devices] can do both. Um, because you can get, off-track and just start doing other things. Um, it can help because you can just search whatever you want to learn.

Overall a theme emerging from student responses related to access to mobile devices was that mobile devices were tools helped make the learner *more*—more engaged and effective, or more distracted and ineffective. In addition to enabling it was often noted (coded 17 times) that mobile devices provided “faster” access for students than traditional methods without a mobile device; faster access to both positive and negative opportunities.

Theme 3 from student interviews: boundaries and gatekeepers. A third theme

that emerged from student interviews was the idea of boundaries and gatekeepers, both physical and not. The themes of “restricted” (coded 9 times), “gatekeeper” (coded 6 times), and “spaces” (coded 10 times) where mobile devices were allowed or not allowed all contributed to this theme. Commonly cited “free spaces” included: the hallways, the lunchroom or cafeteria, and free time. The idea of restricted spaces revolved around the classroom, the teacher, and the bell system. For example, some students noted:

You are allowed to have them out at lunch, and in between classes. You’re allowed to have them in class, if the teacher allows you, you are allowed to be on it, but if not, then you are not allowed to have them out.

We’re not supposed to have [mobile devices] after the first bell rings to go to class. We are not allowed to have them... we are allowed to have them after the last bell rings. And we are allowed to use them if the teacher says we can. Well, mobile devices are allowed and not allowed, well they are allowed outside of school, like over there, in the playground area and they’re also not allowed in here because... I have no reason, well, I don’t know why they’re not allowed in here.

In interviews the students often identified teachers as the “gate-keepers,” both restricting and allowing use of mobile devices. One student said: “They’re really not allowed during classes but if your teacher says pull them out and do something on them you can use it then.” Another student noted, “You’re allowed to have [mobile devices] in class, if the teacher allows you, you are allowed to be on it, but if not, then you are not allowed to have them out.” Finally, a third student mentioned in the interview that mobile device use revolved around the activity.

Um, it all depends like what class, like they’re not allowed in like, during class but some teachers like let you use them for like certain things if you don’t know, like, how to like, um, like, um, like spell something or like draw something then you’re allowed to use them.

Similar to the first theme the idea of choice again rises with the third theme—this

time it's the student's lack of choice. A theme from student's responses was that the use of mobile devices is largely out of their hands—the “boundaries” and “gatekeepers” at the school exist and have been identified and it's up to the students to proceed accordingly.

Teacher Interviews

Theme 1 from teacher interviews: External factors cause self-directed learning. The first theme that emerged from the teacher interviews related to SDL. While students viewed SDL as a result of student choice teachers perceived SDL as a result of external conditions (coded 13 times), namely: presence of an open-ended problem, a task involving group work, or other classroom-environmental factors that facilitated student SDL. Three teachers talked about SDL in relation to a specific assignment.

[self-directed learning is] basically if they're doing an open ended project where they have to design it with criteria that they have to do their own research, problem solving to accomplish it.

Lots of self-directed learning in my classroom comes from group work, where students are able to work with one another, and I would guess I'd say investigate different outcomes or solutions to problems, whether it's on a worksheet or project. Um, they're usually more open ended.

I think there's a lot [of self-directed learning] because our class is more project based, I mean, I let kids kind of explore and do things on their own, rather than being robots that repeat the same project over and over.

In contrast to the students' responses which themed around SDL as a result of student choice and an enabler of student choice the teacher interviews revolved more around specific classroom environment factors (i.e., type of problem being solved, group work situations) which enabled SDL.

Theme 2 from teacher interviews: Mobile devices need strict monitoring.

There was near consensus among teachers that mobile devices were a good tool which belonged in the classroom but only with very strict teacher monitoring. Themes of “monitoring,” “structured,” “limited,” and “control” were all combined to form this theme. Specifically, teachers said: “I believe in [access to mobile devices], but with limited use and with some control,” and another said: “I think [access to mobile devices is] good, if like I say, its structured and they know they’re using it for what it was intended, not just distraction.” Monitoring was a key theme in one teacher’s thoughts about mobile devices.

I think that [access to mobile devices] can be good in a monitored fashion, with activities like the one we did, or other experience design activities. It could be very valuable in the research and understanding what the actual problem is they’re trying to solve and where it fits in the world of what the impact that decision or solution might have.

These teachers’ responses align with the student’s thoughts regarding mobile device use in K-12 settings with boundaries, rules, and gatekeepers. While teachers identified positive outcomes related to mobile devices the theme that arose was one of monitored control of those mobile devices.

Theme 3 from teacher interviews: Computers negate the need for mobile devices. A third theme arising from the teacher interviews was the idea that mobile devices were not necessary if computers were present in the classroom. The lack of student use of mobile devices as a result of the presence of computers was highlighted by one teacher.

I’d have to say [grades would] improve [with access to mobile devices]. In a normal classroom without any access to you know, technology or information I

think it would definitely improve. Where there's computer labs, I mean I don't think people are using them enough it wouldn't change the grade that much. Uh, well, not a lot of students in my classes took out their mobile devices - um, that I saw. Some of them were pulling them out and they were doing Google searches on their phones. Um, rather than the computers in my computer lab. So, I think some of them had forgotten that they could use mobile devices because I did have a computer lab that they just had instant access to.., I think that it's because that they had the computers right in front of them and so, they've had experience with the computers in the classroom before, prior to this study. I feel like if they had not had the computer lab and they had been able to use their mobile devices, they would definitely use their mobile devices. I think I would see that every kid that had the mobile device use it, if they had not had the computer lab.

This finding is especially interesting when contrasted with theme 2 from the student interviews in which students identified mobile devices as “natural,” “comfortable,” and specifically suited for their learning needs.

Theme 4 from teacher interviews: Permission does not overrule the norm.

Observations by the researcher and the teachers noted that although students were given permission to use mobile devices in many of the participating classes the students did not use them. When asked about this observation, teacher responses revolved around the expectations and norms for the classroom and how mobile device use policies were already “established” for their classroom prior to the study. Despite being allowed to use mobile devices, teachers noted the lack of use to the previously established “norms of behavior.”

I had a couple kids looking on the I-pad on the Internet. Honestly I was surprised that when we opened it up to the mobile devices more students have their cell phones out, uh, most of them were just looking for images or for, in of the pill bottle folder things. But I was surprised at, I guess, the lack of using that device, maybe it's because they're not used to using it in my classroom. I really don't know, I, the only thing I can think of is because it's the rule that you don't have your cell phone out in my class, I kind of felt like that was it—the norm....

Okay, well, my particular group was a paper group with the option to use mobile

devices, and I made it clear that if they found a need, and it was justifiable for the activity they could use them, and I was surprised to see how few people actually used them. Uh, I can't, I can't recall specifically recall even one circumstance, which surprised me, given that had permission, where they actually used their mobile device to do it.

Interestingly, although the students noted boundaries and gatekeepers the teachers noted that permission may not be the only restriction to mobile device use in K-12 settings. The idea that classroom "norms" or standards of expected behavior influenced student use sheds additional light on the reasons why students did not choose to use mobile devices during the class.

Summary

A variety of statistical tests were used to analyze the data resulting from this study in an attempt to answer the two research questions.

1. What relationship, if any, exists between middle school student access to mobile devices and student self-directed learning?
2. What relationship, if any, exists between middle school student access to mobile devices and student achievement on an open-ended engineering design problem?

Using the results from the modified *SDLTS* student SDL was analyzed with relation to a variety of variables. Specifically, it was noted that access to mobile devices did not statistically significantly impact student SDL as measured by the modified *SDLTS*.

Using both the student portfolios and the student engineering design products as a representation of student achievement a variety of statistical tests were used to analyze the potential relationships between student achievement and a variety of other variables.

Notably, student access to mobile devices was statistically significantly associated with higher student rankings on the design portfolio but not on the student products.

Semistructured qualitative interviews were conducted with 30 students and the 6 participating teachers following the study. Interview responses were coded descriptively and thematically which produced several key themes. These themes were used to clarify findings from the quantitative analysis and provide context for the study, findings, and researcher observations.

CHAPTER V

DISCUSSION, RECOMMENDATIONS, AND CONCLUSION

With the ubiquitous nature of mobile devices today the question of mobile device inclusion in K-12 classrooms has been debated with competing voices from both sides. Despite claims for and against mobile devices in K-12 classrooms little empirical research exists regarding the impact of mobile devices when included in K-12 classrooms. This research study was designed to explore two questions.

1. What relationship, if any, exists between middle school student access to mobile devices and student self-directed learning?
2. What relationship, if any, exists between middle school student access to mobile devices and student achievement on an open-ended engineering design problem?

Study Overview

This research study explored middle school student SDL and achievement through an open-ended engineering design problem which involved the creation of both a product and a design portfolio. Six middle school TEE teachers with a total of 18 classes and over 700 students were enlisted in the study. Recognizing the presence of multiple variables with likely high-impact factors on the outcomes a counter-balanced research design was used for the study. Teachers, and their classes, were assigned as either “mobile device allowed” or “mobile device not allowed” classrooms for the entirety of the project. Teachers, and their classes, were also assigned to complete the design portfolio either electronically or in a traditional paper-based manner.

Following a full implementation of the study through a pilot-study the full study took place over two weeks in the largest school district in a state located in the western U.S. Teachers were trained prior to the implementation of the study, provided with a detailed classroom script (Appendix C), and observed during their classes by the researcher in an effort to ensure fidelity of the treatment.

On the first day students began by answering questions on the pre-study questionnaire. Students were then taught lessons about appropriate mobile device usage, the engineering design process, and working in groups. Students were instructed regarding the completion of the design portfolio and introduced to the engineering design problem. The engineering design problem challenged students to take provided materials, design, and create a pill holder/dispenser that met a variety of criteria for an elderly client. Students were placed into groups of 3-4 students and provided with a handling collection which consisted of various items chosen to stimulate student thinking. After exploring the handling collection, starting the portfolio, and brainstorming ideas as a group the students returned the handling collection materials (see Appendix F) and were provided with the modelling collection (Appendix G).

Students worked in their groups over four class periods (90 minutes each) through the design and build process and completed the design portfolio. Students were prompted at prescribed times to fill in portions of their design portfolio, respond to questions, and record their ideas. Students in “mobile device allowed” classes were reminded that mobile devices were allowed during the unit but were not forced to use devices. All students were guided by their teachers through the portfolio design process following the

provided script (Appendix C). As part of the engineering design process students were also given access to a variety of tools and build materials (e.g., scissors, glue, tape, etc.).

At the end of the fifth class period the students turned in their final products, portfolios (paper or electronic), and completed the post-study questionnaire. Five students from each teacher were interviewed by the researcher and each teacher was interviewed. All student work was collected and a digital picture obtained for each product, resulting in 177 product pictures. Paper portfolios were digitized resulting in a total of 177 digital portfolios for later grading. All student response data from the pre- and post-questionnaires were collected and conditioned resulting in a total of 555 pre-questionnaire responses, 458 post-questionnaire responses, and 221 matched responses (matching pre- and post-data responses of students).

A panel of five judges was formed joining a variety of individuals with expertise in design, technology, and engineering. These individuals were trained and provided with access to the adaptive comparative judgment (ACJ) grading system. The ACJ grading system presented judges with two artifacts (student portfolios or student products) via computer and asked them to pick the better of the two. This process was repeated by the panel of judges until every portfolio and every product was judged at least 10 times (approximately 175 portfolio and 175 product judgments per judge). The ACJ system, known for its reliability and validity measures (Kimbell et al., 2007), produced an overall reliability coefficient of $r = .97$ for portfolios and $r = .96$ for student products, suggesting extremely high levels of inter-judge reliability across both judgments. The result of the judgments was a rank-order listing for both student portfolios and student products.

These rank order scores for student portfolios and student products were added to the combined data set and all data was analyzed using a variety of statistical techniques (see Chapter IV). Following statistical analyses all student and teacher interviews were transcribed and then analyzed using descriptive, causation, and thematic coding techniques. The resulting themes were summarized in Chapter IV of this document and will be used in the subsequent discussion and recommendations sections.

Using both quantitative and qualitative methods this study aimed to look at middle-school student access to mobile devices and student achievement in a TEE classroom during a STEM activity. Additionally, this study examined the possible relationships between access to mobile devices and student SDL. The study took place during a 2-week time period during which students worked in groups on an open-ended engineering design challenge. The specific research questions that guided this study were:

1. What relationship, if any, exists between middle school student access to mobile devices and student self-directed learning?
2. What relationship, if any, exists between middle school student access to mobile devices and student achievement on an open-ended engineering design problem?

Discussion

While the specific findings and associated statistical data are presented in Chapter IV, an interpretation along with possible implications and discussion is presented below. Findings for each research question will be discussed followed by other notable observations.

Research Question 1

Research question 1 asked, “*What relationship, if any, exists between middle school student access to mobile devices and student self-directed learning*”? After a variety of statistical analyses as well as qualitative interview analyses an important theme emerged that described the relationship between middle-school student SDL and other factors in this study: SDL in middle-school students appears to be related to student and environmental characteristics rather than access to specific technology tools (e.g., mobile devices).

When analyzed, student SDL was independent and even negatively correlated with access to some technology tools. Middle-school student scores on the post-study *SDLTS* were independent of access to mobile devices during the study and interestingly, computer access, another technology tool, at school was negatively correlated with student self-directed learning. Additionally, student self-directedness in learning scores were independent of student portfolio type (paper vs. electronic). Taken together, these findings suggest, that technology tools in and of themselves may not correspond with an increase in student SDL and in some cases may be detrimental to student SDL. These findings appear to align with Mentzer’s (2011) research which also found that access to information (i.e., the Internet via computers) did not improve student designs when compared with other students without internet access in an open-ended engineering design challenge.

This finding is especially interesting in light of the student comments related to SDL during the student interviews. In contrast to teacher comments, which centered on

the learning environment as a catalyst for promoting SDL, student comments revolved around the important nature of student choice in relation to SDL. The introduction or presence of technology tools (e.g., mobile devices, computers) implicitly brings with it a variety of choices for students: choice about time, use, focus, implementation, and more. In light of the student emphasis on choice as a necessary pre-cursor to SDL it would seem to follow that the introduction of new technology tools could correspond with increases in SDL. However, in this study that did not appear to be the case.

A possible reason that new technology tools did not correspond with increases in student SDL comes from another theme emerging from the interviews: regulation. Both teachers and students noted in their interviews that mobile devices in K-12 settings were highly regulated. Teachers were identified by students, and themselves, as gatekeepers and regulators of technology use in their classrooms and schools, and students identified ways different locations and time periods were regulated. Perhaps the introduction of technology tools, with their corresponding choices in regards to use, is only beneficial to student SDL in situations without regulation. It is possible that students did not feel that they were provided a “choice” due to the highly regulatory nature of the classrooms with respect to mobile devices.

Unlike technology tools, a variety of specific student and classroom-environment characteristics did show significant relationships with student SDL. Student characteristics that corresponded with higher levels of self-directedness in learners were: average skill in using mobile devices, higher “digital nativeness” scores, student familiarity with open-ended engineering design problems, and student comfort-level in

working in groups. Notably, student skill in using mobile devices correlated with higher levels of SDL. It may be a possibility that students are teaching themselves SDL skills as they becoming increasingly skilled in using mobile devices.

When compared, the SDL among students overall increased from the pre-study questionnaire to the post-study questionnaire suggesting that a classroom environmental factor associated with higher levels of self-directedness in middle-school students may be the presence of an open-ended engineering design problem. These findings, which denote ways in which factors other than technology tools supported increased SDL (i.e., student and classroom characteristics), are supported by one of the themes from the teacher interviews. In interviews teachers discussed how they perceived SDL to be a product of external conditions rather than student traits. Examples of external conditions provided by teachers which impact self-directed learning were: the presence of an open-ended problem, a task involving group work, or other classroom-environmental factors. Student and teacher responses on factors impacting SDL were different with students focusing on choice, while teachers identified the ways in which classroom environment and external factors impacted student SDL.

Research Question 2

Research question 2 asked, “*What relationship, if any, exists between middle school student access to mobile devices and student achievement on an open-ended engineering design problem*”? Student achievement was assessed through two separate student scores: (1) student portfolio scores and (2) student product scores. Student access to mobile devices was significantly correlated with higher student scores on the portfolio

portion of the assignment but independent of student score on the product portion of the assignment.

There are many possible reasons that access to mobile devices was significantly correlated with higher portfolio scores but independent of product score. One possible reason was derived from the student interviews. In student interviews students were asked why they chose not to use mobile devices on the assignment or why they did not use mobile devices more often as part of the assignment. Student responses themed around the idea that the engineering design challenge presented in class was not the “right type of problem” to use a mobile device. Students cited “factual” and “problems that have one right answer” as the type of problems they would use a mobile device to answer—as opposed to the open-ended type of problem presented in this study. Perhaps students perceived the portfolio, with its direct questions and specific prompts, as the type of assignment that they would use mobile devices to fulfill while the product creation portion of the assignment, with its largely creative and flexible nature, may have been seen as “too open ended” for mobile devices to be used effectively by the students.

In qualitative interviews the teachers and students were in agreement that mobile devices had the potential to improve student’s achievement if students chose to use them correctly. Specifically, students mentioned the “instant access” capabilities associated with mobile devices, access to information and access to distraction. Teachers emphasized the need for control and monitoring of device use, while students interview responses focused on the need for students to practice self-discipline while using devices.

A key finding, supported by both the portfolio and the product rank scores,

suggests that teachers and portfolio medium (paper or electronic) may be the most important factors in student achievement. Students completing portfolios on paper produced significantly better portfolios and products than their counterparts using electronic portfolios. Several possible reasons will be discussed here.

It is possible that the “physical” nature of the paper portfolio as opposed to the “digital” nature of the electronic iPad portfolio was suited better to student needs. The long-standing use of notepads, sketchbooks, and paper and pencil tools in education, artistic, and design endeavors may have impacted students in ways not associated with the digital portfolio tools. Students’ comfort level and familiarity with paper, pencils, and pens was likely high, due to their presence and use in classrooms, and it is possible that the tangible nature of the portfolio and the comfort associated with these “familiar” objects was enough to positively impact students towards their use in the portfolio creation process.

It’s also possible that the paper portfolios were “easier” to fill out than the electronic portfolios. An inherent aspect of the electronic portfolio is the increased time it takes to turn the iPad on, navigate to the *LiveAssess* app, login, find the correct portion of the portfolio, and type in a response. It was also noted in observations by the researcher that it was more difficult for student to “draw” on the iPad than it was for their counterparts to do the same on paper—the lack of a “pencil” drawing tool may have been enough to discourage sketching and drawing among students assigned to the iPad portfolios. These differences in the electronic portfolio may have contributed to an overall “slower” or “cumbersome” process that served to deter students.

It is important to note that in observations by the researcher it was observed that a distinct advantage of the paper-based portfolio resided in its transparent nature. As teachers, students, and the researcher walked the room it took but a passing glance to quickly identify overall progress and completion of the paper portfolio. Whereas, the electronic portfolio, which only displayed one design prompt/section at a time, had a very opaque nature—effectively “hiding” student progress by only displaying one section at a time. The researcher noticed in classroom observations that teachers using the paper-portfolios ensured their students completed the portfolios more easily than teacher using the iPad-based portfolios. Thus, it is possible that one reason paper portfolios groups scored better on the whole than their electronic-portfolio counterparts may be related to the transparent/opaque nature of the portfolio medium.

Another important finding is related to the teacher-impact on student achievement. Similar to other research (Darling-Hammond, 2000) the difference in students grades when compared by teacher was significant. Despite the fact that all teachers in the study were Level 2 teachers, from similar socioeconomic locations (Appendix D), all had similar training and backgrounds, and all were recommended for the study by their CTE coordinator there were significant differences in the final grades received by the students of each teacher, with one teacher in particular scoring significantly higher than his counterparts in the study.

In data analyses the top teacher (Teacher 6) was removed from the data set in an exploratory effort to determine the impacts on the results with the removal of this outlier. Following the removal of the highest teacher another outlier emerged (Teacher 4). This

new outlier was the second teacher in the study assigned to have student's complete portfolios on paper. Significantly the two teachers (Teacher 4 and 6) with the top performing students were both assigned to complete portfolios on paper with their classes. This suggests the impacts of these teachers and the portfolio medium may have been multiplied resulting in higher scores for their students on the portfolios and products.

Also worth noting is that socioeconomic status (SES), a variable often associated with student achievement and success (Darling-Hammond, 2000) was not significant in this study. The school associated with the highest socioeconomic status (Teacher 5) did not produce students that were significantly different than others. In fact, the students from this school performed worse than many other schools included in the study. Although a variety of factors including teacher impact, portfolio medium, and a host of others could have contributed to these findings, it is interesting to note that SES did not appear to have a significant positive impact on student achievement in this study.

Student portfolios. Notably, student access to mobile devices was significantly correlated with higher scores on the design portfolio. Other factors which corresponded with higher portfolio scores were: average time spent with technology, student age, mobile device skill level, and mobile device access at home and school. The relationship of all these factors suggest that students who are provided with access to mobile devices, while it may not significantly impact their SDL, may have improved design portfolios. While access to mobile devices correlated with higher student portfolio scores, student pre-study *SDLTS* and *DNAS* scores were not significantly correlated with student

portfolio scores. This suggests that access to mobile devices correlates with higher portfolio scores independent of student's pre-study disposition towards SDL or their pre-study disposition to technology or other digital native skills.

In addition to student pre-study *SDLTS*, student post-study *SDLTS* scores were also independent of student portfolio score rank. This is an important finding because it suggests that SDL, highlighted and identified as a key skill for 21st century learners (Partnership, 2011), may not be indicative of student achievement, ability, or skill with the engineering design process.

Student products. Unlike the portfolio scores the only significant correlation found between student product scores aside from teacher and portfolio type was student age. Older students trended, as would be expected, towards better scores on their design products. Student portfolio scores were not significantly correlated with pre or post-study *SDLTS*, pre-study *DNAS* score, or access to mobile devices. Once again this seems to suggest that SDL may not be as indicative of student "success" as is often advertised.

It is also intriguing to note that the two teachers with the top performing students in the products and the portfolios (Teacher 6 and Teacher 4) had the youngest students on average (see Table 3). While all students participating in the study were between the ages of 12 and 15 (seventh and eighth grade), all of the students taught by Teacher 4 and Teacher 6 were 13 or younger. These findings strengthen the argument that the impact of teacher and portfolio medium on student success cannot be overlooked. These findings also suggest that further study should be conducted to explore these relationships further.

Other observations. Of particular interest, the researcher noticed that although

many students were given access to mobile devices, students rarely used mobile devices during the product creation or the portfolio creation. Teachers echoed this sentiment during interviews citing several possible reasons for lack of mobile device use including: lack of need for mobile devices, the competition between computers and mobile devices, and classroom norms. Teachers mentioned in interviews that with computers present in the classroom students did not “need” access to mobile devices—highlighting a teacher perception that mobile devices serve as a “replacement” for computers. This idea, however, does not align with student responses in interviews which cited the “natural,” “comfortable,” and “generational-specific” benefits of mobile devices over other technologies, such as computers.

It should be noted that although students cited mobile device-specific benefits the majority (65.4%) of students that were given access to mobile devices during the study reported using mobile devices less than 30 minutes during class over the course of the entire study (over 360 minutes of class time). Observations by the researcher aligned with teacher interviews which cited the classroom norms (traditionally no mobile devices allowed) as a possible factor which influenced student decisions to use mobile devices relatively infrequently. These classroom norms may have influenced the way students framed the design problem, emphasizing a particular path or progression to completion which led students away from using mobile devices. It is also possible that students have only ever utilized mobile devices in certain ways, none of which was perceived as useful for the presented assignment. Without explicit instruction regarding how to use a mobile device for the completion of the assignment students may have seen mobile devices as an

unnecessary tool.

Another possible reason the students did not use mobile devices is simply the effort associated with using them—it may be perceived by the students as an additional effort to access a mobile device, search for information or utilize apps towards the completion of the assignment. This effort, above and beyond the bare minimum required to complete the assignment, may have been perceived as burdensome enough to deter students from using mobile devices.

Another notable observation is related to teacher-impact factor. The findings from this study seem to add strength to other findings which show that teachers are the single-biggest factor influencing student achievement (Darling-Hammond, 2000). Although all teachers in this study were Level 2 teachers and had similar teaching experience, background, class assignment, and recommendations from peers and colleagues, there were significant differences in the achievement of their students. In observations by the researcher one particular teacher (Teacher 6) was noticeably better at guiding the students through the portfolio and product creation process. Although all teachers followed the same script this teacher appeared to do so with more ease and skill. While several other teachers struggled at times to stay caught up with the pace of the project this teacher never struggled with pacing and required the least assistance from the researcher. Of the 176 total portfolios and 176 products this teacher had students that produced 6 out of the top 10 portfolios and 4 out of the top 10 products. Other correlations also demonstrated that teacher-impact was a highly-significant factor. Further analyses revealed that, taking into account potentially influential variables (mobile device access, scores on pre and

post *SDLTS*, scores on *DNAS*, comfort working in groups, working with technology, or with engineering design problems), the most significant variable in student success was which teacher they had. Interestingly the SDL scores of students were not impacted near as significantly by their teacher as student achievement scores (see Table 16).

Recommendations

Recommendations rising from this study are based on quantitative data, qualitative interviews, and researcher observations conducted during the study. Recommendations for further research and analysis are also provided. These recommendations should serve as starting points for future research, discussion, and further inquiry into SDL, mobile devices, and student achievement at the middle-school level in TEE classrooms or with STEM activities.

Recommendations for Self-Directed Learning

As noted above, mobile devices did not make a significant impact on student SDL as measured by the pre- and post-study *SDLTS* questionnaires. However, several other student and classroom-environment characteristics were positively correlated with SDL in a significant way. Student skill in using mobile devices and student “digital nativeness” scores were both positively correlated with higher SDL in students, which may suggest that teachers and schools should emphasize student skills in using and interacting with technology. As students can more effectively interact with different technologies (e.g., mobile devices, tablets, computers, etc.) around them their opportunities and abilities for SDL may also increase.

In addition to technology skills (skill in using mobile devices and student “digital nativeness”), students need to be taught how to work together in groups and how to solve open-ended engineering design problems. Teachers should provide students with these opportunities and specifically teach skills for working in groups as well as best practices for solving open-ended engineering design problems. In teacher interviews teacher responses seemed to suggest that teachers believe these skills should be taught in class and opportunities should be provided to students. The need to teach students these skills and specifically emphasize these skills has been highlighted in other research (Partnership, 2011). As students become more proficient in working together in groups and solving open-ended engineering design problems their SDL may also increase. These opportunities for SDL may correspond with an open-ended engineering design problem situation and the ability to effectively work with others may help students as they progress in their own SDL.

From student interview responses it appears that another way student SDL could be improved would be through increased opportunities for students to make choices regarding their education. These choices, specifically choices with technology, may allow students to practice and strengthen their own SDL abilities and progress in their overall ability to leverage technologies in a way that is beneficial to their own SDL.

Recommendations for Mobile Devices

While mobile devices did not significantly impact student SDL in this study, mobile devices did correlate significantly with higher student achievement on the design portfolio. During student interviews a theme that emerged with relation to mobile devices

was that of the need for direct instruction for students regarding how, where, and when to use their mobile devices. Students mentioned “mobile-friendly” and “mobile-restricted” areas existing in their school and in observations and teacher interviews a theme of “norms” emerged—students choosing not to use mobile devices during class because of an existing norm. Teachers may need to work to change their own classroom norms so that positive and appropriate uses of mobile devices become the new “norm.” Teachers and students may need to work together to align their perceptions of the place for mobile devices in the classroom. Students identified mobile device-specific benefits while teachers noted that mobile devices were “not necessary” if computers were present. The differences between teacher and student perceptions highlight the need for explicit dialogue, discussion, and instruction regarding how mobile devices can and should be used in classrooms.

Student interview responses highlighted different “types of problems” in which mobile devices were useful and other “types of problems” in which mobile devices were not. An analysis of their responses revealed that students perceive mobile devices as useful tools for solving problems with one correct answer (e.g., $43+98=$) This reflects a student perception that mobile devices are tools for access to specific factual information, while students do not appear to identify mobile devices as tools that would allow them to brainstorm, explore, or enhance creativity. Teachers should work to explicitly teach students ways that mobile devices could be leveraged to perform tasks other than simply finding facts. Possible skills teachers could emphasize with relation to students and mobile devices include: exploration, brainstorming, collaborating, creativity,

manufacturing, criteria and constraint identification, and other topics related to the engineering design process.

As noted above it is interesting that mobile device access was positively correlated with student portfolio score while not significantly correlated with student product score. Further investigation as to how students classify the portfolio creation process and the product creation process may reveal additional information as to why mobile devices were positively correlated with portfolio score and not product score.

Recommendations for Further Research

This research aimed to look at the relationships between mobile device access and two specific items: student SDL and student achievement on an open-ended engineering design challenge. Additional relationships between student mobile device access and other factors would shed further light on the debate over mobile devices in the classroom.

This study was conducted with a relatively suburban, middle-class, homogeneous population. Further study at different grade levels (high-school, elementary, secondary), with different population groups (urban, rural), or in different locations would shed additional light and provide valuable comparisons for the findings of this study.

This study was conducted over a 2-week unit, representing a relatively short turnaround between the pre- and post-questionnaire. A longer study spanning multiple terms, classes, or years, would shed significant light on the findings from this study and contribute to the fields of SDL, mobile devices, and TEE in meaningful ways.

This study used an open-ended problem derived from research previously completed by Kimbell (2007, 2012a, 2012b) in the United Kingdom. A different open-

ended problem would be insightful to compare with this research as well as Kimbell's research. Additionally, a similar study with concrete problems would be interesting, especially in light of student comments regarding mobile devices and different "types" of problems.

As teacher-impact was highly significant in this study it is recommended that additional studies be undertaken with varying research designs which allow for additional data that could enhance the findings from this study related to teachers. Studies with one teacher and two classes could be undertaken with one class receiving mobile device access prior to a particular unit and another class receiving similar access following the unit. Consideration of compensatory rivalry and other lurking variables would need to be taken into account in such studies.

The implementation of the ACJ system in K-12 education in the United States is a fairly new concept with relatively little research into its use, implications, and possibilities. Further researcher revolving around the ACJ system and its potential for positive impact in K-12 classrooms deserves to be addressed. This study utilized only a fraction of the overall capabilities of the ACJ engine. ACJ engine capabilities related to letter grades, the production of a normal curve from artifacts, teacher feedback, student reflection, and potential for integration into current learning management systems are all worthy of further exploration and study.

Recommendations Related to this Study

Many revisions were made to this study following the pilot study and researcher reflection and notes. Additional revisions that may improve this study include the

following.

1. Enhancing the handling collection. In researcher and teacher observations it appeared that student brainstorming revolved around the items at hand. Additional items may stimulate additional creativity in the students.
2. Classroom teachers need to have access to student portfolios during the design unit and check student progress often. Classroom teachers could encourage students to complete the portfolios and provide direction for groups if portions of the student portfolio were not complete or not completed correctly. Providing this access, especially in the case of the iPad based *LiveAssess* portfolios, would allow for a better comparison between paper and electronic portfolios following the study.
3. A simple student unique identifier needs should be used in order to increase the probability that students will correctly enter the unique identifier on both the pre- and post-questionnaire. Care should be taken to ensure the identifier is not easily traced back to the student and that the identifier is easy enough for students to understand and produce.
4. Gender was not collected as part of the questionnaires in this study. As gender has been shown to be correlated with higher levels of SDL among middle school students (Reio & Davis, 2005) it is important that future studies collect and utilize gender as a potentially significant variable.
5. Students should be taught specific ways to use mobile devices as part of the engineering design process. Teachers should also work to change the classroom norms so they include positive and appropriate mobile device usage.

Conclusion

Granting access to mobile devices in middle school TEE classrooms during a STEM activity demonstrated the potential for transforming and improving student educational experiences. While student SDL was not significantly impacted by access to mobile devices student achievement showed positive correlations with access to mobile devices. In order for mobile devices to be impactful teachers and students will need to work together to change the classroom norms related to mobile device use. Teaching and

modelling appropriate and effective mobile device use and working to ease the divide between “mobile-friendly zones” and “mobile-restricted zone” may work to improve the effectiveness of mobile device access in K-12 classrooms. It is important that students are taught specific ways to use their mobile devices outside of simply looking up factual data.

In this study student SDL correlated more closely with student and classroom characteristics than it did with access to technology tools. Perhaps the debate surrounding mobile device inclusion in classrooms should shift from the actual tools to the learner and classroom characteristics. Students interviews revealed that students appreciate the ability to exercise their agency when given access to mobile devices, this opportunity to choose may work to increase student SDL.

Like other research (e.g., Darling-Hammond, 2000), this research found that the impact of a teacher on student achievement cannot be overstated; student’s final portfolio and product scores were more directly related to their teacher than any other variable. Focus on effective teaching skills and effective teacher identification and training should take precedence over technology tools and other classroom add-ons. Effective teachers influenced their students in more significant ways than any other variable studied in this research.

Teachers should also work to provide students with open-ended engineering design challenge problems and group work settings. These opportunities may help students improve not only their SDL but their overall achievement. TEE classrooms and STEM activities can help provide opportunities for students to work through open-ended

engineering design problems (USOE, 2014a). The findings from this study show that SDL, a trait identified by the Partnership for 21st Century Learning as a key trait for today's learners (Partnership, 2011), needs to remain a direction for research and exploration—especially at the middle-school level.

REFERENCES

- Agra, M., Blanchard, C., & Wehmeyer, M. L. (2000). Promoting transition goals and self-determination through student self-directed learning: The self-determined learning model of instruction. *Education & Training in Mental Retardation & Developmental Disabilities, 35*, 351-364.
- Alberta Education. (2006). *One-to-one mobile computing: Literature review*. Retrieved from <http://education.alberta.ca/media/528965/litreview.pdf>
- Alberta Education. (2012). *iPads: What are we learning? Summary report of provincial data gathering day*. Retrieved from <http://education.alberta.ca/media/6684652/ipad%20report%20-%20final%20version%202012-03-20.pdf>
- Alfrey, K., & Cooney, E. (2009). *Developing a rubric to assess critical thinking in assignments with an open-ended component*. Retrieved from http://assessment.ucdavis.edu/local_resources/toolkit/Alfrey-Cooney.pdf
- Ames, R. T. (2013). A review of science standard history culminating with next generation science standards. *Journal of Education & Training, 1*(2), 48-57.
- Bain, J., Kimbell, R., Miller, S., & Stables, K. (2004). *Assessing design innovation: A research & development project for the DfES and the qualifications and curriculum authority*. Retrieved from <https://www.stem.org.uk/elibrary/resource/32337/assessing-design-innovation-report>
- Bamberger, Y., & Cahill, C. (2013). Teaching design in middle school: instructors' concerns and scaffolding strategies. *Journal of Science Education & Technology, 22*(2), 171-185.
- Banister, S. (2010). Integrating the iPod Touch in K-12 education: Visions and vices. *Computers in the Schools, 27*(2), 121-131.
- Barker, J. E., Semenov, A. D., Michaelson, L., Provan, L. S., Snyder, H. R., & Munakata, Y. (2014). Less-structured time in children's daily lives predicts self-directed executive functioning. *Frontiers in Psychology, June 17, 2014*. Retrieved from <http://journal.frontiersin.org/article/10.3389/fpsyg.2014.00593/full>
- Bartholomew, S. (2015). Who teaches the STE in STEM? *The Technology & Engineering Teacher, 75*(2), 14-19.
- Berg, B. (2009). *Qualitative research methods for the social sciences*. New York, NY: Pearson

- Becker, K. H., & Park, K. (2011). Effect of integrative approaches among science, technology, engineering, and mathematics (STEM) subjects on students' learning: A meta-analysis. *Journal of STEM Education: Innovations & Research*, 12(5), 23-37.
- Blumberg, P. (2000). Evaluating the evidence that problem-based learners are self-directed learners: A review of literature. In D. H. Evensen & C. E. Hmelo (Eds.), *Problem-based learning: A research perspective on learning interactions* (pp. 199-226). Mahwah, NJ: Erlbaum
- Bybee, R. (2010). Advancing STEM education: A 2020 vision. *Technology & Engineering Teacher*, 70(1), 30-35.
- Center on Media and Child Health. (2010). *Cell phones in the classroom*. Retrieved from <http://cmch.tv/press/cell-phones-in-the-classroom/>
- Chan, T., Roschelle, J., Hsi, S., Kinshuk, Sharples, M., Brown, T., Patton, C. . . . Hoppe, U. (2006). One-to-one technology-enhanced learning: An opportunity for global research collaboration. *Research & Practice in Technology Enhanced Learning*, 1(1), 3-29.
- Cheung, W., & Hew, K. (2009). A review of research methodologies used in studies on mobile handheld devices in K-12 and higher education settings. *Australasian Journal of Educational Technology*, 25(2), 153-183.
- Christensen, C. M., & Horn, M. B. (2011). *The rise of online education*. Retrieved from http://www.washingtonpost.com/national/on-innovations/the-rise-of-online-education/2011/09/14/gIQA8e2AdL_story.html
- Chun, L., Shum, M., & Tian, Y. (2014). Enhancing learners' self-directed use of technology for language learning: The effectiveness of an online training platform. *Computer Assisted Language Learning*, 29(1), 40-60. doi: 10.1080/09588221.2014.889714
- Clark, W., Logan, K., Lukin, R., Mee, A., & Olver, M. (2009). Beyond Web 2.0: Mapping the technology landscapes of young learners. *Journal of Computer Assisted Learning*, 25, 56-69.
- Cohen, J., Cohen, P., West, S. G., & Aiken, L. S. (2003). *Applied multiple regression/correlation analysis in behavioral sciences*. Mahwah, NJ: Routledge.
- Cole, I. (2013). *The maker movement. Raising geeks*. Retrieved from <http://www.raisinggeeks.com/blog/maker-movement/>
- CommonSense Media. (2009). *Cheating goes hi-tech*. Retrieved from <https://www.common SenseMedia.org/blog/cheating-goes-hi-tech>

- CommonSense Media. (2013). *Zero to eight: Children's media use in America 2013*. Retrieved from <https://www.commonsensemedia.org/research/zero-to-eight-childrens-media-use-in-america-2013>
- Cosnefroy, L., & Carre, P. (2014). Self-regulated and self-directed learning: why don't some neighbors communicate? *International Journal of Self-Directed Learning*, Vol. 11(2), 1-12.
- Costa, A. L., & Kallick, B. (2004). Launching self-directed learners. *Educational Leadership*, 62(1), 51-57.
- Crichton, S., Pegler, K., & White, D. (2012). Personal devices in public settings: Lessons learned from an iPod Touch/iPad Project. *Electronic Journal of E-Learning*, 10(1), 23-31.
- Daher, W. (2010). Building mathematical knowledge in an authentic mobile phone environment. *Australasian Journal of Educational Technology*, 26(1), 85-104.
- Darling-Hammond, L. (2000). Teacher quality and student achievement: A review of state policy evidence. *Educational Policy Analysis Archives*, 8(1). Retrieved from <http://epaa.asu.edu/ojs/article/view/392/515>
- Deegan, R., & Rothwell, P. (2010). A classification of m-learning application from a usability perspective. *Journal of the Research Center for Educational Technology*, 6(1), 28-46.
- Demir, O., & Yurdugul, H. (2013). Self-Directed Learning with Technology Scale for Young Students: A validation study. *E-International Journal of Educational Research*, 4(3), 58-73.
- Devlin, T. J., Feldhaus, C. R., & Bentrem, K. M. (2013). The evolving classroom: A study of traditional and technology-based instruction in a STEM classroom. *Journal of Technology Education*, 25(1), 34-54.
- Doering, A., & Henrickson, J. (2015). Fostering creativity through inquiry and adventure in informal learning environment design. *Journal of Technology & Teacher Education*, 23(3), 387-410.
- Dugger, W. E. (2010, December). *Evolution of STEM in the United States*. Paper presented at the 6th Biennial International Conference on Technology Education Research Australia. Retrieved from https://www.researchgate.net/publication/229041732_Evolution_of_STEM_in_the_United_States
- Elder, J. (2009). *OMG! Teachers say texting can be good for teens*. Retrieved from <http://www.ocmboces.org/tfiles/folder889/Cell%20Phones%20in%20Schools%20Binder1.pdf>

- Ericsson (2012). *85 percent of the world's population covered by high-speed mobile Internet in 2017*. Retrieved from <http://www.ericsson.com/news/1617338>
- Executive Office of the President. (2010). *Report to the President. Prepare and inspire: K-12 Education in Science, Technology, Engineering, and Math (STEM) for America's Future*. Retrieved from <http://eric.ed.gov/?id=ED516009>
- Fahnoe, C., & Mishra, P. (2013). Do 21st century learning environments support self-directed learning? Middle school students' response to an intentionally designed learning environment. In R. McBride & M. Searson (Eds.), *Proceedings of Society for Information Technology & Teacher Education International Conference 2013* (pp. 3131-3139). Chesapeake, VA: AACE.
- Fantz, T., DeMiranda, M. A., & Siller, T. J. (2010). Knowing what engineering and technology teachers need to know: A content analysis of pre-service teachers engineering design problems. *Journal of Technology & Design Education*, 21, 307-320.
- Farmer, C., Allen, D. T., Berland, L. K., Crawford, R. H., & Guerra, L. (2012, August). *Engineer your world: An innovative approach to developing a high school engineering design course*. Paper presented at the meeting of the American Society for Engineering Education, San Antonio, TX.
- Federal Communications Commission. (2010). *National broadband plan, recommendation 11.23*. Retrieved from <http://transition.fcc.gov/national-broadband-plan/national-broadband-plan.pdf>
- Ferrer, F., Belvís, E., & Pàmies, J. (2011). Tablet PCs, academic results, and educational inequalities. *Computers & Education*, 56(1), 280-288.
- Fisher, M., King, J., & Tague, G. (2001). Development of a self-directed learning readiness scale for nursing education. *Nurse Education Today*, 21, 516-525.
- Francis, A., & Flanigan, A. (2012). Self-directed learning and higher education practices: Implications for student performance and engagement. *International Journal of Scholarship of Teaching & Learning*, 7(3), 1-18.
- Fritschi J., & Wolf, M. A. (2012). *Turning on mobile learning in North America*. Retrieved from <http://www.unesco.org/new/en/unesco/themes/icts/m4ed/mobile-learning-resources/unescobilelearningseries/>
- Froese, A. D., Carpenter, C. N., Inman, D. A., Schooley, J. R., Barnes, R. B., Brecht, P. W., & Chacon, J. D. (2012). Effects of classroom cell phone use on expected and actual learning. *College Student Journal*, 46(2), 323-332.

- Gall, M. D., Borg, W. R., & Gall, J. P. (1996). *Educational research* (6th ed.). White Plains, NY: Longman.
- Gaskell, A., & Mills, R. (2010). *Can we really learn from mobile handheld devices?* Retrieved from http://wikieducator.org/images/c/ce/Anne_Gaskell.pdf
- Goh, K. (2014). What good teachers do to promote effective student learning in a problem-based learning environment. *Australian Journal of Educational & Developmental Psychology, 14*, 159-166.
- Goliath, C. (2009). *Diffusion of an E-portfolio to assist in the self-directed learning of physicians: An exploratory study*. Retrieved from https://etd.ohiolink.edu/ap/10?101406416239225::NO:10:P10_ETD_SUBID:47214
- Grabowicz, P. (2014). *Web 2.0 and the rise of social media*. Retrieved from <http://multimedia.journalism.berkeley.edu/tutorials/digital-transform/web-20/>
- Groundar, S. (2011, December). *What is the potential impact of using mobile devices in education?* Paper presented at the SIG GlobDev Fourth Annual Workshop, Shanghai, China.
- Grant, M. M., Tamim, S., Brown, D., Sweeney, J. P., Ferguson, F. K., & Jones, L. B. (2015). Teaching and learning with mobile computing devices: Case study in K-12 classrooms. *TechTrends*. Retrieved from <http://link.springer.com/article/10.1007%2Fs11528-015-0869-3>
- Guba, E. G., & Lincoln, Y. S. (1989). *Fourth generation evaluation*. Newbury Park, CA: Sage.
- Guglielmino, L. M. (1977). Development of the self-directed learning readiness scale (Doctoral dissertation). *Dissertation Abstracts International, 38*, 6467A.
- Gureckis, T. M., & Markant, D. B. (2012). Self-directed learning: A cognitive and computational perspective. *Perspectives on Psychological Science, 7*, 464-481.
- Hase, S., & Kenyon, C. (2007). Heutagogy: A child of complexity theory. *Complicity: An International Journal of Complexity and Education, 4*(1), 111-118.
- Heller, D., & Sottile, J. M., Jr. (1996). *Another look at student motivation: A qualitative study*. Retrieved from <http://files.eric.ed.gov/fulltext/ED398524.pdf>
- Hendry, G. D., & Ginns, P. (2009). Readiness for self-directed learning: validation of a new scale with medical students. *Medical Teacher, 31*(10), 918-920.
- Hiemstra, R. (2006). Is the internet changing self-directed learning? Rural users provide some answers. *International Journal of Self-Directed Learning, 3*(2), 45-60.

- Householder, D. L., & Hailey, C. E. (Eds.). (2012). *Incorporating engineering design challenges into STEM courses*. Retrieved from <http://ncete.org/flash/pdfs/NCETECaucusReport.pdf>
- Huang, P. H., Lin, Y. F., & Hwang, G. J. (2010). Formative assessment design for PDA integrated ecology observation. *Educational Technology & Society*, 13(3), 33-42.
- Hwang, G. J., Shi, Y. R., & Chu, H. C. (2011). A concept map approach to developing collaborative Mindtools for context-aware ubiquitous learning. *British Journal of Educational Technology*, 42(5), 778-789. doi:10.1111/j.1467-8535.2010.01102.x
- Hwang, G. J., & Tsai, C. C. (2011). Research trends in mobile and ubiquitous learning: A review of publications in selected journals from 2001 to 2010. *British Journal of Educational Technology*, 42, E65-E70. doi: 10.1111/j.1467-8535.2011.01183.x
- Hwang, W. Y., & Chen, H. S. L. (2012). User's familiar situational contexts facilitate the practice of EFL in elementary schools with mobile devices. *Computer Assisted Language Learning*, 26(2), 101-125. doi:10.1080/09588221.2011.639783
- Hynes, M., Portsmouth, M., Dare, E., Milto, E., Rogers, C., & Hammer, D. (2011). *Infusing engineering design into high school STEM courses*. Retrieved from <http://ncete.org/flash/pdfs/Infusing%20Engineering%20Hynes.pdf>
- International Technology and Engineering Education Association [ITEEA]. (2007). *Standards for Technological Literacy* (3rd ed.). Reston, VA: Author.
- International Technology and Engineering Education Association [ITEEA]. (2016). *Integrative STEM Education*. Retrieved from <http://www.iteea.org/Resources1507/56194.aspx>
- Johnson, L., Adams, S., & Cummins, M. (2013). *The NMC horizon report: 2012 higher education edition*. Austin, TX: The New Media Consortium. Retrieved from <http://www.nmc.org/pdf/2013-technology-outlook-for-STEM-education.pdf>
- Johnson, L., Adams, S., & Haywood, K. (2011). *The NMC horizon report: 2011 K-12 Edition*. Austin, TX: The New Media Consortium. Retrieved from <http://www.nmc.org/pdf/2011-Horizon-Report-K12.pdf>
- Jolls, T. (2015). The new curricula: How media literacy education transforms teaching and learning. *Journal of Media Literacy Education*, 7(1), 65-71.
- Kaiser Foundation. (2010). *Daily media use among children and teens up dramatically from five years ago*. Retrieved from <http://kff.org/disparities-policy/press-release/daily-media-use-among-children-and-teens-up-dramatically-from-five-years-ago/>.

- Kicken, W., Brand-Gruwel, S., van Merriënboer, J., & Slot, W. (2009). Design and evaluation of a development portfolio: how to improve students' self-directed learning skills. *Instructional Science*, 37(5), 453-473.
- Kiger, D., Herro, D., & Prunty, D. (2012). Examining the influence of a mobile learning intervention on third grade math achievement. *Journal of Research on Technology Education*, 45(1), 61-82.
- Kim, R., Olfman, L., Ryan, T., Eryilmaz, E. (2013). Leveraging a personalized system to improve self-directed learning in online educational environments. *Computers & Education*, 70, 150-160.
- Kim, S., Holmes, K., & Mims, C. (2005). Mobile wireless technology use and implementation: Opening a dialogue on the new technologies in education. *Techtrends: Linking Research & Practice to Improve Learning*, 49(3), 54-64.
- Kimbell, R. (2007). E-assessment in project e-scape. *Design & Technology Education: An International Journal*, 12(2), 66-76.
- Kimbell, R. (2012a). Evolving project e-scape for national assessment. *International Journal of Technology & Design Education*, 22, 135-155.
- Kimbell, R. (2012b). The origins and underpinning principles of e-scape. *International Journal of Technology & Design Education*, 22, 123-134.
- Kimbell, R., Wheeler, T., Miller, S., Pollitt, A. (2007). *E-scape portfolio assessment phase 2 report*. London, England: TERU, Goldsmiths, University of London.
- Kirschner, P. A., Sweller, J., & Clark, R. E. (2006). Why minimal guidance during instruction does not work: an analysis of the failure of constructivist, discovery, problem-based, experiential, and inquiry-based teaching. *Educational Psychologist*, 41(2), 75-86.
- Kitchen, T. (2014). *From tools of knowledge to tools of creativity*. Retrieved from http://timkitchen.wikispaces.com/file/view/knowledgetocreativity_tkitchen.pdf
- Knowles, M. (1975). *Self-directed learning: A guide for learners and teachers*. Englewood Cliffs, NJ: Prentice Hall/Cambridge.
- Kuznekoff, J., & Titsworth, S. (2013). The impact of mobile phone usage on student learning. *Communication Education*, 62(3), 233-252.
- Lammi, M., & Becker, K. (2013). Engineering design thinking. *Journal of Technology Education*, 24(2), 55-77.

- Lee, K., Tsai, P. S., Chait, C.S., & Koht, J. H. L. (2014). Students' perceptions of self-directed learning and collaborative learning with and without technology. *Journal of Computer Assisted Learning, 30*(5), 425-437.
- Lenhart, A. (2012). *Teens, smartphones & texting: Cell phone ownership*. Retrieved from <http://www.pewInternet.org/2012/03/19/cell-phone-ownership/>
- Lenhart, A., Ling, R., Campbell, S., Purcell, K. (2010). *Teens and mobile phones*. Retrieved from <http://www.pewInternet.org/files/old-media/Files/Reports/2010/PIP-Teens-and-Mobile-2010-with-topline.pdf>
- Liu, M., Navarrete, C. C., & Wivagg, J. (2014). Potentials of mobile technology for K-12 Education: An investigation of iPod touch use for English language learners in the United States. *Educational Technology & Society, 17*(2), 115-126.
- Liu, M., Scordino, R., Geurtz, R, Navarrete, C., Ko, Y. J., & Lim, M. H. (2014). A look at research on mobile learning in K-12 education from 2007 to present. *Journal of Research on Technology in Education, 46*(4), 325-372.
- Lloyd, J. (2010). *Cell phones head to class*. Retrieved from <http://www.mysanantonio.com/news/education/article/Cell-phones-head-to-class-780555.php>
- Lorain, R. (2014). *Brain development in young adolescents: Good news for middle school teachers*. Retrieved from <http://www.nea.org/tools/16653.htm>
- Lounsbury, J. W., Levy, L. J., Park, S. H., Gibson, L. W., & Smith, R. (2009). An investigation of the construct validity of the personality trait of self-directed learning. *Learning & Individual Differences, 19*(4), 411-418.
- Loveland, T., & Dunn, D. (2014). Teaching engineering habits of mind in technology education. *Technology & Engineering Teacher, 73*(8), 13-19.
- Makoe, M. (2012). Teaching digital natives: Identifying competencies for mobile learning facilitators in distance education. *South African Journal of Higher Education, 26*(1), 91-104.
- Massachusetts Department of Education. (2006). *Massachusetts science and technology/engineering curriculum framework*. Retrieved from <http://www.doe.mass.edu/frameworks/scitech/1006.pdf>
- Mayer, R. (2004). Should there be a three-strikes rule against pure discovery learning? The case for guided methods of instruction. *American Psychologist, 59*, 14-19.
- McCaffrey, M. (2011). Why mobile is a must. *T.H.E. Journal, 38*(2), 21-22.

- Mentzer, N. (2011). *Engineering design thinking and information gathering*. Retrieved from http://digitalcommons.usu.edu/ncete_publications/162
- Miller, G. (1956). The magical number seven, plus or minus two: Some limits on our capacity for processing information. *The Psychological Review*, 63, 81-97.
- Mitchell, L. (2014). Rise of the YouTube makeup artist: Nearly half of women use online tutorials. *Express*. Retrieved from <http://www.express.co.uk/life-style/style/464633/Pixiwoo-Lauren-Curtis-Frozen-Nearly-half-of-women-copy-popular-online-makeup-tutorials>
- Mok, M. M. C., Leung, S. O., & Shan, P. W.-J. (2005). A comparative study on the self-directed learning of primary students in Hong Kong and Macau. *International Journal of Self-directed Learning*, 2(2), 39-54.
- Moran, G. (2011). Maker faire and the growth of do-it-yourself. *Entrepreneur*. Retrieved from <http://www.entrepreneur.com/article/220527>
- National Council on Teacher Quality. (2009). *Tackling the STEM crisis: Five steps your state can take to improve the quality and quantity of its K-12 math and science teachers*. Retrieved from http://www.nctq.org/p/docs/nctq_nmsi_stem_initiative.pdf
- Next Generation Science Standards. (2014). *About the standards*. Retrieved from <http://www.nextgenscience.org/three-dimensions>
- Norris, C., Hossain, A., & Soloway, E. (2011). Using smartphones as essential tools for learning: A call to place schools on the right side of the 21st century. *Educational Technology*, 51(3), 18-25.
- NPD Group. (2008). *Kids and consumer electronics IV*. Port Washington, NY: Author.
- O'Bannon, B., & Thomas, K. (2015). Mobile phones in the classroom: Preservice teachers answer the call. *Computers & Education*, 85, 110-122.
- Park, Y. (2011). A pedagogical framework for mobile learning: Categorizing educational applications of mobile technologies into four types. *International Review of Research in Open & Distance Learning*, 12(2), 78-102.
- Partnership. (2011). *Framework for 21st century learning*. Retrieved from <http://www.p21.org/our-work/p21-framework>
- Pearson. (2013). *Pearson student mobile device survey 2013, national report: Students in grades 4-12*. Retrieved from <http://www.pearsoned.com/wp-content/uploads/Pearson-Student-Mobiledevice-Survey-2013-National-Report-on-Grades-4-to-12-public-release.pdf>

- Pfeiffer, V. I., Gemballa, S., Jarodzka, H., Scheiter, K., & Gerjets, P. (2009). Situated learning in the mobile age: Mobile devices on a field trip to the sea. *ALT-J: Research in Learning Technology*, 17(3), 187-199.
- Pew Research Center. (2015). *Teens, social media & technology overview 2015*. Retrieved from <http://www.pewInternet.org/2015/04/09/teens-social-media-technology-2015/>
- Pollitt, A. (2004). *Let's stop marking exams*. Retrieved from <http://www.cambridgeassessment.org.uk/images/109719-let-s-stop-marking-exams.pdf>
- Pollitt, A. (2012). The method of adaptive comparative judgment. *Assessment in Education: Principles, Policy & Practice*, 19(3), 281-300.
- Pollitt, A., & Crisp, V. (2004, September). *Could comparative judgments of script quality replace traditional marking and improve the validity of exam questions?* Paper presented at the BERA Annual Conference, UMIST Manchester, England.
- Prensky, M. (2007). Changing paradigms. *Educational Technology*, July-August. Retrieved from <http://www.marcprensky.com/writing/Prensky-ChangingParadigms-01-EdTech.pdf>
- Project Red. (2011). *The technology factor: Nine keys to student achievement and cost-effectiveness*. Retrieved from http://www.pearsonfoundation.org/downloads/ProjectRED_TheTechnologyFactor.pdf
- Project Tomorrow. (2011). *The new 3 E's of education: Enabled, engaged, empowered - how today's educators are advancing a new vision for teaching and learning*. Retrieved from http://www.tomorrow.org/speakup/pdfs/SU10_3EofEducation_Educators.pdf
- Project Tomorrow. (2012a). *Learning in the 21st century mobile devices + social media = personalized learning in the 21st century mobile devices + social media = personalized learning*. Retrieved from <http://www.tomorrow.org/speakup/MobileLearningReport2012.html>
- Project Tomorrow. (2012b). *Mapping a personalized learning journey. K-12 students and parents connect the dots with digital learning*. Retrieved from http://www.tomorrow.org/speakup/pdfs/SU11_PersonalizedLearning_Students.pdf
- Project Tomorrow. (2013). *Speak up survey: From chalkboards to tablets: The emergence of the K-12 classroom*. Retrieved from http://www.tomorrow.org/speakup/SU12_DigitalLearners_StudentReport.html

- Project Tomorrow. (2014). *Mobile devices increasingly being seen as tools for learning. National survey explores connection between use of digital learning tools and college and career readiness*. Retrieved from <http://www.tomorrow.org/speakup/pr/SpeakUp2013JunePressRelease.pdf>
- Quillen, I. (2010). Schools open doors to students' mobile devices. *Digital Directions*. Retrieved from <http://www.edweek.org/dd/articles/2010/10/20/01mobile.h04.html>
- Raths, D. (2013). *Making mobile devices a learning tool*. Retrieved from <http://campustechnology.com/articles/2013/05/01/making-mobile-devices-a-learning-tool.aspx?CTMOB>
- Reeve, E. M. (2015). STEM Thinking! *Technology & Engineering Teacher*, 75(4), 8-16
- Reio, T. G., Jr., & Davis, W. (2005). Age and gender differences in self-directed learning readiness: A developmental perspective. *International Journal of Self-Directed Learning*, 2(1), 40-49.
- Ribble, M. (2011). *Digital citizenship: using technology appropriately*. Retrieved from http://www.digitalcitizenship.net/Nine_Elements.html
- Ribble, M., & Bailey, G. (2007). *Digital citizenship in schools*. Washington, DC: ISTE. ISBN: 978-1-56484-232-9.
- Rissanen, A. J. (2014). Active and peer learning in STEM education strategy. *Science Education International*, 25(1), 1-7.
- Robledo, S. J. (2012). Mobile devices for learning: What you need to know. *Edutopia*. Retrieved from: <http://www.edutopia.org/pdfs/guides/edutopia-mobile-learning-guide.pdf>
- Rockland, R., Bloom, D. S., Carpinelli, J., Burr-Alexander, L., Hirsch, L. S., & Kimmel, H. (2010). Advancing the "E" in K-12 STEM education. *Journal of Technology Studies*, 36(1), 53-64.
- Roehrig, G. H., Moore, T. J., Wang, H., & Park, M. S. (2012). Is adding the E enough? Investigating the impact of K-12 engineering standards on the implementation of STEM integration. *School Science & Mathematics*, 112(1), 31-44.
- Rowe, P. G. (1987). *Design thinking*. Cambridge, MA: The MIT Press.
- Saeednia, Y. (2011). *Self-directed learning among children of ages nine to eleven in Tehran: Generating a Persian version of SDLR-ABE*. Retrieved from <http://eric.ed.gov/?id=ED526802>

- Saks, K., & Leijen, A. (2014). Distinguishing self-directed and self-regulated learning and measuring them in the E-learning context. *Procedia - Social & Behavioral Sciences*, 112, 190-198.
- Saldaña, J. (2013). *The coding manual of qualitative researchers* (2nd ed.). Los Angeles, CA: Sage.
- Sanders, M. E., & Wells, J. G. (2010) *Virginia Tech, Integrative STEM Education Graduate Program*. Retrieved from <http://www.soe.vt.edu/istemed>
- Schenker, L. (2009). Schools embrace txt msg. *The Salt Lake Tribune*. Retrieved on September 24, 2014 from: http://www.sltrib.com/education/ci_12179870
- Seifert, T. (2015). Pedagogical applications of smartphone integration in teaching: Lecturers, pre-service teachers and pupils' perspectives. *International Journal of Mobile & Blended Learning*, 7(2), 1-16. doi:10.4018/ijmbl.2015040101
- Sheppard, S. D., Macatangay, K., Colby, A., & Sullivan, W. M. (2009). *Educating engineers: Designing for the future of the field*. San Francisco, CA: Jossey-Bass.
- Shuler, C. (2009). *Pockets of potential*. Retrieved from http://www.joanganz.cooneycenter.org/wp-content/uploads/2010/03/pockets_of_potential_1_.pdf
- Sung, Y. T., Hou, H. T., Liu, C. K., & Chang, K. E. (2010). Mobile guide system using problem-solving strategy for museum learning: A sequential learning behavioral pattern analysis. *Journal of Computer Assisted Learning*, 26(2), 106-115.
- Sungar, S., & Tekkaya, C. (2006). Effects of problem-based learning and traditional instruction on self-regulated learning. *The Journal of Educational Research*, 99, 308-317.
- Sutton, B. B. (2011). Mobile devices in the classroom: Stem stuff. *Edutopia*. Retrieved from <http://www.edutopia.org/groups/science-technology-engineering-mathematics-education/70218>
- Swan, K., van't Hooft, M., Kratcoski, A., & Unger, D. (2005). Uses and effects of mobile computing devices in K-8 classrooms. *Journal of Research on Technology in Education*, 38(1), 99-112.
- Tan, S. C., Ong, K. K. A., Chai, C. S., Cheah, H. M., Wang, Q., & Chen, W. (2013). *Implementation of IT masterplan 3 in Singapore: Insights from the mid-term evaluation*. Retrieved from <http://140.118.59.33/GCJCE/papers/journal270.pdf>
- TeachEngineering. (2015). *The engineering design process*. Retrieved from <https://www.teachengineering.org/engrdesignprocess.php>

- Teo, T. (2013). An initial development and validation of a Digital Natives Assessment Scale (DNAS). *Computers & Education*, 67, 51-57.
- Teo, T., Tan, S. C., Lee, C. B., Chai, C. S., Koht, J. H. L., Chen, W. L., & Cheah, H. M. (2010). The self-directed learning with technology scale (SDLTS) for young students: An initial development and validation. *Computers & Education*, 55, 1764-1771. doi:10.1016/j.compedu.2010.08.001
- Thomas, J. W. (1993). Promoting independent learning in the middle grades: the role of instructional support practices. *The Elementary School Journal*, 93(5), 575-591
- Thomas, K. M., & McGee, C. D. (2012). The only thing we have to fear is... 120 characters. *Techtrends: Linking Research & Practice to Improve Learning*, 56(1), 19-33.
- Thurstone, L. L. (1927). A law of comparative judgment, *Psychological Review*, 34, 273-286.
- Traxler, J. (2005, June). *Defining mobile learning*. Paper presented at the IADIS International Conference on Mobile Learning, Malta.
- Tsai, C. W., & Chung, Y. F. C. (2011). Learning through sharing and regulation: A case study of using web-supported collaborative learning with initiation and self-regulated learning. *International Journal of Web-based Learning & Teaching Technologies*, 6(1), 1-11.
- Tulagan, B. (2013). Meet Generation Z: The second generation with the giant “Millennial” cohort. *Rainmaker Thinking*. Retrieved from <http://rainmakerthinking.com/newsletters/testing-newsletter/>
- Utah State Office of Education. (2014a). *CTE overview: About us*. Retrieved from <http://schools.utah.gov/cte/about.html>
- Utah State Office of Education. (2014b). *Safety and program management guide*. Retrieved from <http://www.schools.utah.gov/CTE/tech/DOCS/SafetyGuide.aspx>
- Utah State Office of Education. (2014c). *Middle school education requirements*. Retrieved from <http://www.schools.utah.gov/CURR/gradinfo/Home/Middle-school-Requirements.aspx>
- Van Deur, P. (2004). Gifted primary students’ knowledge of self-directed learning. *International Education Journal*, 4(4), 64-74.
- Van Deur, P., & Murray-Harvey, R. (2005). The inquiry nature of primary schools and students’ self-directed learning knowledge. *International Education Journal*, 5(5), 166-177.

- Wan, Y. (2011) *Mobile learning*. Retrieved from ftp://ftp.ode.state.oh.us/geodoc/Ohio_Digital_Learning/Mobile%20Learning-ed_Final.pdf
- West, D. M. (2013). *Mobile Learning: transforming education, engaging students, and improving outcomes*. Retrieved from <http://www.brookings.edu/research/papers/2013/09/17-mobile-learning-education-engaging-students-west>
- Woodruff, K. (2013). *A history of STEM: Reigniting the challenge with NGSS and CCSS*. Retrieved from <http://www.us-satellite.net/STEMblog/?p=31>
- Wong, L. H. (2013). Enculturating self-directed learners through a facilitated seamless learning process framework. *Technology, Pedagogy & Education*, 22(3), pp. 319-338. doi:10.1080/1475939X.2013.778447
- Yong, S. T., & Gates, P. (2014). Born digital: Are they really digital natives? *International Journal of e-Education, e-Business, e-Management and e-Learning*, 4(2), 102-105
- Zsiga, P., & Webster, M. (2007). Why should secondary educators be interested in self-directed learning? *International Journal of Self-Directed Learning*, 4(2), 58-68.

APPENDICES

Appendix A

Modified Self-Directed Learning with Technology Scale

Modified Self-directed Learning with Technology Scale

Based on: Teo T., Tan S. C., Lee C. B., Chai C. S., Koh J. H. L., Chen W. L., Cheah H. M., (2010). The self-directed learning with technology scale (SDLTS) for young students: An initial development and validation, *Computers & Education*, 55 (4), pp. 1764-1771. <http://dx.doi.org/10.1016/j.compedu.2010.08.001>.

Self-management

1. I go online to ask my teachers questions on my lessons when I am not in school.
2. I use the computer to share my thoughts and ideas about my schoolwork (e.g., through multimedia storytelling, voice-recording, blogs).

Intentional learning

1. I find out more information on the Internet to help me understand my lessons better.
2. I use the computer to work with information for my learning.
3. I use the computer to become better at a skill that I am interested in e.g., learn a language.
4. I use the computer to get ideas from different websites and people to learn more about a topic.

Also based on: Guglielmino, L. M. (1977). *Development of the self-directed learning readiness scale*. Unpublished doctoral dissertation, University of Georgia. Dissertation Abstracts International. 38(11a): 6467.

See also: Fisher, King, & Tague (2010). The self-directed learning readiness scale for nursing education revisited: A confirmatory factor analysis, *Nurse Education Today*, Volume 30, Issue 1, Pages 44-48, ISSN 0260-6917, <http://dx.doi.org/10.1016/j.nedt.2009.05.020>.

Self-Management

1. I am self-disciplined
2. I am organized
3. I set strict time frames
4. I have good management skills
5. I am methodical
6. I am systematic in my learning
7. I set specific times for my study
8. I prioritize my work
9. I can be trusted to pursue my own learning
10. I am confident in my ability to search out new information

Desire for Learning

1. I want to learn new information
2. I enjoy learning new information
3. I have a need to learn
4. I enjoy a challenge
5. I do enjoy studying
6. I critically evaluate new ideas
7. I learn from my mistakes
8. I need to know why
9. When presented with a problem I cannot resolve, I will ask for assistance

Self-Control

1. I am responsible for my own decisions/actions
2. I am in control of my life
3. I have high personal standards
4. I prefer to set my own learning goals
5. I evaluate my own performance
6. I am responsible
7. I am able to focus on a problem
8. I am aware of my own limitations
9. I can find out information for myself
10. I have high beliefs in my abilities

Q22 Please rate the degree to which the following statements describe you as a learner, using a 1-5 Likert scale where 1 means strongly disagree and 5 means strongly agree. Drag the sliders to the number that best represents your answer.

- _____ I go online to answer questions related to schoolwork when I am not in school. (1)
- _____ I use the computer or a mobile device to share my thoughts and ideas about my schoolwork (e.g., social media, blogs, etc.). (2)
- _____ I go online to learn about school topics I am interested in (for example: how airplanes fly) when I am not in school. (3)
- _____ I go online to learn about non-school topics I am interested in (for example: where my favorite musician grew up) when I am not in school. (4)
- _____ I am structured and self-disciplined when I go online. (5)
- _____ I am organized in my learning. (6)
- _____ I am confident in my ability to search out new information (7)
- _____ I am responsible for my own decisions/actions and have control over my life and my pursuit of knowledge. (8)
- _____ I am able to focus on a problem and find out information for myself. (9)
- _____ I prefer to set my own learning goals (10)
- _____ I evaluate my own performance (11)

Q23 Please rate the degree to which the following statements describe you as a learner, using a 1-5 Likert scale where 1 means strongly disagree and 5 means strongly agree. Drag the sliders to the number that best represents your answer.

- _____ I obtain information on the Internet to help me understand concepts from my schoolwork better. (1)
- _____ I use the computer or mobile devices to organize and work with information related to my learning. (2)
- _____ I use the computer or a mobile device to become better at a skill that I am interested in (for example: to learn a language). (3)
- _____ I want to learn new information and I enjoy learning new information. (4)

- _____ I enjoy the challenge of learning and studying. (5)
- _____ When presented with a problem I cannot resolve, I will ask for assistance or go online to find an answer. (6)
- _____ I want to find out the “why” behind things and learn more (7)
- _____ I learn from my mistakes and set goals to improve my learning (8)
- _____ I use technology (e.g., personal computers, mobile devices, etc.) to learn about topics that interest me. (9)
- _____ I use a wide variety of technologies (e.g., computers, tablets, mobile-phones) to learn, study, and communicate with others (10)

Appendix B

Digital Natives Assessment Scale

Digital Natives Assessment Scale

Derived from: Timothy Teo (2013). An initial development and validation of a Digital Natives Assessment Scale (DNAS), *Computers & Education*, 67, September 2013, pp. 51-57.

Cited in:

Allen, K.A., Ryan, T., Gray, D.L., McInerney, D.M., Waters, L. (2014). Social media use and social connectedness in adolescents: The positives and the potential pitfalls. *Australian Educational and Developmental Psychologist*, 31 (1), 18-31.

Braccini, A.M., Federici, T. (2013). A measurement model for investigating digital natives and their organizational behavior. *International Conference on Information Systems (ICIS 2013): Reshaping Society through Information Systems Design*, 1, 159-169.

Teo, T. (2015). Comparing pre-service and in-service teachers' acceptance of technology: Assessment of measurement invariance and latent mean differences. *Computers and Education*, 83, 22-31.

Teo, T., Khlaisang, J., Thammetar, T., Ruangrit, N., Satiman, A., Sunphakitjumnong, K. (2014). A survey of pre-service teachers' acceptance of technology in Thailand. *Asia Pacific Education Review*, 15 (4), 609-616.

Teo, T., Zhou, M. (2014). Explaining the intention to use technology among university students: A structural equation modeling approach. *Journal of Computing in Higher Education*, 26 (2), 124-142.

Also derived from: *Experience with Technology Questionnaire*. Developed by the *Educating the Net Generation* Group. This questionnaire came out of a collaborative project involving the University of Melbourne, the University of Wollongong, and Charles Stuart University and was funded by the Australian Learning and Teaching Council from:

Bennett, S., Kennedy, G., Dalgarno, B., Judd, T., Gray, K., & Waycott, J. (2008). Immigrants and natives: Investigating differences between staff and students' use of technology. In R. Atkinson & C. Macbeths (Eds.), *Annual Conference of the Australasian Society for Computers in Learning in Tertiary Education* (pp. 484-492). Melbourne, Australia: Deakin University.

See Also:

Chang, R., Kennedy, G. & Petrovic, T. (2008). Web 2.0 and user-created content: Students negotiating shifts in academic authority. In *Hello! Where are you in the*

landscape of educational technology? Proceedings ascilite Melbourne 2008.

- Kennedy, G., Dalgarno, B., Bennett, S., Judd, T., Gray, K., & Chang, R. (2008). Immigrants and Natives: Investigating differences between staff and students' use of technology. In *Hello! Where are you in the landscape of educational technology?* Proceedings ascilite Melbourne 2008.
- Kennedy, G., Dalgarno, B., Gray, K., Judd, T., Waycott, J., Bennett, S. et al. (2007). The net generation are not big users of Web 2.0 technologies: Preliminary findings. In *ICT: Providing choices for learners and learning*. Proceedings ascilite Singapore 2007 (pp. 517-525).
- Kennedy, G., Krause, K.-L., Gray, K., Judd, T., Bennett, S., Maton, K. et al. (2006). Questioning the Net Generation: A collaborative project in Australian higher education. In L. Markauskaite, P. Goodyear & P. Reimann (Eds.), *Who's learning? Whose technology?* Proceedings of the 23rd Annual Conference of the Australasian Society for Computers in Learning in Tertiary Education (pp. 413-417). Sydney: Sydney University Press.
- Petrovic, T., Kennedy, G., Chang, R., & Waycott, J. (2008). Podcasting: is it a technology for informal peer learning? In *Hello! Where are you in the landscape of educational technology?* Proceedings ascilite Melbourne 2008.

Q14 How SKILLED are you at using technology to perform the tasks listed? If you have never done the listed task, please choose "never used." Drag the sliders to the number that best represents your answer.

_____ Use a mobile -device to manage, create, or manipulate digital photos, digital audio, or digital videos (1)

_____ Use a mobile device to access information via the Internet (2)

_____ Use a mobile device to learn new skills (3)

_____ Use a mobile device to communicate with others (for example: text, phone call, email, etc.) (4)

_____ Use a mobile device to send pictures, videos, or audio files to someone else (5)

Q20 Rate the level to which you agree or disagree with the following statements as they relate to you. Drag the sliders to the number that best represents your answer.

_____ I am able to surf the Internet and perform another activity comfortably (1)

_____ I can check email, messages, and/or communicate with others (electronically) at the same time (2)

_____ When using the Internet, I am able to listen to music as well (3)

_____ I am able to communicate with my friends and do my work at the same time (4)

_____ I am able to use more than one application on the computer or a mobile device at the same time (5)

_____ I can chat on the phone with a friend and message another at the same time (6)

Q22 Rate the level to which you agree or disagree with the following statements as they relate to you. Drag the sliders to the number that best represents your answer.

_____ I use pictures more than words when I wish to explain something (1)

_____ I use a lot of pictures, emojis, emoticons, etc. when I send messages (2)

_____ I prefer to receive messages with graphics and icons (3)

_____ I use pictures to express my feelings better (4)

Q24 Rate the level to which you agree or disagree with the following statements as they relate to you. Drag the sliders to the number that best represents your answer.

_____ I wish to be rewarded for everything I do (1)

_____ I expect quick access to information when I need it (2)

_____ When I send out a message (text, email, other), I expect a quick reply (3)

_____ I expect websites, apps, and other places I access regularly to be constantly updated or improved (4)

_____ When I study, I prefer to learn those things that I can use quickly first (5)

Q18 Rate the level to which you agree or disagree with the following statements as they relate to you. Drag the sliders to the number that best represents your answer.

_____ I use the Internet everyday (1)

_____ I use computers and/or mobile devices for many things in my life (2)

_____ When I need to know something, I search the Internet first (3)

_____ I use the computer and/or a mobile device for leisure every day (4)

_____ I keep in contact with my friends through the computer or a mobile device every day (5)

Appendix C
Classroom Script

Classroom Script

Day	Time	Activity	Corresponding section in portfolio (paper and electronic)
TEACHERS		Helpful Resources: <ul style="list-style-type: none"> • URLs for student questionnaires (Appendix Q) • Timeline for this study (Appendix R) • Questions for student dice rolls (Appendix S) • Consent forms (Appendix T) • Student worksheet for digital citizenship lesson (Appendix U) 	
1	Entire Class	Students take pre-study tests online at: http://www.tinyurl.com/alpinestudypre	
2	0-35 minutes	Students learn about engineering design (Appendix H) Any students that did not fill out the 2 questionnaires last class should do so now	
	Start Activity (at 35 minutes)	Explain the rules and expectations for the design process <ul style="list-style-type: none"> • Students will be working in teams of 3 to brainstorm, design, and model a medicine holder/dispenser for the elderly • A major part of this activity is the completion of the design portfolio. A design portfolio is a representation of your thoughts, struggles, questions, accomplishments, and the overall process that takes place as you work together to design your medicine holder/dispenser. • <i>Show students the portfolio (paper or electronic) and ensure that each group either has a portfolio or is on their iPad with the portfolio pulled up.</i> • Read one of the prompts and explain to the students that <i>what</i> they put in the box is very important. They need to answer the questions completely and legibly. Students do not need to worry about having too much or too little information, rather they should focus on having the right amount of information to answer the question or prompt. Student's responses should take the form of a complete sentence. 	
	At 42 minutes	Introduce the context and engineering design challenge <ul style="list-style-type: none"> • Pass out engineering design challenges to students (see below) • Read through the engineering design challenge with the class and answer any questions students may have 	
	After 50 minutes	Announce the groups and have the students sit with their groups. <ul style="list-style-type: none"> • Explain that the groups were made by the researcher and the teacher beforehand. 	

		<ul style="list-style-type: none"> • <i>The unit is only 2 weeks long so students shouldn't worry if they don't get placed in a group with their friends</i> <p>Introduce the handling collection and let student explore the handling collection in their groups</p> <ul style="list-style-type: none"> • Play the handling collection video (found in the google drive folder) and tell the students it will be playing while they work. It is a collection of images to help them think about possibilities. • Tell students that care should be taken to not break or otherwise misuse any of the items. • Explain that the collection consists of various items for the students to help stimulate their thinking. • Ask the students the following questions (meant to prompt creativity) and encourage discussion. The goal here is to get the students to think outside the box, to come up with lots of connections between everyday materials and their design challenge. <ul style="list-style-type: none"> ○ What are examples of containers you can think of? (i.e., milk, egg, shoes, etc.) ○ How do we divide things? (dividers, by color, by size, by shape) ○ How do we make things secure? (locks, passwords, codes) ○ What kinds of lids are there? (screw on, snap on, set on, tie on) ○ What are ways we dispense things? (Pez dispenser, dog food dispenser, Kleenex box) ○ How do we carry things? (handles, in boxes, with wheels, etc.) 	
	After 70 minutes	<p>Students continue playing with ideas</p> <ul style="list-style-type: none"> • Encourage students to talk with their group members about their initial ideas from the handling collection for the design challenge and then allow them time to talk and brainstorm • PASS OUT PORTFOLIOS—paper or iPad (1 per group) & supplies (1 per group) • Remind groups to fill in sections 1-3, & section 18 on their portfolios (paper or electronic). • <i>Help any students that need help finding those sections or filling them out.</i> • <i>If some groups are not brainstorming, consider asking them questions to help get the conversation started</i> <ul style="list-style-type: none"> ○ <i>What did you think of the handling materials?</i> ○ <i>Have any of you seen something that we could modify or work from to get</i> 	1, 2, 3

		<p><i>started?</i></p> <ul style="list-style-type: none"> ○ <i>What are some of the constraints or considerations we need to work around?</i> <ul style="list-style-type: none"> ● Remind students about answering the questions in complete sentences. Remind students to answer the questions in a legible and complete manner. 	
	After 80 minutes	<p>Students cleanup work areas</p> <ul style="list-style-type: none"> ● Have the students gather their handling collection and place it back in the bag. Collect these bags and set them aside (the researcher will take them) ● Student put all supplies in the bag and return the bags to the teacher (these need to be returned to the researcher—the students will not be allowed to use the handling collections during the build) <p>END OF DAY 2</p>	
3	Start	<p>Have students sit in their groups and review what they worked on yesterday</p> <p>Discussion about criteria for success</p> <ul style="list-style-type: none"> ● Ask all the students to quiet down for a class discussion and wrap up for the day ● <i>What are the criteria we need to take into consideration? (see engineering design challenge for ideas)</i> ● <i>How will we know if we were successful?</i> ● <i>What will a “good” product look like?</i> ● <i>What are some things NOT listed on the engineering design challenge that might also be important?</i> <p>Have all students fill in section 4 of their portfolios</p> <ul style="list-style-type: none"> ● Remind students of the design challenge and answer any questions they may have ● <i>Pass out the modelling supply bags to each group.</i> ● <i>Tell the students to not open the bags until you are done explaining what the modelling kit is</i> <p>Talk about the modelling kit</p> <ul style="list-style-type: none"> ● <i>The modelling kit contains all the materials the students can use as they design and “model” their final products. As they will start modelling today there are a few things they need to know:</i> ● The supplies in the modelling kit need to be shared between the group and they are only allowed to use the items they find there. ● Care should be taken that supplies from one group/modelling kit do not get mixed with 	<p>4</p> <p>6</p>

		<p>another</p> <ul style="list-style-type: none"> Everything needs to go in the labeled plastic bag at the end of each class <p>Students work in groups to develop ideas</p> <ul style="list-style-type: none"> Have the students continue brainstorming ideas with their partners. Monitor the students as they brainstorm and look through the modelling kit. Students should begin to jot down notes and ideas (box 6) Students should also begin modelling, as a group, based on their discussion. 	
	<p>After 15 minutes</p>	<p>Students develop ideas</p> <ul style="list-style-type: none"> Ask students “what specific requirements will your design need to have to be really successful?” <i>If there are no students offering ideas, consider asking them some prompting questions like:</i> <ul style="list-style-type: none"> <i>Who will use this device?</i> <i>What might the user need to make this design really user-friendly?</i> <i>Where will this device be stored or travel to?</i> <i>What does this device hold? How many? How do you know?</i> Instruct students to fill in box 5 on their portfolios Have students share their responses on box 5 with other groups <p>Students do first dice roll and respond to questions</p> <ul style="list-style-type: none"> Tell students that throughout the design process they will have an opportunity to roll a dice. Each number of the dice responds to a design-question they will then respond to on their paper. The questions are: <ol style="list-style-type: none"> What is going well? What is not going well? If you could change anything about your design right now what would it be? What do you like most about another person’s design? What has been the hardest part of the design process so far? What do you consider your best success so far in the design process? Have students roll the dice (there is only one portfolio per group so they should answer the question as a group and the scribe should fill out the portfolio) Have students jot a few notes in section 6 and possibly draw a small picture that represents their current thinking in the design process for what 	<p>5</p> <p>6a</p>

		they want to do	
	After 40 minutes	<p>Students conduct first “red-pencil review”</p> <ul style="list-style-type: none"> • Inform students that they will now conduct their “red-pencil review.” Let students know this is a normal part of the design process and they shouldn’t worry if their design gets marked up with lots of red. Students will swap portfolios with another group who will conduct the review. • <i>Help students that might be worried about the review know that the review will not impact their grade and the review is a good thing, not something to be worried about.</i> • Have students switch papers with another group (it does NOT matter what other group they switch with). • Red pencils are found in each groups design bag (each group will need one) • Explain to the students that the process of completing a “red-pencil review” is fairly simple and meant to help the designers <i>see</i> and <i>think</i> about things they may not have anticipated. • Students should look at the design process and ideas on the paper (boxes 1-6) and circle with a red pencil potential problems, mistakes, or things they have questions about. Student should then write a brief note identifying their concern with the red pencil on the paper. • Walk around and monitor students as they complete the “red-pencil review” This process should take between 5-10 minutes. • After 10 minutes have students return the design portfolio papers to their proper owners • <i>Students completing an electronic portfolio will hand their iPad to another group. The other group will look through their portfolio and then write suggestions for improvement on a separate piece of paper using their red pen.</i> • Encourage students to briefly visit with the group of designers that own the paper/iPad they marked and explain their red-pencil markings <p>Teachers take, print, and tape 1st photo in portfolio for each group using the provided camera (see below)</p> <ul style="list-style-type: none"> • Explain that at various points in the design process the students will be taking pictures of their current design to document their progress and help them remember what they’ve done and how far they’ve come • <i>Each teacher will be provided with one Fujifilm Instax camera. This camera works similar to a Polaroid in that it will immediately print out a small (credit-card sized) photo.</i> • Explain that teachers are the only ones operating 	6
			7

		<p>the cameras. The teacher will come around at specific times and take pictures of each group's product. The group should then take the picture and place it in the appropriate box on their portfolio.</p> <ul style="list-style-type: none"> • <i>Teachers: go around from group to group and take 1 picture of each group's current product. Have the group tape the picture in box 7 on their portfolio</i> • <i>Groups using iPads will use the built in camera to take the picture at this point in time.</i> 	
	After 80 minutes	<p>Students continue to develop, design, and prototype ideas with their modelling collection materials</p> <p>At 80 Minutes Teachers take photo 2 and provide it to each group</p> <ul style="list-style-type: none"> • <i>Teachers: go around from group to group and take 1 picture of each group's current product. Have the group tape the picture in box 8 on their portfolio</i> • <i>Groups using iPads will use the built in camera to take the picture at this point in time.</i> <p>Students do second dice roll and respond to questions</p> <ul style="list-style-type: none"> • Ask students to roll the dice again and respond to the corresponding question for whatever number they roll. The answer should go in box 6 in the sub-box for dice roll 2 <p>Students cleanup work areas</p> <ul style="list-style-type: none"> • Inform students that all their group supplies should go in the plastic bag that has the modeling collection (i.e. paperwork, portfolios, all modeling collection pieces, anything else the group wants to use as they design). Each plastic bag will be labeled and will stay with the group the entire time. • Help ensure that all bags are labeled with the group number (use a sharpie to label the bag) • Make sure all supplies for each group are stored in the group's bag <p>Student store supplies in classroom</p> <ul style="list-style-type: none"> • Have the students store the bags for their group's in a spot the teacher deems appropriate <p>END OF DAY 3</p>	<p>6</p> <p>8</p> <p>6b</p>
4	Start	<p>Start</p> <ul style="list-style-type: none"> • Have students come in and sit with their groups • Pass out group bags with all supplies <p>Students complete personal reflection</p> <ul style="list-style-type: none"> • Tell students that to start out the day today they will complete personal reflections on their current design. There are 3 spots so that each team member has one spot to write down their 	

	<p>thoughts.</p> <ul style="list-style-type: none"> Point out boxes 10, 11, and 12 on the portfolio so the students know where to complete the reflection. Explain that they should simply note the things they like (by the thumbs up) and the things they don't like (by the thumbs down). Each person should have 3-5 minutes to write down their reflection and then pass the paper on to the next team-member. <p>Students work with their team to complete the team reflection</p> <p>Students get out all their supplies and continue modelling</p>	10, 11, 12
After 15 minutes	<p>Students plan for what they will do next</p> <ul style="list-style-type: none"> Have the students turn their portfolio sheet over and locate box 13 on the back side. Tell students that it's time to make a plan as a group—a plan for what they want to do next and how they will accomplish their plan. <i>Some groups may struggle with this step, especially with deciding the next step.</i> Encourage students to talk openly and honestly about their thoughts and what they want to do next. Help students see that part of working as a team is compromising and working together to accomplish a common goal. Allow students 5 minutes to talk and make a plan for their next steps Have students fill in box 13 on their portfolio <i>Help any groups that are struggling to work together or make a plan by suggesting ways they can compromise or starting points for moving forward</i> 	13
After 20 minutes	<p>Students complete review of ideas box (wackiest, best, problems, next)</p> <ul style="list-style-type: none"> Have students place their portfolios on their desk where they are easily accessible. <i>Point out box 14 and help students see that there is room for 4 drawings to go in that box (representing the four categories of: wackiest, best, problems, next)</i> Tell students that for this activity they will move around the room and look at all the ideas of the class. They will then return to their seat and as a group they will identify the wackiest and the best idea they've seen. As a group they should draw those 2 ideas on post-it notes and place them in the appropriate spot in box 14. Afterward, groups should discuss and decide what the big problems they've seen are and what they will do next. These two concepts (big problems and plan for next steps) should be drawn in the appropriate 	14

		<p>spot in box 14 on their portfolio</p> <ul style="list-style-type: none"> • <i>Groups using iPads will designate one member of their team to stay and demonstrate their idea while the rest of the group travels around the room to look at different ideas.</i> • <i>Groups using iPads will then complete the activity via the iPad</i> 	
	After 35 minutes	<p>Students take, print, and paste their 3rd photo in their portfolio</p> <ul style="list-style-type: none"> • <i>Teachers: go around from group to group and take 1 picture of each group's current product. Have the group tape the picture in box 9 on their portfolio</i> • <i>Groups using iPads will use the built in camera to take the picture at this point in time.</i> 	9
	After 45 minutes	<p>Students review progress and set goals for continued work</p> <ul style="list-style-type: none"> • Have students pause briefly (3-5 minutes), review their goals (Box 6 & 13) and decide what they will do next. Encourage them to discuss their progress together in a <i>positive</i> manner. 	6 13
	After 50 minutes	<p>Students review celebrate their progress</p> <ul style="list-style-type: none"> • Have students review their progress by comparing their current proto-type with their previous drawings and entries 	14
	After 55 minutes	<p>Students complete the third dice roll and respond to questions</p> <ul style="list-style-type: none"> • Remind students of the questions and point out where their response goes (sub-box of box 6) 	6c
	After 70 Minutes	<p>Students take, print, and paste 4th photo in portfolio</p> <ul style="list-style-type: none"> • <i>Teachers: go around from group to group and take 1 picture of each group's current product. Have the group tape the picture in box 15 on their portfolio</i> • <i>Groups using iPads will use the built in camera to take the picture at this point in time.</i> <p>Students do fourth dice roll and respond to questions</p> <ul style="list-style-type: none"> • Remind students of the questions and point out where their response goes (sub-box of box 6) 	15 6d
	After 85 minutes	<p>Students cleanup work areas Student store supplies in classroom cubby</p> <ul style="list-style-type: none"> • Make sure all group supplies including their portfolio, handling collection, and modelling kit are all in their tub and have students store them in the designated <p>END OF DAY 4</p>	
5	Start	<p>Start</p> <ul style="list-style-type: none"> • Have students sit with their groups • Hand out group bags • Green pencils are located in each bag • Inform students that they will only have around 	15, 6

		<ul style="list-style-type: none"> • Have students place all group supplies back in the bag except the final model and the portfolio <p>Students complete team reflection</p> <ul style="list-style-type: none"> • Have students work in a group to complete portfolio boxes 19-21 (each person completes one box) <p>Collect all the group bags</p>	19, 20, 21
	After 60 minutes	<p>Students ensure that their personal information is on the portfolio (including their group number)</p> <ul style="list-style-type: none"> • Make sure students are aware of the information needed for box 18 and give them time to fill in this information now. <p>Students turn in all portfolios (paper or electronic)</p> <ul style="list-style-type: none"> • As students turn in their portfolios have them bring them to you so you can check box 18 to make sure all the information is included. <p>Students complete the post-study questionnaire found at: http://tinyurl.com/alpinestudypost</p> <ul style="list-style-type: none"> • Ask students to leave their portfolio and final model on their desk and work on the questionnaires. The students should be familiar with the questionnaires and can access them at the same provided URL. • Help students feel at ease by letting them know that there are no right or wrong answers—they are simply asked to be honest and accurate as they fill out the questionnaires. Show the students (via projector) how to access the questionnaires on Qualtrics. Ask the students to please fill out the questionnaire and then sit quietly until all students are done • <i>Please encourage students to be honest and thorough as they think about and answer the questionnaires.</i> • <i>Monitor students as they fill out the questionnaires and help as needed.</i> <ul style="list-style-type: none"> ○ If students did not fill out the questionnaire to start the unit DO NOT have them fill out a questionnaire at the end. 	18
	After 90 minutes	<p>End of Activity</p> <ul style="list-style-type: none"> • Thank the class for their participation in the activity and allow them to show off their designs to their neighbors • Collect all portfolios & final designs • Return all projects, portfolios, and modelling bags (with any extra materials) to the researcher. 	

Engineering Design Challenge

Context: An elderly individual enjoys traveling internationally. Ideally, this person would like to travel internationally between 2-3 months of the year. This person has a few ailments and allergies that require medication. In addition, this person also takes vitamins.

Challenge: You have been hired to design a new medicine dispenser for this client. Your design should:

1. Be easy to use
 - a. Easy to open and close
 - b. Easy to get pills in and out
2. Assist this person in remembering when to take the pills
 - a. Day of the week and time of day
 - b. Correct number of pills that should be taken.

Criteria & Constraints: Your design should:

1. Remind the person when to take each pill (that is: time of day and day of the week).
2. Remind the person how many of each pill to take.
3. Be small enough to fit easily in a purse, handbag, backpack, or pocket for travel (should fit easily within an 8" x 8" x 8" cube)
4. Be childproof (that is: difficult for a child to open).

Resources: The breakdown for when pills should be taken and the quantities is included here.

Pill Name	Pill Size	Number taken at each dose	When to take the pill
Vitamin A	0	2	Monday (morning)
Vitamin B	2	1	T/TH (night)
Vitamin C	1	1	Sunday (morning)
Iron	2	1	M/W/F (morning)
Allegra D	0	1	Daily (morning)
Potassium	1	1	Daily (night)
Sodium	0	1	T/TH (morning)

	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
Morning	Allegra D Vitamin C	Allegra D Vitamin A Iron	Allegra D Sodium	Allegra D Iron	Allegra D Sodium	Allegra D Iron	Allegra D
Night	Potassium	Potassium	Potassium Vitamin B	Potassium	Potassium Vitamin B	Potassium	Potassium



Pill Size 0

M&M Mini

Height: .35"

Width: .35"

Thickness: .2"



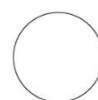
Pill Size 1

M&M Candy

Height: .47"

Width: .47"

Thickness: .25"



Pill Size 2

M&M Peanut Butter

Height: .6"

Width: .6"

Thickness: .3"

- For this design challenge you can assume that all pills are the sizes and shapes shown above and listed in the table

Supplies:

Students will be provided with tools, materials, and supplies to proto-type and build while they are designing. Students should plan carefully to conserve materials as no additional materials will be provided. All material does not need to be used in the design. Building items include:

General Supplies

- Plastic bag containing all supplies
- 10 3x5 cards
- 2 copies of the engineering design process
- 2 copies of the engineering design challenge
- 1 pair of dice
- 2 red pencils
- 2 green pencils
- 1 Pentax Fujifilm instant camera (paper groups)
- Film (paper groups—130 sheets per teacher)
- 1 pad of post-it notes

Handling collection

- 3 small bottles
- 1 small piece of cardboard
- 1 spool of thread
- 3 Sewing Needles
- 2 strips of cloth
- Wire (2' picture hanging wire, no. 2)
- Clay (one 4 oz. container)

Modeling Collection

- 1 plastic cup
- Plastic (one 12" x 12" sheet - .007" thickness)
- Cardstock (two 8.5" x 11" sheets, assorted colors)
- Rubber bands (approximately 25, assorted sizes/shapes)
- String (polyester kite string, 3')
- Paper clips (20 small, 10 large)
- Straws (ten flexible neck)
- Dowel (four .125 X 4")
- 20 m&m's minis (to represent pill size 0)
- 15 m&m's (to represent pill size 1)

- 10 m&m's peanut butter (to represent pill size 2)
- 5 buttons
- 4 clothespins
- 20 jumbo craft sticks
- 15 toothpicks
- 10 small cups with lids
- 10 interlocking craft sticks
- 10 Pipe cleaners

Classroom Supplies (provided by the teacher)

- Tape (masking tape, 1 roll)
- Hot glue gun and glue (10 glue sticks)
- Scissors (1 pair)
- Paper (8.5" x 11" sheets, white)

Evaluation Rubric: students will complete a design portfolio that will document their process as they design their product. Students will be rated based on their design portfolio and their final product using the rubrics below.

Portfolio Evaluation

Item	Evaluation Criteria	Item Weight Value
Questions/Prompts	Each question or prompt was responded to by the students with an explanation, picture, or drawing.	2
Pictures	Each picture box contains a picture representing student work. Pictures demonstrate a logical progression of the product through the design process.	1
Design Process	Steps of the engineering design process are clearly demonstrated by the students in the portfolio. <ol style="list-style-type: none"> 1. Identify the need or problem 2. Research the need or problem 3. Develop possible solutions 4. Select the best possible solution 5. Construct a prototype 6. Test and evaluate the solution 7. Communicate the solution 8. Redesign 9. Finalize the design 	1
Overall Portfolio	Portfolio is easy to read, follow, and understand	1
Self-directed Learning	Student demonstrated self-directed learning in their portfolio creation	1

Product Design Evaluation

Item	Description	Item Weight Value
Criteria and Constraints	Designed product satisfies provided criteria and constraints	1.5
Feasible & Functional	Designed product is both feasible and functional	1.5
Aesthetics	Design product is aesthetically pleasing	1
Creativity	Designed product demonstrates original thought, insight, and innovation	1

Appendix D

District, School, and Teacher Demographic Data

Table D1

District Demographic Information

District	Grade span	Total students	Total schools	Total teachers	Teachers by grade	Student/teacher ratio	Students with IEPs	ELL students	Free lunch or reduced-price lunch-eligible	Enrollment by race/ethnicity
School District	PK - 12	73,975	81	3078	24.03	24.03	8,341	2,086	27%	American Indian / Alaskan: 410 Asian / Pacific islander: 951 Black: 282 Hispanic: 4,392 White: 6,5262 Two or more races: 1,876

Table D2

School Demographic Information

School	Grade span	Total students	Enrollment by grade	Student/teacher ratio	Title I school?	Free lunch eligible & reduced-price lunch-eligible	Enrollment by gender	Enrollment by race/ethnicity
Middle School 1	7-9	1533	7: 570	24.97	No	Free lunch: 296	Male: 768	American Indian / Alaskan: 9
			8: 490			Reduced-price lunch: 127	Female: 765	Asian / Pacific islander: 41
			9: 473					Black: 9
Middle School 2	7-9	1286	7: 475	22.96	No	Free lunch: 297	Male: 681	American Indian / Alaskan: 5
			8: 433			Reduced-price lunch: 176	Female: 605	Asian / Pacific islander: 21
			9: 378					Black: 16
								Hispanic: 118
								White: 1080
								Two or more races: 46

(table continues)

School	Grade span	Total students	Enrollment by grade	Student/teacher ratio	Title I school?	Free lunch eligible & reduced-price lunch-eligible	Enrollment by gender	Enrollment by race/ethnicity
Middle School 3	7-9	1201	7: 441	25.13	No	Free lunch: 217	Male: 641	American Indian / Alaskan: 6
			8: 367			Female: 560	Asian / Pacific islander: 27	
			9: 393			Reduced-price lunch: 71	Black: 5	
Middle School 4	7-9	1336	7: 487	25.60	No	Free lunch: 107	Male: 664	American Indian / Alaskan: 3
			8: 422			Female: 672	Asian / Pacific islander: 17	
			9: 427			Reduced-price lunch: 39	Black: 9	
Middle School 5	7-9	1467	7: 502	24.49	No	Free lunch: 245	Male: 748	American Indian / Alaskan: 6
			8: 494			Female: 719	Asian / Pacific islander: 23	
			9: 471			Reduced-price lunch: 112	Black: 14	
							Hispanic: 107	
							White: 1263	
							Two or more races: 54	

Table D3

Teacher Classroom Demographic Information

Teacher	Class period	Boys	Girls	Total
Middle School Teacher 1	B5	24	7	31
	B6	28	6	34
	B7	27	6	33
	B8	24	12	36
Middle School Teacher 2	A3	25	9	34
	A4	30	6	36
	B5	26	5	31
Junior High Teacher 1	A1/A4	60	14	74
Middle School Teacher 3	A1	32	2	34
	A4	27	3	30
	B6	18	3	21
Middle School Teacher 4	B5	30	7	37
	B7	33	7	40
	B8	31	10	41
Middle School Teacher 5	A4	29	1	30
	B5	28	5	33
	B8	23	4	27
TOTAL				602

Appendix E

Demographic Questions from Pre-Study Questionnaire

Demographic Questions from Pre-Study Questionnaire

Q24 Please enter your unique identifier in the box below: Your unique identifier consists of: Last letter of your last name + your age + birth date (day not month) + last 2 digits of your student/lunch number

EXAMPLE: My unique identifier would be W30509

My name is Scott Bartholomew
I am 30 years old
I was born June 5
My student/lunch number is 085109

Q21 Please enter your teacher's last name here:

Q22 Please enter your class period here:

Q1 There are no right or wrong answers on this questionnaire. Please answer honestly and accurately. All students that complete the questionnaire will be awarded full points for completing. Each question will only allow you to select one answer—please select the BEST answer for the question, meaning the answer that is the most accurate for you. Many questions should be answered using a 1-5 scale, where 1 = “strongly disagree” and 5 = “strongly agree.” If you are unsure on any question, please choose the response "I don't know"

Q2 What is your age?

- 12 (1)
- 13 (2)
- 14 (3)
- 15 (4)
- 16 (5)
- 17 (6)

Q22 Think about your grades on average. On average what grades do you receive in classes? (This is for all your classes combined. Please just make your best guess as to the grades you receive or choose the answer that best represents your grades).

- A's (3.5 - 4.0 GPA) (1)
- B's (2.5 - 3.4 GPA) (2)
- C's (1.5 - 2.4 GPA) (3)
- D's (1.0 - 1.4 GPA) (4)
- F's (below 1.0 GPA) (5)
- Refused (6)
- Don't Know (7)

Q23 Think about your grades in Technology Classes (sometimes called CTE or Career and Technical Education classes). On average what grades do you receive in these classes? (This includes any Technology class you may have taken - but not any other classes in other subject areas. Please just make your best guess as to the grades you receive or choose the answer that best represents your grades).

- A's (3.5 - 4.0 GPA) (1)
- B's (2.5-3.4 GPA) (2)
- C's (1.5-2.4 GPA) (3)
- D's (1.0-1.4 GPA) (4)
- F's (below 1.0 GPA) (5)
- Refused (6)
- Don't Know (7)

Q3 Do you have access to a computer at home? If so, how much time do you spend on your home computer daily?

- No, I don't have access to a computer at home (1)
- Yes, 0-30 minutes (2)
- Yes, 31-60 minutes (3)
- Yes, 61-90 minutes (4)
- Yes, 91-120 Minutes (5)
- Yes, more than 2 hours (6)
- I don't know (7)

Q4 Do you have access to a computer at school? If so, how much time do you spend on the computer at school daily?

- No, I don't have access to a computer at school (1)
- Yes, 0-30 minutes (2)
- Yes, 31-60 minutes (3)
- Yes, 61-90 minutes (4)
- Yes, 91-120 Minutes (5)
- Yes, more than 2 hours (6)
- I don't know (7)

Q5 Do you have access to a mobile device at home? If so, how much time do you spend on this mobile device daily at home? This does not have to be a device you own - simply a device you have access to and can use if you want. A "mobile device" is any electronic device you can hold in your hand that can access the Internet (i.e., smartphone, iPad, e-reader, tablet, etc.)

- No, I don't have access to a mobile device at home (1)
- Yes, 0-30 minutes (2)
- Yes, 31-60 minutes (3)
- Yes, 61-90 minutes (4)
- Yes, 91-120 Minutes (5)
- Yes, more than 2 hours (6)
- I don't know (7)

Q6 Do you have access to a mobile device at school (either owned by the school or a personal device)? If so, how much time do you spend on a mobile device daily at school? A "mobile device" is any electronic device you can hold in your hand that can access the Internet (i.e., smartphone, iPad, e-reader, tablet, etc.)

- No, I don't have access to a mobile device at school (1)
-
- Yes, 0-30 minutes (2)
- Yes, 31-60 minutes (3)
- Yes, 61-90 minutes (4)
- Yes, 91-120 Minutes (5)
- Yes, more than 2 hours (6)
- I don't know (7)

Q24 Are personal mobile devices allowed during class/school at the school you attend?

- Yes - in all classes (1)
- Yes - in most classes (2)
- Yes - but only in a few classes (3)
- No - not in any classes (4)

Q25 What rules (if any) are there associated with personal mobile devices at your school?

Q7 On average, how many minutes do you spend on the following throughout the entire day (including time at school)? Drag the slider to the number that best represents your answer

- _____ Facebook (1)
- _____ Twitter (2)
- _____ Instagram (3)
- _____ Snapchat (4)
- _____ Text messaging (5)
- _____ YouTube (6)
- _____ Personal Email (7)

Q8 Thinking about time spent on a computer or mobile device, what percentage of your time on the computer or with mobile devices is spent in the following activities during one day on average? Enter percentages on the right (Total must equal 100 percent)..Do not put the percentage symbol (%) - just put the number representing the percentage (e.g., 90)

- _____ Messaging or communicating with friends (through voice or text) (1)
- _____ Watching videos or listening to music (2)
- _____ Playing video games (3)
- _____ Working on homework (4)
- _____ Creating content that you will share with others (e.g., videos, pictures, etc.) (5)
- _____ Social Media (e.g., Facebook, Twitter, Instagram, etc.) (6)
- _____ I don't know (7)

Q9 Thinking about your time at home and school, how many computers and/or mobile devices do you have access to? (These do not need to be devices you own - this is simply asking about devices that you have access to use if you wanted to use them)

- I don't know (1)
- 0 (2)
- 1 (3)
- 2 (4)
- 3 (5)
- 4 (6)
- 5 (7)
- 6 (8)
- 7 (9)
- 8 (10)
- 9 (11)
- 10 (12)
- 11 (13)
- 12 (14)
- More than 12 (15)

Q28 How OFTEN, on average, have you used the following technologies in the past year (in and out of school settings)? Drag the sliders to the number that best represents your answer.

- _____ Use a mobile -device to manage, create, or manipulate digital photos, digital audio, or digital videos (1)
- _____ Use a mobile device to access information via the Internet (2)
- _____ Use a mobile device to learn new skills (3)
- _____ Use a mobile device to communicate with others (for example: text, phone call, email, etc.) (4)
- _____ Use a mobile device to send pictures, videos, or audio files to someone else (5)

Appendix F
Healing Collection Supplies

Handling Collection Supplies

- 1 small bottle
- 1 piece of Cardstock (8.5" x 11")
- One 1' piece of string
- 1 strip of cloth
- 1 pipe cleaner
- 1 dowel (.125" X 4")
- 1 small cup with a lid
- 2 rubber bands
- 1 paper clip
- 1 straw (flexible neck)
- 1 clothespin
- 2 buttons

Appendix G

List of Modelling Collection Supplies for Each Group

List of modelling collection supplies for each group

Classroom Supplies (provided by the teacher)

- Tape (masking tape, 1 roll)
- Hot glue gun and glue (10 glue sticks)
- Scissors (1 pair)
- Paper (8.5" x 11" sheets, white)







Portfolio Supplies

- Plastic bag containing all supplies
- 10 3x5 cards
- 2 copies of the engineering design process
- 2 copies of the engineering design challenge
- 1 pair of dice
- 2 red pencils
- 2 green pencils
- 1 Pentax Fujifilm instant camera (paper groups)
- Film (paper groups—130 sheets per teacher)
- 1 pad of post-it notes

Modeling Collection

- 1 plastic cup
- 2 small bottles
- 1 strip of cloth
- Wire (2' picture hanging wire, no. 2)
- 1 spool of thread
- 3 Sewing Needles
- 1 small piece of cardboard
- Plastic (one 12" x 12" sheet - .007" thickness)
- 1 piece of Cardstock (8.5" x 11")
- Rubber bands (approximately 25, assorted sizes/shapes)
- String (polyester kite string, 3')
- Paper clips (20 small, 10 large)
- 9 Straws (flexible neck)
- Three dowels (.125" X 4")
- 20 M&M's minis (to represent pill size 0)
- 15 M&M's (to represent pill size 1)
- 10 M&M's peanut butter (to represent pill size 2)
- 3 buttons
- 3 clothespins
- 20 jumbo craft sticks
- 15 toothpicks
- 9 small cups with lids
- 10 interlocking craft sticks
- 9 Pipe cleaners
- Clay (one 4 oz. container)

Appendix H
Paper-Based Portfolio


<p>1 Team member 1 - what are your thoughts and ideas?</p> <p>Where will you go to find more thoughts and ideas?</p>	<p>2 Team member 2 - what are your thoughts and ideas?</p> <p>Where will you go to find more thoughts and ideas?</p>	<p>3 Team member 3 - what are your thoughts and ideas?</p> <p>Where will you go to find more thoughts and ideas?</p>	<p>4 Where is your medicine dispenser intended to be used?</p> <p>Who is your client? What specific design needs do they have?</p>
<p>5 What specific things will your design need to have to be really successful?</p>	<p>7 Place your first photo here (cut the picture to fit)</p>	<p>8 Place your second photo here (cut the picture to fit)</p>	<p>9 Place your third photo here (cut the picture to fit)</p>
<p>10 Team member 1 - what do you think of your ideas so far?</p> <p></p> <p>_____</p> <p></p>	<p>6 Use this space for notes, sketches, and ideas.</p> <div> <p>6a - First dice roll notes</p> <p>_____</p> <p>_____</p> <p>_____</p> <p>_____</p> </div> <div> <p>6b - Second dice roll notes</p> <p>_____</p> <p>_____</p> <p>_____</p> <p>_____</p> </div> <div> <p>6c - Third dice roll notes</p> <p>_____</p> <p>_____</p> <p>_____</p> <p>_____</p> </div> <div> <p>6d - Fourth dice roll notes</p> <p>_____</p> <p>_____</p> <p>_____</p> <p>_____</p> </div> <div> <p>6e - Fifth dice roll notes</p> <p>_____</p> <p>_____</p> <p>_____</p> <p>_____</p> </div>		
<p>11 Team member 2 - what do you think of your ideas so far?</p> <p></p> <p>_____</p> <p></p>			
<p>12 Team member 3 - what do you think of your ideas so far?</p> <p></p> <p>_____</p> <p></p>			


13 What will you do next?	15 Place your fourth photo here (cut to fit)	16 Place your fifth photo here (cut to fit)	17 Place your sixth photo here (cut to fit)
----------------------------------	---	--	--

18 Team Member 1 _____
Team Member 2 _____
Team Member 3 _____
Teacher's Name _____
Class Period _____
School _____


Write your group # below


19 Team member 1 - what are your thoughts on your final product?







20 Team member 2 - what are your thoughts on your final product?





21 Team member 3 - what are your thoughts on your final product?





14

Wackiest Idea
(From another group)

Best Idea
(From another group)

Biggest weakness
(on your own design)

What's next?
(Draw a picture of your next task)

Drawing go here


Appendix I

Electronic Portfolio Screenshots

LiveAssess Total: 02:32:34 Box 0: 00:02:34 4 / 31 User: ASD-Group99 Connected: ●

Box 2

Team member 2 - What are your first thoughts and ideas?
Click the image to input text





Partner 2

LiveAssess Total: 02:32:19 Box 0: 00:02:19 11 / 31 User: ASD-Group99 Connected: ●

Box 6

Use this space for notes, sketches, and ideas. Click on the pencil to draw and the keyboard to type notes or ideas





Total: 02:32:06
Box 0: 00:02:06
20 / 31
User: ASD-Group99
Connected: ●









Box 10

Team member 1 - What do you think of your ideas so far? Click on the icons to put in positive and negative ideas.




Total: 02:31:50
Box 0: 00:01:50
24 / 31
User: ASD-Group99
Connected: ●

Take pictures or draw the wackiest idea (from another group), the best idea (from another group), the biggest weakness (of your own design), and what you plan to do next using the icons below.

-  Wackiest Idea (from another group)
-  Wackiest Idea (from another group)
-  Best Idea (from another group)
-  Best Idea (from another group)
-  Biggest Weakness (of your own design)
-  Biggest Weakness (of your own design)
-  What's next? (Take a picture of your next task)
-  What's next? (Draw a picture of your next task)

Appendix J

Overview of Classroom Schedule

Overview of Classroom Schedule

Day	Time	Activity	Corresponding section in portfolio (paper and electronic)
1	Entire Class	Students take pre-study tests (Appendix E, Appendix G) and learn about digital citizenship and mobile device use (Appendix H)	
2	0-45 minutes	Students learn about engineering design (Appendix H)	
	Start Activity	Explain the rules and expectations for the design process	
	After 5 minutes	Introduce the context and engineering design challenge	
	After 10 minutes	Pass out handling collection and let student explore handling collection	
	After 20 minutes	Students are placed in groups Students begin playing with ideas	1, 2, 3
	After 35 minutes	Discussion about criteria for success Students cleanup work areas Student store supplies in classroom cubby END OF DAY 2	4
3	Start	Introduce the modelling kit Students work in groups to develop ideas	
	After 15 minutes	Students develop ideas Students do first dice roll and respond to questions	5
	After 40 minutes	Students conduct first “red-pencil review” Students take 1 st photo for portfolio	6
	After 80 minutes	Students continue to develop design ideas Students take 2 nd photo for portfolio Students do second dice roll and respond to questions Students cleanup work areas Student store supplies in classroom cubby END OF DAY 3	7 5

4	Start	Students complete personal reflection Students work with their team to complete the team reflection	10, 11, 12
	After 15 minutes	Students plan for what they will do next	13
	After 20 minutes	Students complete review of ideas (wackiest, best, problems, next)	14
	After 35 minutes	Students take 3 rd photo for their portfolio	8
	After 45 minutes	Students review progress and set goals for continued work	
	After 50 minutes	Students review their portfolios to see their progress and celebrate their progress	
	After 55 minutes	Students continue modelling their ideas Students complete the third dice roll and respond to questions	5
	After 70 Minutes	Students take 4 th photo for portfolio Students do fourth dice roll and respond to questions	9 5
	After 85 minutes	Students cleanup work areas Student store supplies in classroom cubby END OF DAY 4	
5	Start	Students complete a green-pencil review	
	After 5 minutes	Students take 5 th photo for portfolio Students do fifth dice roll and respond to questions	15 5
	After 10 minutes	Students continue with final development (modelling) Students take, print, and paste 6 th photo in portfolio	16
	After 45 minutes	Students cleanup work area and supplies Students complete team reflection Students complete the fast-forward activity	19, 20, 21 22 17
	After 60 minutes	Students ensure that their personal information is on the portfolio—INCLUDING THEIR GROUP NUMBER Students turn in all portfolios (paper or electronic) Students complete the <i>post-questionnaire</i> • http://www.tinyurl.com/alpinestudypost	18
	After 90 minutes	End of Activity	

Appendix K

Lesson Plan for Digital Citizenship, Mobile Device Use,
Engineering Design, and Teamwork

Lesson Plan for Digital Citizenship, Mobile Device Use, Engineering Design, and Teamwork

GRADE LEVEL: 7-8

UTAH CLASSIFICATION INSTRUCTIONAL PROGRAM (CIP) CODE: 21.01012—
Exploring Technology

LESSON PLAN ABSTRACT:

Students will learn about digital citizenship, proper mobile device use, and the steps in the engineering design process

LESSON PLAN STANDARDS:

- Exploring Technology Standard 1, Objective 3
- Exploring Technology Standard 9, Objective 3
- ITEEA Standards for Technological Literacy Standard 11,
 - Benchmarks (H, I, J, K L)

TIMELINE OF LESSON: 1.5 class periods (135 Minutes)

MATERIALS:

- PowerPoint (see resource DVD & the slides identified in the outline)
- Worksheets and engineering design process graphic (provided by the researcher, see below)
- 3x5 cards (1 per students, provided by the researcher)
- Computer & projector

INSTRUCTION & PRACTICE

Teacher instructions	Corresponding slide in PowerPoint
<p>CLASS PERIOD 1 WELCOME & QUESTIONNAIRES (35 MINUTES)</p> <ul style="list-style-type: none"> • Explain to the students that for the next 2 weeks (5 class periods) the class will be part of a research conducted by Utah State University. All students will be able to participate. (1 Minute) • Tell students that to start the unit they will take a questionnaire on the computer. Help students feel at ease by letting them know that there are no right or wrong answers—they are simply asked to be honest and accurate as they fill out the questionnaires. Show the students (via projector) how to access the questionnaire on Qualtrics. Ask the students to please fill out the questionnaire and then sit quietly until all students are done. (4 Minutes) • Have the students get on the computers and fill out the questionnaire, which includes the demographic questions, the Digital Natives Assessment Scale, and the modified self-directed learning with technology questionnaire. • The URL for this is: http://tinyurl.com/alpinestudypre • Administration of Questionnaire (20 Minutes) <p>Students return to their seats (5 Minutes)</p> <p>DIGITAL CITIZENSHIP & MOBILE DEVICES (30 minutes) QUESTION (2 minutes): What is digital citizenship? Does anyone have any guesses? Why is digital citizenship</p>	<p>SLIDE 1</p> <hr/> <p>SLIDE 2</p> <hr/> <p>SLIDE 3</p>

<p>important? Discussion with students. Ask follow-up questions as appropriate.</p> <p>EXPLAIN (3 minutes): Digital citizenship can be defined as the norms of appropriate, responsible behavior with regard to technology use. Digital citizenship means we are responsible and we act appropriately with technology. Today’s students need to practice the themes of proper digital citizenship to ensure appropriate, safe, and respectful use of technology.</p>	SLIDE 4
<p>DEFINE THEMES OF DIGITAL CITIZENSHIP (10 minutes):</p> <p>DIGITAL CITIZENSHIP THEMES</p> <ol style="list-style-type: none"> 1. Digital Access 2. Digital Commerce 3. Digital Communication 4. Digital Literacy 5. Digital Etiquette 6. Digital Law 7. Digital Rights & Responsibilities 8. Digital Health & Wellness 9. Digital Security (self-protection) 	SLIDE 5
<p>Define each term (see PowerPoint) and help students understand terms they may not be familiar with. Move quickly (roughly 1 minute per theme/slide)</p>	SLIDES 6-14
<p>ACTIVITY (10 minutes)</p> <p>Pass out the digital citizenship worksheets (see below) and ask students to work on filling them out with a neighbor</p> <p>Walk around the room and help students fill out the worksheet and stay on task</p> <p>Walk through the correct answers to the worksheet with the students and answer any questions they have. Talk with the students about why it’s important to be good digital citizens—especially as it relates to using their mobile devices in school.</p>	SLIDE 15
	SLIDE 16

<p>TEAMWORK ACTIVITY (25 Minutes)</p> <p>Display slide 17 and ask students what they think it means to be a good team member.</p> <p>Discussion (2 Minutes)</p> <p>Show the video (top 10 teamwork plays from 2009 NBA—3 Minutes)</p>	SLIDE 17
<p>Tell the students that a large part of this assignment will depend on their ability to work in teams. They will be paired up with 2-3 other students while they complete the engineering design challenge.</p> <p>Show slide 18 and ask for volunteers to answer the questions (5 minutes):</p> <ul style="list-style-type: none"> What are different “positions” someone could play on a team? (Pitcher, quarterback, catcher, etc.) Why are ALL roles important to the team’s success? What can we do if our team or teammates aren’t working well together? 	SLIDE 18
<p>Show the Remember the Titans video clip on teamwork (3 minutes)</p> <p>Talk with the students about the importance of working as teammates. Students will need to be open to new ideas, to allowing others ideas to be used, and open to friendly-criticism of their ideas. Additionally, students need to all pitch in so that no one has to carry the entire team themselves. (5 minutes)</p>	SLIDE 19
<p>Tell the students that to finish class you will be watching one last video clip about an engineering design firm called IDEO. At IDEO the engineers work in teams to solve challenges. Not everyone there is an engineer—people come from all different backgrounds—this helps the teams be better and come up with better products. Have the students write down examples of good teamwork while they watch the video.</p> <p>IDEO video (10 minutes)</p> <p>-Time permitting: End class by talking about teamwork and stressing the importance of being good team members while the students work on their design challenges next class</p>	SLIDE 20

<p>END OF CLASS PERIOD 1</p>	
<p>CLASS PERIOD 2</p> <p>WELCOME & REVIEW (7 Minutes)</p> <p>Welcome students to class and remind them that for the next 2 weeks they will be participating in a study conducted by a student at Utah State University. Today they will begin working on an engineering design challenge.</p> <p>Have students to turn to a neighbor and see if they can list the 9 themes of digital citizenship</p> <p>Briefly review with the students:</p> <ol style="list-style-type: none"> 1. Digital Access 2. Digital Commerce 3. Digital Communication 4. Digital Literacy 5. Digital Etiquette 6. Digital Law 7. Digital Rights & Responsibilities 8. Digital Health & Wellness 9. Digital Security (self-protection) <p>ENGINEERING DESIGN PROCESS (38 Minutes)</p> <p>Display a picture of Mars through the projector (see PowerPoint)</p> <p>Tell students that they have been hired to build an apartment complex on Mars for astronauts that will be living there for 6 month a time. Encourage student responses and participation and you discuss the following questions (10 minutes):</p>	<p>SLIDE 21</p> <p>SLIDE 22</p> <p>SLIDE 23</p> <p>SLIDE 24</p>

<p>What would you build? What would it look like? How would you build it? How would you make decisions regarding the building of this complex?</p>	<p>SLIDE 25</p>
<p>Pass out blank pieces of paper and colored pencils or crayons—have the students take 10 minutes to draw a picture of what they would design to solve this challenge. Tell students that starting this class period they will be working in groups on an engineering design challenge similar to the design of apartments on Mars. They will be working in groups (formed by the teacher and the researcher) to research, design, prototype, and model a medicine holder/dispenser for elderly patients. (3 minutes)</p>	<p>SLIDE 26</p>
<p>Display the Engineering Design Process Picture (included on the Google drive folder) on the board. Walk the students through the steps in the design process and highlight the fact that the process is iterative (i.e., we can start at any step and move backwards/forwards continuously until we come up with</p>	<p>SLIDE 27</p>

the final design). Help the students see that the same process they used to come up with housing for life on Mars is called the engineering design process by asking them questions and identifying how they went through the process earlier without realizing it. (22 minutes)

Point to each step as you ask questions and discuss the answers.

1—Did we identify a need? What is it? (living space for astronauts spending 6 months on Mars)

2—Did we do any research into the problem? What are some things we could research?

3—Did we develop possible solutions? What were some of our solutions? (the answers the students provided earlier)

4—How could we select the best possible solution? How would we know it's the best?

5—What is a prototype? What are some materials we could use to build a prototype?

6—How could we test our solution? What does it mean to evaluate? How could we evaluate the solution we came up with?

7—What do you think it means to “communicate the solution”? How could we spread the word about our new invention?

8—Why do you think we might have to re-design our original idea?

9—We're done—how do we know it works?

SLIDE 28

Show students the Engineering Design Process Video (see Google drive folder) Move to Appendix C—Classroom Script

SLIDE 29

Power point slides included below (8 pgs.).	
---	--



Welcome

- ▶ For the next 2 weeks (5 class periods) our class will be part of research conducted by Utah State University
- ▶ To start each student will take 2 brief questionnaires about your use and familiarity with technology.
 - ▶ 1 - Questionnaire (pre)
 - ▶ <http://tinyurl.com/alpinestudypre>
- ▶ There are no right or wrong answers on this questionnaire. Please answer honestly and accurately. All students that complete the questionnaire will be awarded full points for participation. Each question will only allow you to select one answer - please select the BEST answer for the question, meaning the answer that is the most accurate for you.
- ▶ Many questions will be answered using a 1-7 scale, where 1 = "strongly disagree," 4 = "neither agree nor disagree," and 7 = "strongly agree."

What is digital citizenship?

- ▶ Does anyone have any guesses?
- ▶ Why might "digital citizenship" be important?

Digital Citizenship

- ▶ the norms of appropriate, responsible behavior with regard to technology use. Digital citizenship means we are responsible and we act appropriately with technology. Today's students need to practice the themes of proper digital citizenship to ensure appropriate, safe, and respectful use of technology

9 Themes of Digital Citizenship

- ▶ 1. Digital Access
- ▶ 2. Digital Commerce
- ▶ 3. Digital Communication
- ▶ 4. Digital Literacy
- ▶ 5. Digital Etiquette
- ▶ 6. Digital Law
- ▶ 7. Digital Rights & Responsibilities
- ▶ 8. Digital Health & Wellness
- ▶ 9. Digital Security (self-protection)

1 - Digital Access

- ▶ recognize that not everyone has the same opportunities when it comes to technology. We should work towards equal access for everyone



2 - Digital Commerce

- ▶ a large portion of the market today is driven by electronic buying and selling of goods. Digital citizens should be aware and educated with regards to buying and selling things online.




3 - Digital Communication

- ▶ the electronic exchange of information has dramatically changed the way we communicate with one another. Digital communication can greatly enhance our abilities to communicate with each other, but only if used properly.



4 - Digital Literacy

- ▶ learners must be taught how to learn and interact in a digital society. As learners become proficient they can be considered digitally literate.



5 - Digital Etiquette

- ▶ appropriate standards, rules, behaviors, and procedures for acting in a digital world.



6 - Digital Law

- ▶ laws associated with crime, theft, hacking, or other forms of digital mischief.



7 - Digital Rights & Responsibilities

- ▶ everyone in the digital world has basic rights (for example: privacy, freedom of speech, etc.) that should be protected



8 - Digital Health & Wellness

- ▶ interacting with digital technologies can impact our health and mood positively or negatively. Users of digital media should be careful to not let technology impact them in harmful ways.



9 - Digital Security (self-protection)

- ▶ users of digital technology need to take measures to protect themselves, their identity, passwords, financial information, and any personal information they do not want to be stolen by malicious parties.



Let's practice

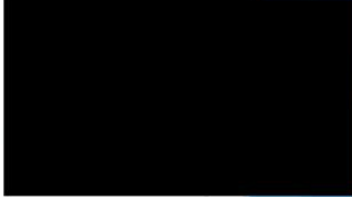
- ▶ Teachers please hand out the digital citizenship worksheets
- ▶ Students work with your neighbor to fill in the blanks.
 - ▶ The story talks about all 9 of the themes related to digital citizenship. Place the appropriate theme in the blank.
 - ▶ The back side of your worksheet has the themes with their definitions for you to review as needed

9 Themes of Digital Citizenship

- ▶ 1. Digital Access
- ▶ 2. Digital Commerce
- ▶ 3. Digital Communication
- ▶ 4. Digital Literacy
- ▶ 5. Digital Etiquette
- ▶ 6. Digital Law
- ▶ 7. Digital Rights & Responsibilities
- ▶ 8. Digital Health & Wellness
- ▶ 9. Digital Security (self-protection)

Teamwork


- ▶ What does it mean to be a "good" team-member?
- ▶ NBA Teamwork highlights



Team members

- ▶ *What are different "positions" someone could play on a team?*
- ▶ *Why are ALL roles important to the teams success?*
- ▶ *What can we do if our team or teammates aren't working well together?*

Remember the Titans



IDEO

Online discussion and Web address information given during this program may no longer be accurate.

ABC has left these references intact to preserve the integrity of this program.

First Slide Day 2

- ▶ This slide marks the beginning of the PowerPoints slides for Day 2

Welcome Back!

- ▶ Today we will continue with the research being conducted through Utah State University
- ▶ Teachers - please pass out the 3x5 cards to the students

- ▶ Today we will begin working on an engineering design challenge!


Review

- ▶ What are the 9 themes of digital citizenship?
- ▶ How do they apply to the use of mobile-devices?
- ▶ Can anyone name all 9 without looking?

9 themes of digital citizenship

- ▶ 1. Digital Access
- ▶ 2. Digital Commerce
- ▶ 3. Digital Communication
- ▶ 4. Digital Literacy
- ▶ 5. Digital Etiquette
- ▶ 6. Digital Law
- ▶ 7. Digital Rights & Responsibilities
- ▶ 8. Digital Health & Wellness
- ▶ 9. Digital Security (self-protection)

Let's switch gears a little....



You've been hired to build an apartment complex on Mars for astronauts (spending 6 months at a time) living on Mars.



- 1 - What would you build?
- 2 - What would it look like?
- 3 - How would you build it?
- 4 - How would you make the decisions that would go into the construction of this complex?

Your Challenge

- ▶ You will be working in groups to:
 - ▶ Research
 - ▶ Brainstorm
 - ▶ Design
 - ▶ prototype and model

a medicine holder/dispenser for elderly patients



What is the engineering design process?

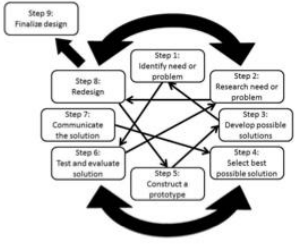


Figure 4. The NCEET engineering design model
Source: Hynes et al., 2011, p. 9



Appendix L

Qualitative Semistructured Interview Questions for Teachers

Qualitative Semistructured Interview Questions for Teachers

Goal: Obtain a better understanding of the experience and perceptions of teachers as they participated in the study.

Methods: Qualitative interviews will be conducted with each teacher in the study. All teachers will be interviewed in a semistructured interview format and asked the same questions (see below). Interviews will be recorded (audio only) and transcribed. The researcher will analyze and code the interview data for themes, ideas, and possible clues related to the study (thematic-coding protocol). Emerging themes will be identified and the data will be coded again following thematic-coding protocol and causal relationships will be identified. Themes, ideas, and causal relationships will be compared with data emerging from the quantitative portion of the analysis.

Teacher Questioning Guide

Introduction: I am interested in learning more about your experience with the research. Please know that all your responses will be kept completely confidential and will not be tied to your name in any way. The questions will be related to self-directed learning and mobile devices in the classroom.

Self-directed learning is defined as: “a process in which individuals take the initiative, with or without the help of others, in diagnosing their learning needs, formulating learning goals, identifying human and material resources for learning, choosing and implementing appropriate learning strategies, and evaluating learning outcomes. (Knowles 1975, p. 18).”

Mobile devices are defined as: “Hand-held technology (e.g., smartphones, or tablet PCs) that provides continuous accessibility to users anytime, anywhere without using a wire or cable to connect to networks (like the Internet), and allows them to transmit data or communicate with others (derived from Kim et al. 2013, p. 55)”

Thank you for your time.

Questions

1. In your opinion, what does self-directed learning “look like” in your classroom?
2. Thinking about your classroom outside of this study, how much opportunity is there for self-directed learning in your classroom?
3. Thinking about this study, how did the self-directed learning of students compare with times past?
4. In the past what has your classroom looked like with relation to mobile device use?

5. What are your impressions of including mobile devices in K-12 classrooms?
6. Do you believe mobile devices improve or hinder student **self-directed learning**? Why/Why not?
7. Do you believe mobile devices improve or hinder **student achievement, as measured by grades and performance on assignments**? Why/Why not?
8. Talk to me about how students used the mobile devices during the study.
9. If you did this again right now, what would you change?

Appendix M

Semistructured Interview Questions for Students

Semistructured Interview Questions for Students

Goal: Obtain a better understanding of the experience and perceptions of students as they participated in the study.

Methods: Qualitative interviews will be conducted with one student from each class in the study. Students will be randomly selected and checked to ensure permission has been obtained prior to the interview. All students will be interviewed in a semistructured interview format and asked the same questions (see below). Interviews will be recorded (audio only) and transcribed. The researcher will analyze and code the interview data for themes, ideas, and possible clues related to the study (thematic-coding protocol). Emerging themes will be identified and the data will be coded again following thematic-coding protocol and causal relationships will be identified. Themes, ideas, and causal relationships will be compared with data emerging from the quantitative portion of the analysis.

Student Questioning Guide

Introduction: I am interested in learning more about your experience with the research. Please know that all your responses will be kept completely confidential and will not be tied to your name in any way. The questions will be related to self-directed learning and mobile devices in the classroom.

Self-directed learning is defined as: “a process in which individuals take the initiative, with or without the help of others, in diagnosing their learning needs, formulating learning goals, identifying human and material resources for learning, choosing and implementing appropriate learning strategies, and evaluating learning outcomes. (Knowles 1975, p. 18).”

Mobile devices are defined as: “Hand-held technology (e.g., smartphones, or tablet PCs) that provides continuous accessibility to users anytime, anywhere without using a wire or cable to connect to networks (like the Internet), and allows them to transmit data or communicate with others (derived from Kim et al. 2013, p. 55)”

Thank you for your time.

Questions

1. In your opinion, what does self-directed learning “look like”?
2. Thinking about your experience at school outside of this study, how much opportunity is there for self-directed learning at school?
3. Thinking about this study, how did your own self-directed learning and the self-directed learning of your peers compare with times past?
4. Describe mobile device use in school settings at your school?
5. What are your impressions of including mobile devices in K-12 classrooms?
6. Do you believe mobile devices improve or hinder student **self-directed learning**? Why/Why not?
7. What aspects of mobile devices improved or hindered student self-directed learning? Why? Can you provide some examples?
8. What things in class were easier or more challenging as a result of the inclusion of mobile devices?
9. Do you believe mobile devices improve or hinder **student achievement, as measured by grades and performance on assignments**? Why/Why not?
10. How did students use mobile devices as part of this assignment? Do you think the ways students used them (or didn't use them) had a positive or negative impact on their performance in class? Why?
11. In your opinion did students understand the assignment? The portfolio creation process? The rules and opportunities associated with mobile device?
12. What opportunities, if any, have you had to complete open-ended design problems outside of this assignment? How did this assignment compare with other opportunities?
13. Do you have any other thoughts regarding mobile devices, self-directed learning, student achievement, or anything related to this research that stand out to you?

Appendix N

Engineering Design Challenge and Scoring Rubric

Engineering Design Challenge and Scoring Rubric

Context: An elderly individual enjoys traveling internationally. Ideally, this person would like to travel internationally between 2-3 months of the year. This person has a few ailments and allergies that require medication. In addition, this person also takes vitamins.

Challenge: You have been hired to design a new medicine dispenser for this client. Your design should:

3. Be easy to use
 - a. Easy to open and close
 - b. Easy to get pills in and out
4. Assist this person in remembering when to take the pills
 - a. Day of the week and time of day
 - b. Correct number of pills that should be taken.

Criteria & Constraints: Your design should:

5. Remind the person when to take each pill (that is: time of day and day of the week).
6. Remind the person how many of each pill to take.
7. Be small enough to fit easily in a purse, handbag, backpack, or pocket for travel (should fit easily within an 8" x 8" x 8" cube)
8. Be childproof (that is: difficult for a child to open).

Resources: The breakdown for when pills should be taken and the quantities is included here.

Pill Name	Pill Size	Number taken at each dose	When to take the pill
Vitamin A	0	2	Monday (morning)
Vitamin B	2	1	T/TH (night)
Vitamin C	1	1	Sunday (morning)
Iron	2	1	M/W/F (morning)
Allegra D	0	1	Daily (morning)
Potassium	1	1	Daily (night)
Sodium	0	1	T/TH (morning)

	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
Morning	Allegra D Vitamin C	Allegra D Vitamin A Iron	Allegra D Sodium	Allegra D Iron	Allegra D Sodium	Allegra D Iron	Allegra D
Night	Potassium	Potassium	Potassium Vitamin B	Potassium	Potassium Vitamin B	Potassium	Potassium



Pill Size 0

M&M Mini

Height: .35"

Width: .35"

Thickness: .2"

Pill Size 1

M&M Candy

Height: .47"

Width: .47"

Thickness: .25"

Pill Size 2

M&M Peanut Butter

Height: .6"

Width: .6"

Thickness: .3"

- For this engineering design challenge you can assume that all pills are the sizes and shapes shown above and listed in the table

Supplies:

Students will be provided with tools, materials, and supplies to proto-type and build while they are designing. Students should plan carefully to conserve materials as no additional materials will be provided. All material does not need to be used in the design. Building items include:

General Supplies

- Plastic bag containing all supplies
- 10 3x5 cards
- 2 copies of the engineering design process
- 2 copies of the engineering design challenge
- 1 pair of dice
- 2 red pencils
- 2 green pencils
- 1 Pentax Fujifilm instant camera (paper groups)
- Film (paper groups—130 sheets per teacher)
- 1 pad of post-it notes

Handling collection

- 3 small bottles
- 1 small piece of cardboard
- 1 spool of thread
- 3 Sewing Needles
- 2 strips of cloth
- Wire (2' picture hanging wire, no. 2)
- Clay (one 4 oz. container)

Modeling Collection

- 1 plastic cup
- Plastic (one 12" x 12" sheet - .007" thickness)
- Cardstock (two 8.5" x 11" sheets, assorted colors)
- Rubber bands (approximately 25, assorted sizes/shapes)
- String (polyester kite string, 3')
- Paper clips (20 small, 10 large)
- Straws (ten flexible neck)
- Dowel (four .125 X 4")
- 20 m&m's minis (to represent pill size 0)
- 15 m&m's (to represent pill size 1)
- 10 m&m's peanut butter (to represent pill size 2)
- 5 buttons
- 4 clothespins

- 20 jumbo craft sticks
- 15 toothpicks
- 10 small cups with lids
- 10 interlocking craft sticks
- 10 Pipe cleaners

Classroom Supplies (provided by the teacher)

- Tape (masking tape, 1 roll)
- Hot glue gun and glue (10 glue sticks)
- Scissors (1 pair)
- Paper (8.5" x 11" sheets, white)

Evaluation Rubric: students will complete a design portfolio that will document their process as they design their product. Students will be rated based on their design portfolio and their final product using the rubrics below.

Portfolio Evaluation

Item	Evaluation Criteria	Item Weight Value
Questions/Prompts	Each question or prompt was responded to by the students with an explanation, picture, or drawing.	2
Pictures	Each picture box contains a picture representing student work. Pictures demonstrate a logical progression of the product through the design process.	1
Design Process	Steps of the engineering design process are clearly demonstrated by the students in the portfolio. 10. Identify the need or problem 11. Research the need or problem 12. Develop possible solutions 13. Select the best possible solution 14. Construct a prototype 15. Test and evaluate the solution 16. Communicate the solution 17. Redesign 18. Finalize the design	1
Overall Portfolio	Portfolio is easy to read, follow, and understand	1
Self-directed Learning	Student demonstrated self-directed learning in their portfolio creation	1

Product Design Evaluation

Item	Description	Item Weight Value
Criteria and Constraints	Designed product satisfies provided criteria and constraints	1.5
Feasible & Functional	Designed product is both feasible and functional	1.5
Aesthetics	Design product is aesthetically pleasing	1
Creativity	Designed product demonstrates original thought, insight, and innovation	1

Appendix O
ACJ Judgment Results

ACJ Judgment Results

Judge	Completed Rounds of Judgments (Student Creations)	Completed Rounds of Judgments (Student Portfolios)
Judge 1	201	201
Judge 2	195	195
Judge 3	177	175
Judge 4	175	175
Judge 5	200	200
<i>Rounds of Judgment Completed:</i>	10	10
<i>Reliability Coefficient:</i>	0.959	0.972

Appendix P

Ordinal Rankings for Student Portfolios and Student Products

Table P1

Student Product Rank

Final rank	Group	Parameter value
1	Group 200	10.2957
2	Group 100	9.02399
3	Group 12	8.54563
4	Group 192	8.3571
5	Group 147	8.32434
6	Group 105	7.98913
7	Group 61	7.90939
8	Group 02	7.88595
9	Group 72	7.57638
10	Group 05	7.41628
11	Group 28	7.33661
12	Group 117	7.2867
13	Group 30	7.27549
14	Group 18	6.9204
15	Group 118	6.67499
16	Group 197	6.57915
17	Group 07	6.4252
18	Group 182	6.31127
19	Group 87	6.30699
20	Group 150	6.07166
21	Group 19	5.98736
22	Group 107	5.96492
23	Group 01	5.6166
24	Group 123	5.5849
25	Group 76	5.41675
26	Group 113	5.35137
27	Group 34	5.31067
28	Group 38	5.29348
29	Group 189	5.25733
30	Group 185	4.99174
31	Group 199	4.97414
32	Group 68	4.96244
33	Group 85	4.88276
34	Group 58	4.88103
35	Group 96	4.84487
36	Group 112	4.8058

(table continues)

Final rank	Group	Parameter value
37	Group 103	4.56799
38	Group 45	4.49585
39	Group 25	4.39308
40	Group 110	4.33635
41	Group 135	4.08235
42	Group 35	4.01205
43	Group 27	3.93175
44	Group 106	3.80395
45	Group 127	3.53742
46	Group 138	3.51471
47	Group 42	3.50603
48	Group 11	3.48422
49	Group 63	3.45243
50	Group 157	3.20236
51	Group 52	3.19724
52	Group 31	3.11694
53	Group 195	3.11541
54	Group 24	3.006
55	Group 21	2.93995
56	Group 16	2.80649
57	Group 108	2.74629
58	Group 26	2.73017
59	Group 64	2.65674
60	Group 39	2.65047
61	Group 44	2.57933
62	Group 132	2.34739
63	Group 130	2.34402
64	Group 145	2.25356
65	Group 115	2.13435
66	Group 134	1.95314
67	Group 81	1.89769
68	Group 129	1.87615
69	Group 116	1.82111
70	Group 186	1.7009
71	Group 131	1.52946
72	Group 66	1.50782
73	Group 140	1.3976
74	Group 53	1.36789
75	Group 194	1.31998
76	Group 79	1.2473

(table continues)

Final rank	Group	Parameter value
77	Group 46	1.06288
78	Group 111	0.956476
79	Group 188	0.589712
80	Group 86	0.585427
81	Group 136	0.561896
82	Group 156	0.530319
83	Group 152	0.493861
84	Group 98	0.333992
85	Group 181	0.323619
86	Group 08	0.292973
87	Group 71	0.162769
88	Group 90	0.0702774
89	Group 65	-0.0214868
90	Group 198	-0.151819
91	Group 06	-0.204096
92	Group 143	-0.226665
93	Group 121	-0.374467
94	Group 109	-0.445359
95	Group 122	-0.719197
96	Group 13	-0.755785
97	Group 126	-0.832637
98	Group 82	-0.850452
99	Group 29	-0.871522
100	Group 32	-0.934807
101	Group 51	-0.98096
102	Group 84	-1.0631
103	Group 80	-1.13293
104	Group 83	-1.20024
105	Group 77	-1.2319
106	Group 124	-1.26566
107	Group 155	-1.43868
108	Group 43	-1.51981
109	Group 92	-1.52178
110	Group 154	-1.52368
111	Group 120	-1.62813
112	Group 33	-1.72754
113	Group 36	-1.84888
114	Group 184	-1.85923
115	Group 91	-1.86159
116	Group 139	-1.91065

(table continues)

Final rank	Group	Parameter value
117	Group 70	-2.03027
118	Group 133	-2.04764
119	Group 137	-2.13435
120	Group 60	-2.17326
121	Group 153	-2.385
122	Group 97	-2.57855
123	Group 148	-2.69608
124	Group 190	-2.79029
125	Group 125	-2.80229
126	Group 128	-2.8473
127	Group 15	-2.97904
128	Group 99	-3.11722
129	Group 14	-3.1717
130	Group 149	-3.25207
131	Group 191	-3.31127
132	Group 104	-3.38163
133	Group 48	-3.49385
134	Group 20	-3.56988
135	Group 04	-3.67165
136	Group 187	-3.73854
137	Group 74	-3.86431
138	Group 67	-3.89572
139	Group 41	-4.02949
140	Group 69	-4.13726
141	Group 119	-4.48648
142	Group 22	-4.48882
143	Group 59	-4.59945
144	Group 55	-4.6465
145	Group 09	-4.74154
146	Group 196	-4.9216
147	Group 93	-5.07063
148	Group 03	-5.48768
149	Group 193	-5.51055
150	Group 10	-5.5425
151	Group 54	-5.55518
152	Group 78	-5.95652
153	Group 17	-5.95693
154	Group 141	-5.99961
155	Group 114	-6.06767
156	Group 88	-6.27918

(table continues)

Final rank	Group	Parameter value
157	Group 37	-6.48055
158	Group 56	-6.53141
159	Group 144	-6.62159
160	Group 151	-6.80843
161	Group 57	-7.12523
162	Group 142	-7.45553
163	Group 62	-7.6434
164	Group 23	-7.68962
165	Group 49	-7.74838
166	Group 101	-7.8691
167	Group 47	-7.95055
168	Group 95	-8.35016
169	Group 89	-8.56573
170	Group 50	-8.69991
171	Group 102	-8.77091
172	Group 73	-8.88621
173	Group 183	-9.33999
174	Group 75	-9.9169
175	Group 94	-9.98053
176	Group 146	-11.2199

Table P2

Student Portfolio Rank Order

Final rank	Group name	Parameter value
1	Group 122	10.841
2	Group 012	10.7852
3	Group 129	9.96109
4	Group 192	9.25312
5	Group 185	9.06241
6	Group 182	9.04985
7	Group 155	9.04258
8	Group 062	8.95879
9	Group 114	8.50816
10	Group 052	8.30856
11	Group 115	8.26477
12	Group 099	8.17218
13	Group 066	8.08682
14	Group 017	7.86782
15	Group 118	7.86156
16	Group 183	7.85846
17	Group 002	7.80194
18	Group 130	7.75846
19	Group 069	7.67154
20	Group 196	7.55225
21	Group 113	7.40694
22	Group 156	7.32232
23	Group 116	7.28382
24	Group 112	7.15081
25	Group 199	6.84574
26	Group 108	6.77193
27	Group 006	6.64026
28	Group 186	6.62253
29	Group 063	6.56991
30	Group 019	6.51584
31	Group 057	6.36443
32	Group 061	6.30922
33	Group 151	6.21621
34	Group 023	6.09577
35	Group 093	6.09102
36	Group 181	5.98452

(table continues)

Final rank	Group name	Parameter value
37	Group 060	5.8793
38	Group 051	5.84976
39	Group 194	5.82524
40	Group 058	5.77156
41	Group 120	5.52015
42	Group 153	5.37249
43	Group 195	5.31447
44	Group 097	5.26908
45	Group 188	4.90115
46	Group 187	4.89225
47	Group 119	4.88616
48	Group 015	4.75686
49	Group 102	4.69677
50	Group 003	4.58214
51	Group 024	4.4572
52	Group 056	4.42445
53	Group 152	4.34961
54	Group 154	4.29655
55	Group 033	4.28794
56	Group 157	4.13605
57	Group 197	4.03195
58	Group 067	4.00322
59	Group 190	3.77784
60	Group 100	3.76683
61	Group 007	3.49277
62	Group 011	3.34713
63	Group 005	3.06527
64	Group 010	2.83367
65	Group 008	2.79131
66	Group 009	2.47532
67	Group 030	2.4688
68	Group 189	2.41044
69	Group 036	2.32868
70	Group 123	2.13136
71	Group 125	2.07111
72	Group 001	2.02019
73	Group 200	1.99601
74	Group 111	1.78645
75	Group 068	1.69433
76	Group 059	1.60207

(table continues)

Final rank	Group name	Parameter value
77	Group 035	1.23593
78	Group 149	1.07186
79	Group 039	0.632454
80	Group 135	0.572328
81	Group 091	0.538345
82	Group 126	0.515633
83	Group 110	0.395391
84	Group 020	0.192454
85	Group 095	0.131313
86	Group 018	-0.06329
87	Group 117	-0.07002
88	Group 029	-0.09663
89	Group 103	-0.14029
90	Group 055	-0.35902
91	Group 184	-0.38784
92	Group 021	-0.5003
93	Group 139	-0.51368
94	Group 031	-0.65121
95	Group 193	-0.71552
96	Group 054	-0.97287
97	Group 070	-1.05897
98	Group 198	-1.09261
99	Group 016	-1.09737
100	Group 128	-1.40362
101	Group 106	-1.4904
102	Group 013	-1.52111
103	Group 028	-1.55182
104	Group 142	-1.69095
105	Group 105	-1.70471
106	Group 004	-1.96583
107	Group 094	-1.99074
108	Group 121	-2.12782
109	Group 032	-2.35059
110	Group 144	-2.60058
111	Group 064	-2.62872
112	Group 022	-2.67538
113	Group 037	-2.74633
114	Group 065	-3.01402
115	Group 124	-3.01486
116	Group 043	-3.13988

(table continues)

Final rank	Group name	Parameter value
117	Group 014	-3.20895
118	Group 044	-3.48503
119	Group 042	-3.79351
120	Group 026	-3.88513
121	Group 132	-3.88956
122	Group 127	-3.92869
123	Group 079	-4.11557
124	Group 092	-4.19046
125	Group 191	-4.3462
126	Group 050	-4.64633
127	Group 148	-4.81812
128	Group 137	-4.8532
129	Group 053	-4.87501
130	Group 047	-5.02182
131	Group 025	-5.05088
132	Group 098	-5.05517
133	Group 138	-5.18271
134	Group 034	-5.23705
135	Group 101	-5.32131
136	Group 090	-5.38189
137	Group 133	-5.63943
138	Group 083	-5.64282
139	Group 141	-5.6614
140	Group 104	-6.01962
141	Group 140	-6.02363
142	Group 041	-6.10333
143	Group 048	-6.15618
144	Group 046	-6.31825
145	Group 045	-6.65146
146	Group 077	-6.65363
147	Group 136	-6.76209
148	Group 134	-6.78502
149	Group 078	-6.7985
150	Group 087	-6.90839
151	Group 073	-6.97256
152	Group 027	-7.00732
153	Group 131	-7.17607
154	Group 096	-7.1844
155	Group 049	-7.44956
156	Group 145	-7.47813

(table continues)

Final rank	Group name	Parameter value
157	Group 076	-7.57181
158	Group 074	-7.89012
159	Group 072	-8.00045
160	Group 082	-8.08981
161	Group 080	-8.10491
162	Group 086	-8.40347
163	Group 143	-8.47303
164	Group 071	-8.51241
165	Group 075	-8.72277
166	Group 081	-8.81484
167	Group 085	-8.82839
168	Group 150	-8.85631
169	Group 089	-8.89033
170	Group 147	-9.29113
171	Group 084	-9.48498
172	Group 038	-10.0367
173	Group 107	-10.2605
174	Group 088	-11.2291
175	Group 146	-11.2311

Appendix Q

URL Links for Pre- and Post-Questionnaire

Pre-Questionnaire

<http://tinyurl.com/alpinestudypre>

Post-Questionnaire

<http://tinyurl.com/alpinestudypost>

Appendix R
Timeline for Study

Timeline for Study

Proposed Time	Activity	Location
May 2015	Proposal Defense	Logan, Utah
June 2015-August 2015	Secure IRB Approval	Utah State University Participating school districts (pilot and main study)
September 2015-October 2015	Pilot Study	Participating middle school
November 2015-December 2015	Study Data Collection	Participating School District
January 2016-March 2016	Data Analysis Findings Dissertation write-up Revisions	Logan, Utah
April 2016	Dissertation Defense	Logan, Utah
May-August 2016	Approval, paperwork, etc.	Logan, Utah

Appendix S
Questions for Dice Rolls

Questions for Dice Rolls

1. What is going well?
2. What is not going well?
3. If you could change anything about your design right now what would it be?
4. What do you like most about another person's design?
5. What has been the hardest part of the design process so far?
6. What do you consider your best success so far in the design process?

Appendix T

Student, Parent, and Teacher Informed Consent



INFORMED CONSENT

Access to Mobile-Devices & Student Self-directed Learning

Introduction/ Purpose: Dr. Edward Reeve and PhD. student Scott Bartholomew in the department of Technology & Engineering Education at Utah State University are conducting a research study to find out more about how mobile-devices (i.e. smartphones) influence student self-directed learning and achievement. Your student has been asked to take part because of their enrollment in *Exploring Technology* at (School Name). There will be approximately 30 participants at this site. There will be approximately 300 total participants in this research.

Procedures: If you agree for your student to be in this research study, your student will be expected to complete the same activities as their classmates in class. Students choosing not to participate will complete the same activities as their classmates but their data will not be used as part of the study. All students will complete two short questionnaires prior to the study and one questionnaire at the conclusion of the study. Students will use a unique-identifier when responding to questions which will help protect them remain anonymous. During the study all students will be taught about digital citizenship (appropriate device use) and then work in groups on a design problem and fill out a design portfolio. As part of the study students in certain classes will be permitted access to mobile-devices while students in other classes will not. Additionally, some students will complete the design portfolios using an electronic app (*LiveAssess*) while others will complete the same portfolio on paper. At the conclusion of the study teachers and students will be randomly selected and given the opportunity to provide feedback in an interview with the researcher. Students and teachers will be notified if they are randomly selected but will not be required to participate in an interview. The interview will focus on student perceptions of the design problem, mobile-devices, self-directed learning, and the design portfolio. Interviews will be audio-recorded. Audio recordings will be saved on a password-protected hard-drive accessible only by the PI and the student researcher.

Your student's portfolio will be digitized and uploaded to a grading app called *CompareAssess*. A panel of graders consisting of educators will grade the portfolios. *CompareAssess* facilitates grading by projecting two portfolios side-by-side. The panel of graders simply selects which portfolio is better and a new comparison is shown – this process is repeated until all the student work has been compared and assigned a rank. Once again – your student's work will not be identifiable by name, rather, their unique identifier will be used.

Risks: Participation in this research study may involve some added risks or discomforts. For example, your student may be nervous that their interview responses will be recorded. Your student may also wish to use a mobile-device but not be allowed to (as a result of your class being part of the non-mobile-device access group). Additionally, your student's unique identifier may be recognized by one of the panel-members during grading (this is unlikely, but possible).

Benefits: No direct benefits to the participants are expected as a result of this study. However, educators may learn more about students' access to mobile devices as it relates to their learning.

Explanation & offer to answer questions: Scott Bartholomew has explained this research study to you through this form, and answered any question you have called him with or sent to him. If you have other



Page 2 of 3

INFORMED CONSENT

Access to Mobile-Devices & Student Self-directed Learning

questions or research-related problems, you may reach (PI) Edward Reeve at (435) 797-3642 or ed.reeve@usu.edu. Alternatively you can contact Scott Bartholomew at (801) 368-7875 or scott.bartholomew@aggiemail.usu.edu.

Voluntary nature of participation and right to withdraw without consequence: Participation in research is entirely voluntary. You may refuse to allow your child to participate or withdraw at any time without consequence or loss of benefits. If at any time you wish to withdraw from this research simply notify your child's teacher (teacher name here) or the student researcher, Scott Bartholomew, scott.bartholomew@aggiemail.usu.edu or (801) 368-7875.

Confidentiality Research: records will be kept confidential, consistent with federal and state regulations. Only the investigator (Dr. Ed Reeve) and the PhD. student Scott Bartholomew will have access to the data, which will be kept on a password protected hard drive. According to federal law the researcher will be required to report any findings that could indicate child abuse or neglect. To protect your privacy, no personal, identifiable information will be recorded and your responses will correspond with a study identifier. All student identifiers and any identifiable information or materials will be destroyed after 3 years using the data destruction software *HDDErase*. All additional study data will be destroyed after 15 years using the data destruction software *HDDErase*.

IRB Approval Statement: The Institutional Review Board for the protection of human participants at Utah State University has approved this research study. If you have any questions or concerns about your rights or a research-related injury and would like to contact someone other than the research team, you may contact the IRB Director at (435) 797-0567 or email irb@usu.edu to obtain information or to offer input.

Copy of consent: You have been given two copies of this Informed Consent. Please sign both copies and keep one copy for your files.

Investigator Statement: "I certify that the research study has been explained to the individual, by me or my research staff, and that the individual understands the nature and purpose, the possible risks and benefits associated with taking part in this research study. Any questions that have been raised have been answered."

Signature of Researcher(s)

Edward Reeve
Principal Investigator
435-797-3642
ed.reeve@usu.edu

Scott Bartholomew
Student Researcher
801-368-7875
scott.bartholomew@aggiemail.usu.edu

09/28/2015



INFORMED CONSENT
Access to Mobile-Devices & Student Self-directed Learning

PARENTAL PERMISSION

Please select one of the boxes below. By signing below, I designate whether I agree to participate or I do not agree to participate.

- I agree for my child to participate I do not wish for my child to participate
- I allow my child to participate in classroom activities, but do not wish to have them interviewed

Parent/Guardian signature

Student's Name

Date

STUDENT PERMISSION

Minor Participants: Students, please indicate below whether you agree or disagree to participate and sign below.

Student Consent: I understand that my parent(s) or guardian(s) are aware of this research study and that they have given permission for me to participate. I understand that it is up to me to participate even if they say yes. If I do not want to be in this study, I do not have to and no one will be upset if I don't want to participate or if I change my mind later and want to stop. I can ask any questions that I have about this study now or later. By signing below, I agree to participate.

Please select one of the boxes below.

- I agree to participate I do not wish to participate
- I will participate in classroom activities, but do not wish to be interviewed

Student Signature

Date

**Consentimiento de información
Acceso de dispositivos móviles y estudiante de aprendizaje**

Introducción / Objetivos: El Dr. Edward Reeve y estudiante adctorado: Scott Bartholomew en el Departamento de Ciencias Aplicadas de Tecnología y Educación en la Universidad Estatal de Utah están llevando a cabo un estudio de investigación para averiguar más acerca de cómo de dispositivos móviles (smartphones) es decir, la influencia estudiante autodirigido de aprendizaje y logros. Su estudiante se le ha pedido a participar debido a su inscripción en Estudio de la Tecnología en (nombre de la escuela). Habrá aproximadamente 30 participantes en este sitio. Habrá aproximadamente 300 participantes en total en esta investigación.

Procedimientos: Si usted está de acuerdo para que su estudiante participe en este estudio de investigación, se espera que el estudiante complete las mismas actividades que sus compañeros de clase en clase. Los estudiantes que elijan no participar completarán las mismas actividades que sus compañeros de clase, pero sus datos no serán utilizados como parte del estudio. Todos los estudiantes completar dos cuestionarios cortos antes del estudio y un cuestionario al final del estudio. Los estudiantes usarán un identificador único al responder a las preguntas que le ayudarán a proteger a permanecer en el anonimato. Durante el estudio de todos los estudiantes se les enseña acerca de la ciudadanía digital (uso de dispositivo adecuado) y luego trabajan en grupos en un problema de diseño y llenar un portafolio de diseño. Como se permitirá parte de los estudiantes de estudio en ciertas clases de acceso a los teléfonos-dispositivos, mientras que los estudiantes de otras clases no. Además, algunos estudiantes completarán las carteras de diseño utilizando una aplicación electrónica (LiveAssess) mientras que otros completar la misma cartera en el papel. A la conclusión de los profesores del estudio y los estudiantes serán seleccionados al azar y se les da la oportunidad de proporcionar información en una entrevista con el investigador. Los estudiantes y los profesores serán notificados si son seleccionados al azar, pero no estarán obligados a participar en una entrevista. La entrevista se centrará en las percepciones de los estudiantes del problema de diseño, mobil-dispositivos, aprendizaje autodirigido y la cartera de diseño. Las entrevistas serán grabadas en audio. Las grabaciones de audio se guardarán en una unidad de disco duro protegido por contraseña accesible sólo por la PI y el investigador de los estudiantes.

La cartera de su estudiante será digitalizada y subida a una aplicación de clasificación llamada CompareAssess. CompareAssess facilita la clasificación mediante la proyección de dos carteras de lado a lado. El panel de grado simplemente selecciona qué cartera es mejor y una nueva comparación se muestra - este proceso se repite hasta que todo el trabajo de los estudiantes se ha comparado y le asigna un rango. Una vez más - el trabajo de su hijo no va a ser identificada por su nombre, más bien, se utilizará su identificador único.

Riesgos: La participación en este estudio de investigación puede implicar algunos riesgos o molestias adicionales. Por ejemplo, el estudiante puede estar nervioso que se registrarán sus respuestas de la entrevista. Su hijo también podría usar un dispositivo móvil, pero no se le permite (como resultado de su clase de ser parte del grupo de acceso no móvil del dispositivo). Además, el identificador único de su estudiante puede ser reconocido por uno de los miembros del panel durante la clasificación (esto es poco probable, pero posible).

Beneficios: No hay beneficios directos para los participantes se espera que como resultado de este estudio. Sin embargo, los educadores pueden aprender más sobre el acceso de los estudiantes a los dispositivos móviles, ya que se relaciona con su aprendizaje.

Explicación y oferta para responder a las preguntas: Scott Bartholomew ha explicado este estudio de investigación a través de este formulario, así como sus respuestas a cualquier pregunta que le ha llamado con o enviado a él. Si usted tiene otras preguntas o problemas relacionadas con la investigación, pueden alcanzar (PI) Edward Reeve al (435) 797-3.642 o ed.reeve@usu.edu . Alternativamente, usted puede contactar a Scott Bartholomew al (801) 368-7875 o scott.bartholomew@aggiemail.usu.edu .

Voluntario de la participación y el derecho a retirarse sin consecuencias : La participación en la investigación es totalmente voluntaria. Usted puede negarse a permitir que su hijo participe o retirar en cualquier momento sin consecuencia o pérdida de beneficios. Si en algún momento desea retirarse de esta investigación simplemente notifique al maestro de su hijo (nombre del maestro aquí) o el estudiante investigador Scott Bartholomew, scott.bartholomew@aggiemail.usu.edu o (801) 368-7875.

La confidencialidad de Investigación: Los registros se mantendrán confidenciales, de acuerdo con las regulaciones federales y estatales. Sólo el investigador (Dr. Ed Reeve) y el estudiante a doctorado Scott Bartholomew tendrá acceso a los datos, que se mantendrán en un disco duro protegido por contraseña. De acuerdo con la ley federal se requerirá el investigador reportar cualquier hallazgo que podrían indicar abuso o negligencia infantil. Para proteger su privacidad, la información de identificación personal será grabado y sus respuestas se corresponderá con un identificador de estudio. Todos los identificadores de los estudiantes y cualquier información de identificación o materiales serán destruidos después de 3 años utilizando el HDDerase software de destrucción de datos. Todos los datos de los estudios adicionales serán destruidos después de 15 años utilizando el HDDerase software de destrucción de datos.

Declaración de Aprobación del IRB: La Junta de Revisión Institucional para la protección de los participantes humanos en la Universidad del Estado de Utah ha aprobado este estudio de investigación. Si usted tiene alguna pregunta o inquietud acerca de sus derechos o una lesión relacionada con la investigación y le gustaría ponerse en contacto con alguien que no sea el equipo de investigación, puede comunicarse con el Director del IRB al (435) 797 a 0567 o por correo electrónico irb@usu.edu para obtener más información.

Copia del consentimiento: Se le ha dado dos copias de este Consentimiento Informado. Por favor, firmar ambas copias y mantenga una copia para sus archivos.

Declaración del Investigador: "Certifico que el estudio de investigación se ha explicado a la persona, por mí o mi personal de investigación, y que el individuo entiende la naturaleza y finalidad, los posibles riesgos y beneficios asociados con la participación en este estudio de investigación. Y cualquier pregunta que tengan se hayan sido contestadas."

Firma del Investigador (s)

Edward Reeve
Principal Investigator
435-797-3642
ed.reeve@usu.edu

Scott Bartholomew
Student Researcher
801-368-7875
scott.bartholomew@aggiemail.usu.edu

Firma del participante: Al firmar abajo, yo eh decidido si estoy de acuerdo en participar o no estoy de acuerdo en participar.

Estoy de acuerdo de que mi hijo participe No deseo que mi hijo participe

Yo permito que mi hijo participe en las actividades de clase, pero no deseo tenerlos entrevistados

Nombre del Padre/Guardián

Firma del estudiante

Fecha

Participantes menores: Estudiantes, si sus padres / tutores acordaron para que usted participe en la investigación por favor indique a continuación si está de acuerdo o en desacuerdo a participar y firmar a continuación.

Asentimiento de Estudiante: Entiendo que mi padre (s) o guardián son conscientes de este estudio de investigación y que han dado permiso para mí participación. Yo entiendo que es a mí a participación, incluso si dicen que si. Si yo no quiero estar en este estudio, yo no tengo que estarlo y nadie se molesta si no quiero participar o si cambio de opinión después y me quiero retirar. Puedo hacer cualquier pregunta que tengo sobre este estudio ahora o más tarde. Al firmar abajo, estoy de acuerdo en participar.

Acepto participar No deseo participar

Participaré en las actividades de clase, pero no deseo ser entrevistado

Nombre / Firma

Fecha



Department of ASTE
6000 Old Main Hill
Logan UT 84322
Telephone: (435) 797-3642



Page 1 of 4

INFORMED CONSENT

Access to Mobile-Devices & Student Self-directed Learning

Introduction/ Purpose: Dr. Edward Reeve and PhD. student Scott Bartholomew in the Department of Applied Sciences Technology and Education at Utah State University are conducting a research study to find out more about how mobile-devices (i.e. smartphones) influence student self-directed learning and achievement. You have been asked to take part because you current teach the *Exploring Technology* class at (School Name). There will be approximately 1 teacher-participant at this site and approximately 60 student participants. There will be approximately 300 total student participants in this research and 6 total teacher participants.

Procedures: If you agree to participate in this research study, you will be expected to complete a two-hour training prior to the study. The researcher and/or PhD student will travel to your school and train you on what is expected and answer any questions you may have. The training will take place after school and the researcher and/or PhD student will provide you with the outline for the project and walk through each step of implementation. Examples will be provided of teaching, portfolio completion, and grading. During the training you will complete a similar (shortened) version of the design challenge that your students will complete – allowing you the opportunity to ask any questions you may have to help as you complete the study with your students. The training will be recorded and a video copy of the training will be provided to you for your reference. Additionally, the researcher and PI will provide email, cell-phone, and office-phone numbers for your use should any further questions arise.

For this research you students will work in groups to solve an open-ended design problem. Students will also complete a design portfolio as part of the process. Informed consent forms will be provided to you for your students. All your students will complete the same activities as their classmates in class - students choosing not to participate will complete the same activities as their classmates but their data will not be used as part of the study. All students will complete two short questionnaires prior to the study and one questionnaire at the conclusion of the study. Students will use a unique-identifier when responding to questions which will help protect them remain anonymous. During the study all students will be taught about digital citizenship (appropriate device use) and then work in groups on a design problem and fill out a design portfolio. As part of the study students in certain classes will be permitted access to mobile-devices while students in other classes will not. Additionally, some students will complete the design portfolios using an electronic app (*LiveAssess*) while others will complete the same portfolio on paper.

At the conclusion of the study teachers and students will be randomly selected and given the opportunity to provide feedback in an interview with the researcher. Students and teachers will be notified if they are randomly selected but will not be required to participate in an interview. The interview will focus on student perceptions of the design problem, mobile-devices, self-directed learning, and the design portfolio. Interviews will be audio-recorded. Audio recordings will be saved on a password-protected hard-drive accessible only by the PI and the student researcher.

06/3/2015



INFORMED CONSENT

Access to Mobile-Devices & Student Self-directed Learning

Following the in-class portion of the study the student's portfolios will be digitized and uploaded to a grading app called *CompareAssess*. A panel of graders consisting of educators will grade the portfolios. *CompareAssess* facilitates grading by projecting two portfolios side-by-side. The panel of graders will simply select which portfolio is better and a new comparison will be shown – this process is repeated until all the student work has been compared and assigned a rank. Once again – the student's work will not be identifiable by name; rather their unique identifier will be used. You may be asked to be on the panel of graders. If you are asked and you agree to participate in the grading process you will be trained on the use of the *CompareAssess* app and any questions you may have will be answered.

Risks: Participation in this research study may involve some added risks or discomforts. For example, you or your students may be nervous that their responses will be recorded. You may wish that your class be allowed to use mobile-devices even if they are not selected as one of the mobile-device groups.

Benefits: No direct benefits to the participants are expected as a result of this study.

Explanation & offer to answer questions: Scott Bartholomew has explained this research study to your students and answered their questions. If you have other questions or research-related problems, you may reach (PI) Edward Reeve at (435) 797-3642 or ed.reeve@usu.edu. Alternatively you can contact Scott Bartholomew at (801) 368-7875 or scott.bartholomew@aggiemail.usu.edu.

Voluntary nature of participation and right to withdraw without consequence: Participation in research is entirely voluntary. You may refuse to participate or withdraw at any time without consequence or loss of benefits. If at any time you wish to withdraw from this research simply notify your teacher (teacher name here) or the researcher (Scott Bartholomew, scott.bartholomew@aggiemail.usu.edu).

Confidentiality Research: records will be kept confidential, consistent with federal and state regulations. Only the investigator (Dr. Ed Reeve) and the PhD. student Scott Bartholomew will have access to the data, which will be kept on a password protected hard drive. According to federal law the researcher will be required to report any findings that could indicate child abuse or neglect. To protect your privacy, no personal, identifiable information will be recorded and your responses will correspond with a study identifier. All student identifiers and any identifiable information or materials will be destroyed after 3 years using the data destruction software *HDDErase*. All additional study data will be destroyed after 15 years using the data destruction software *HDDErase*.

IRB Approval Statement: The Institutional Review Board for the protection of human participants at Utah State University has approved this research study. If you have any questions or concerns about your rights or a research-related injury and would like to contact someone other than the research team,



Department of ASTE
6000 Old Main Hill
Logan UT 84322
Telephone: (435) 797-3642



Page 3 of 4

INFORMED CONSENT

Access to Mobile-Devices & Student Self-directed Learning

you may contact the IRB Director at (435) 797-0567 or email irb@usu.edu to obtain information or to offer input.

Copy of consent: You have been given two copies of this Informed Consent. Please sign both copies and keep one copy for your files.



Department of ASTE
6000 Old Main Hill
Logan UT 84322
Telephone: (435) 797-3642



INFORMED CONSENT
Access to Mobile-Devices & Student Self-directed Learning

Investigator Statement: "I certify that the research study has been explained to the individual, by me or my research staff, and that the individual understands the nature and purpose, the possible risks and benefits associated with taking part in this research study. Any questions that have been raised have been answered."

Signature of Researcher(s)

Edward Reeve
Principal Investigator
(435-797-3642)
(ed.reeve@usu.edu)

Scott Bartholomew
Student Researcher (or Co-PI)
(801-368-7875)
(scott.bartholomew@aggiemail.usu.edu)

Signature of Participant By signing below, I designate whether I agree to participate or I do not agree to participate.

I agree to participate

I do not wish to participate

Teacher signature

Date

Appendix U

Student Worksheet for Digital Citizenship Lesson

STUDENT WORKSHEET

Name _____ Teacher's Name _____ Date _____

Read the following short story and fill out the worksheet below. Each time you see a blank _____ you should fill it in with one of the 9 themes written on the board. Fill in the blanks with the theme you think is best represented by that part of the story. You may work with a neighbor or as directed by your teacher. Look on the back to see the themes and a short description of each.

John was assigned a report at school. His friend Blake was assigned as John's partner. Blake asked John if he could come over to John's house to work on the report because Blake didn't have the Internet where he lived. John told Blake to come over at 3:30 to work on the project, he was happy that he had the Internet and he was also surprised that not everyone had the Internet at their homes. _____

John and Blake decided to do a report on dinosaurs and archaeologists (someone who studies the past). They decided to listen to some music as they worked on their report. Blake's turned to John:

"Hey John, I have all the Beatles music on my thumb drive. My older brother downloaded it off a friends CD collection and shared it with me. Here, you can have it too—just drag it to your desktop." John put the thumb drive in and they started listening to the music. _____

As John started searching for information about dinosaurs a pop-up invited him to buy the latest book about dinosaurs on Amazon.com _____ John closed the pop-up and resumed searching. After a few links that weren't what John was looking for he found some good information. John copied the link and Blake asked him to email it to him so he had it too. As John went to his email account and logged in Blake noticed that John didn't have the password for his email saved.

"Why don't you just have the computer save your password for you?" Blake asked John.

"I don't know, I guess it just makes me nervous that someone else might get on to my email," John replied. _____ John sent Blake the email _____ with the links and logged off.

After working on their report Blake and John started playing video games on the computer—after an hour John turned the computer off.

"Playing for too long makes my eyes go crazy and my head hurt," he explained to Blake.

"Really?" Blake asked, "That never happens to me. I wish we had a computer at home—I'd play all night long if I could."

"No—not me. My eyes and head hurt too bad," John replied.

"Hey," Blake interjected, "Guess what I say in class today while Mrs. Brown was teaching us about social media _____, I saw Brooke log into her Facebook account and post a bunch of stuff about how much she hates the Tyler."

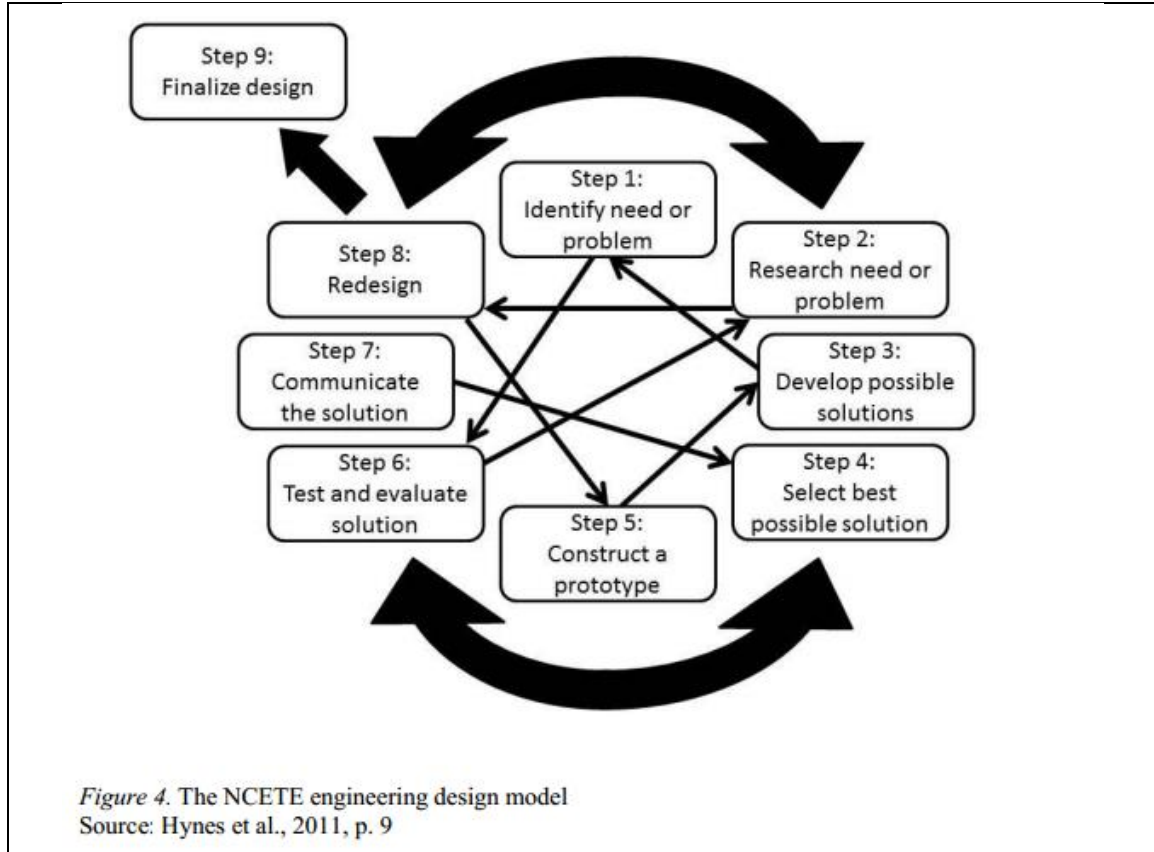
"Did you tell Mrs. Brown?" John asked. "I like Tyler, he doesn't seem that bad to me."

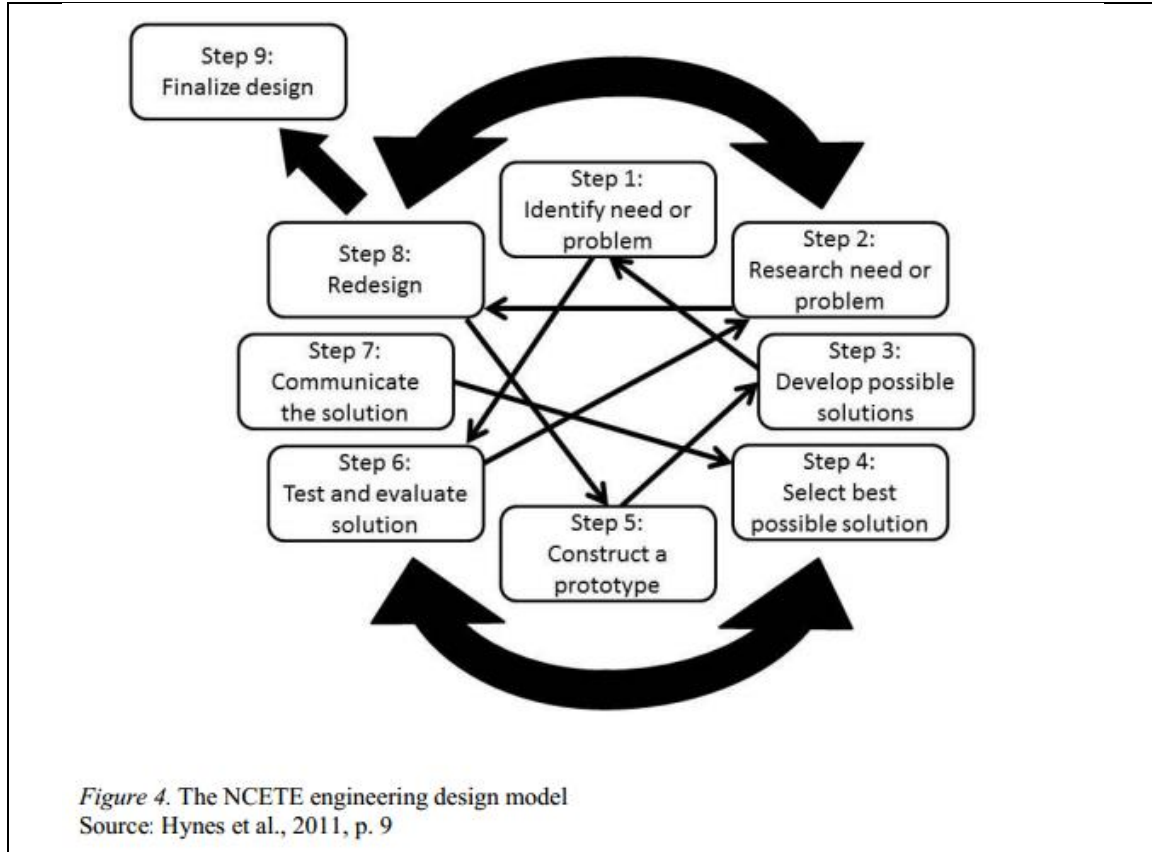
"I agree, Tyler's fine, but she hates him. I didn't say anything...I just figured it's her right to post whatever she wants on her page." _____

“Yea, but don’t you think that you should report stuff like that to the teacher? I mean, that’s not really right to put that stuff on Facebook right?” _____

9 Themes of Digital Citizenship

1. **Digital Access:** recognize that not everyone has the same opportunities when it comes to technology. We should work towards equal access for everyone
2. **Digital Commerce:** a large portion of the market today is driven by electronic buying and selling of goods. Digital citizens should be aware and educated with regards to buying and selling things online.
3. **Digital Communication:** the electronic exchange of information has dramatically changed the way we communicate with one another. Digital communication can greatly enhance our abilities to communicate with each other, but only if used properly.
4. **Digital Literacy:** learners must be taught how to learn and interact in a digital society. As learners become proficient they can be considered digitally literate.
5. **Digital Etiquette:** appropriately standards, rules, behaviors, and procedures for acting in a digital world.
6. **Digital Law:** laws associated with crime, theft, hacking, and other forms of digital mischief.
7. **Digital Rights & Responsibilities:** everyone in the digital world has basic rights (for example: privacy, freedom of speech, etc.) that should be protected
8. **Digital Health & Wellness:** interacting with digital technologies can impact our health and mood positively or negatively. Users of digital media should be careful to not let technology impact them in harmful ways.
9. **Digital Security (self-protection):** users of digital technology need to take measures to protect themselves, their identity, passwords, financial information, and any personal information they do not want to be stolen by malicious parties.





TEACHERS COPY

Read the following short story and fill out the worksheet below. Each time you see a blank _____ you should fill it in with one of the 9 themes written on the board. Fill in the blanks with the theme you think is best represented by that part of the story. You may work with a neighbor or as directed by your teacher. Look on the back to see the themes and a short description of each.

John was assigned a report at school. His friend Blake was assigned as John's partner. Blake asked John if he could come over to John's house to work on the report because Blake didn't have the Internet where he lived. John told Blake to come over at 3:30 to work on the project, he was happy that he had the Internet and he was also surprised that not everyone had the Internet at their homes. **DIGITAL ACCESS**

John and Blake decided to do a report on dinosaurs and archaeologists (someone who studies the past). They decided to listen to some music as they worked on their report. Blake's turned to John:

"Hey John, I have all the Beatles music on my thumb drive. My older brother downloaded it off a friend's CD collection and shared it with me. Here, you can have it too—just drag it to your desktop." John put the thumb drive in and they started listening to the music. **DIGITAL LAW**

As John started searching for information about dinosaurs a pop-up invited him to buy the latest book about dinosaurs on Amazon.com **DIGITAL COMMERCE** John closed the pop-up and resumed searching. After a few links that weren't what John was looking for he found some good information. John copied the link and Blake asked him to email it to him so he had it too. As John went to his email account and logged in Blake noticed that John didn't have the password for his email saved.

"Why don't you just have the computer save your password for you?" Blake asked John.

"I don't know, I guess it just makes me nervous that someone else might get on to my email," John replied. **DIGITAL SECURITY** John sent Blake the email **DIGITAL COMMUNICATION** with the links and logged off.

After working on their report Blake and John started playing video games on the computer—after an hour John turned the computer off.

"Playing for too long makes my eyes go crazy and my head hurt," he explained to Blake. **DIGITAL HEALTH & WELLNESS**

"Really?" Blake asked, "That never happens to me. I wish we had a computer at home—I'd play all night long if I could."

"No—not me. My eyes and head hurt too bad," John replied.

"Hey," Blake interjected, "Guess what I say in class today while Mrs. Brown was teaching us about social media **DIGITAL LITERACY**, I saw Brooke log into her Facebook account and post a bunch of stuff about how much she hates the Tyler."

"Did you tell Mrs. Brown?" John asked. "I like Tyler, he doesn't seem that bad to me."

"I agree, Tyler's fine, but she hates him. I didn't say anything... I just figured it's her right to post whatever she wants on her page." **DIGITAL RIGHTS & RESPONSIBILITIES**

"Yea, but don't you think that you should report stuff like that to the teacher? I mean, that's not really right to put that stuff on Facebook right?" **DIGITAL ETIQUETTE**

9 Themes of Digital Citizenship

1. **Digital Access:** recognize that not everyone has the same opportunities when it comes to technology. We should work towards equal access for everyone
2. **Digital Commerce:** a large portion of the market today is driven by electronic buying and selling of goods. Digital citizens should be aware and educated with regards to buying and selling things online.
3. **Digital Communication:** the electronic exchange of information has dramatically changed the way we communicate with one another. Digital communication can greatly enhance our abilities to communicate with each other, but only if used properly.
4. **Digital Literacy:** learners must be taught how to learn and interact in a digital society. As learners become proficient they can be considered digitally literate.
5. **Digital Etiquette:** appropriately standards, rules, behaviors, and procedures for acting in a digital world.
6. **Digital Law:** laws associated with crime, theft, hacking, and other forms of digital mischief.
7. **Digital Rights & Responsibilities:** everyone in the digital world has basic rights (for example: privacy, freedom of speech, etc.) that should be protected
8. **Digital Health & Wellness:** interacting with digital technologies can impact our health and mood positively or negatively. Users of digital media should be careful to not let technology impact them in harmful ways.
9. **Digital Security (self-protection):** users of digital technology need to take measures to protect themselves, their identity, passwords, financial information, and any personal information they do not want to be stolen by malicious parties.

CURRICULUM VITAE

SCOTT BARTHOLOMEW

79 W 400 S
 Logan, UT 84321
 801-368-7875
 scottbartholomew@gmail.com

EDUCATION

- Ph.D. Curriculum & Instruction** **2016**
 Utah State University, Logan UT
 Technology Education Emphasis
 Dissertation: A mixed-method study of mobile devices and student self-directed learning and achievement during a middle school STEM activity
- M.S. Technology** **2011**
 Brigham Young University, Provo UT
 Thesis: A Study Analyzing Five Instructional Methods for Teaching Sketchpad to Junior High Students
- B.S. Technology & Engineering Education** **2010**
 Brigham Young University, Provo UT
 Emphasis: Information & Communication Technologies
 Phi Kappa Phi

AWARDS

- Outstanding Affiliate Representative (ITEEA) **2016**
- Graduate Teacher of the Year, Utah State University **2015-2016**
- CTETE 21st Century Leadership Academy Participant **2015 – 2016**
- Foundation for Technology and Engineering Educators
 Outstanding Graduate Student Award winner **2015**
- Agricultural Systems & Technology Education Assistantship **2013 – present**
- Undergraduate Research Grant Recipient **2008 – 2009**
- College of Engineering Scholarship **2007 – 2011**
- Brigham Young Scholar **2003 – 2010**

TEACHING EXPERIENCE

Graduate Instructor Utah State University, Logan UT Developed course syllabus, covered academic content, administered all grades, assisted students in course projects and assignments	2013 - present
<i>Communications Technology</i>	2013 - present
<i>Agricultural Systems Technology</i>	2014 - present
<i>Computer-Aided Drafting and Design</i>	2014 - present
<i>Energy, Power, & Transportation</i>	2015 – present
<i>Architectural Drafting</i>	2015 – present
Middle School Technology & Engineering Education Instructor (Utah State Certification: Technology and Engineering Education) Alpine School District, Saratoga Springs UT Responsible for course development and implementation for 7 different subjects. Responsibly coordinated efforts between administration, parents, department members, and staff.	2010 – 2013
Video-Production & Graphic Design Adult Education Instructor Utah Valley University, Orem UT Developed course curriculum for an innovative course offering. Adjusted course materials for a diverse group of students.	2010 - 2013
Community Outreach Computer Science Teacher Brigham Young University, Provo UT Coordinated research and outreach efforts for an afterschool computer science program designed to help improve mathematical skills among middle school students.	2010
Graduate Instructor Brigham Young University, Provo UT Designed and introduced a new college-level course with emphasis on 3d modeling, animation, and photography.	2006 - 2010
Foreign Language Instructor Missionary Training Center, Provo UT Responsible for the language and instructional training of over 2000 church-service representatives.	2005 - 2010

RELATED EXPERIENCE

K-12 Professional Development Workshop Instructor Designed, sought, and received funding for a professional development workshop offered to statewide K-12 teachers introducing teachers to quadcopters and designing implementation of quadcopters into K-12 classrooms	2015-2016
--	------------------

- National Competition Scenario Developer** 2014-2015
TSA Tests of Engineering Aptitude, Mathematics, and Science (TEAMS)
Developed scenario involving wind energy for the national high school competition
- Technology & Engineering Education Test Question Developer** 2014 - present
ETS: PRAXIS Secondary Education Licensing Test
Developed test questions for the Technology & Engineering Education portion of the national teacher licensing test
- Coach, Westlake High School** 2013
Saratoga Springs, UT
High School Boys' Volleyball Coach
- Media Specialist, Issimo Productions** 2013
Lindon, UT
Worked with a creative team in the design of multimedia requests for clients. Performed the following duties: videography, editing, storyboarding, modeling, and animation.
- Coach, Westlake High School** 2012 – 2013
Saratoga Springs, UT
High School Girls' Volleyball Coach
- Webmaster, Pogi Marketing** 2007 - present
Designed, created, and continually maintained 4 different retail websites with millions of dollars of inventory.
- Program Coordinator, Especially for Youth Programs** 2007 - 2010
Provo, UT
Oversee all logistical preparation and implementation for summer camps serving thousands of youth. Act as liaison between campus and program representatives.

PUBLICATIONS AND PAPERS (REFEREED JOURNALS)

- Bartholomew, S. (2015). Who Teaches the STE in STEM? *The Technology & Engineering Teacher*, October 2015, pp. 14-19
- Bartholomew, S. (2014). Why we can't afford to lose CTE in Schools. *International Journal of Vocational and Technical Education*, 6 (2), pp.7-12, DOI: 10.5897/IJVTE2014.0149
- Bartholomew, S. (2014). Infusing Creativity into Technology Education through an Understanding of Neuroscience. *Journal of Education and Training*, 1 (1), pp. 133-140. <http://dx.doi.org/10.5296/jet.v1i1>

Wright, G., Shumway, S., Terry, R., & Bartholomew, S. (2012). Analysis of five instructional methods for teaching sketchpad to junior high students. *Journal of Technology Education*, 24 (1), pp. 54-72

Terry, R., Wright, G., & Bartholomew S. (2011). Developing and assessing STEM curriculum with the intent of promoting technological literacy. *ASEE Conference Proceedings, Objectives, Assessment, and Methods for Teaching Technological Literacy*, Vancouver, Washington, USA

PUBLICATIONS AND PAPERS (NON-REFEREED JOURNALS)

Bartholomew, S. (2015). Successfully integrating robotics into your curriculum. *ACTE: Techniques*, October 2015, pp. 14-17

Bartholomew, S. (2015). Including Mobile Devices in the Classroom. *ACTE: Techniques*, April 2015, pp. 8-9

Bartholomew, S. (2015). My Journey with Self-Directed Learning. *ACTE: Techniques*, February 2015, pp. 46-50

Bartholomew, S. (2010). What is the most effective method of multimedia instruction? *Technology Education Research Conference Proceedings*, Gold Coast, Australia

Bartholomew, S. (2010). An Evaluation of Student Teaching Evaluation. *Technology Education Research Conference Proceedings*, Gold Coast, Australia

GRANTS

Utah State University Extension Grant
\$10,000
Co-Investigator, Drones in Agriculture
Fall 2015

Cache Valley Historical Society Grant
\$1,000
Principal Investigator, Historical Research Project
Fall 2015

Tests of Engineering Aptitude, Mathematics, and Science (TEAMS)
\$2,000
Co-Investigator, *Technology Student Association*
Fall 2014

ORCA Grant
\$1,000
Co-Investigator, Photography Field Project
FALL 2008

CONFERENCE PRESENTATIONS

- Mobile Devices in K-12 Education*
International Technology & Engineering Educators
Association Washington DC, USA **2016**
- Quadcopters: STEM Collaboration in Classrooms and Competitions*
International Technology & Engineering Educators
Association Washington DC, USA **2016**
- Mini Quadcopters in K-12 classrooms*
UACTE Mid-Winter Conference, St. George, Utah, USA **2016**
- Why Society can't afford to lose TEE*
International Technology & Engineering Educators
Association Milwaukee, Wisconsin, USA **2015**
- How mobile-devices increase self-directed learning*
International Technology & Engineering Educators
Association Milwaukee, Wisconsin, USA **2015**
- Engaging Students through designing and building quad-copters*
UACTE Mid-Winter Conference, Corner Canyon, Utah, USA **2015**
- Infusing Creativity into Technology Education through an Understanding of Neuroscience*
International Technology & Engineering Educators
Association Orlando, Florida, USA **2014**
- Design, Create, & Build your own Children's Toys (Laser Projects)*
UACTE Mid-Winter Conference, Saratoga Springs, Utah,
USA **2014**
- DIY Life-sized Vinyl Stickers*
UACTE Mid-Winter Conference, Saratoga Springs, Utah,
USA **2014**
- Easy Lego Mindstorms Projects*
UACTE Mid-Winter Conference, Saint George, Utah, USA **2013**
- Awesome Laser Projects*
UACTE Mid-Winter Conference, Saint George, Utah, USA **2013**
- Intro to Animation – Teaching animation using free software applications*
UACTE Summer Conference, Logan, Utah, USA **2012**
- Design a “dream-fort” – 3d modeling with Google Sketchup*
UACTE Summer Conference, Logan, Utah, USA **2012**

<i>How to teach and use Green Screen Technologies</i> UACTE Mid-Winter Conference, Saint George, Utah, USA	2011
<i>Design a “dream-fort” – 3d modeling with Google Sketchup</i> UACTE Mid-Winter Conference, Saint George, Utah, USA	2011
<i>What is the most effective method of computer-based multimedia instruction?</i> E-Learn 2010, World Conference on E-Learning in Corporate, Government, Healthcare, and Higher Education. Orlando, Florida, USA	2010
<i>An Evaluation of Student Teaching Evaluation</i> President’s Leadership Council, Brigham Young University, Provo, Utah, USA	2010
<i>How to effectively teach Multimedia</i> International Technology and Engineering Education Association Conference, Charlotte, North Carolina, USA	2010
<i>What is the most effective method of teaching multimedia?</i> Utah Conference on Undergraduate Research, Southern Utah University, Cedar City, Utah, USA	2009
<i>How to effectively teach Multimedia</i> International Technology and Engineering Education Association Conference, Nashville, Tennessee, USA	2009
<i>Evaluating Student Teacher Evaluation</i> Utah Conference on Undergraduate Research, Southern Utah University, Cedar City, Utah, USA	2008

SERVICE

TEECA Competitive Event Coordinator <i>International Technology & Engineering Education Association</i>	2015 - 2016
ITEEA State Affiliate Representative (Utah) <i>International Technology & Engineering Education Association</i>	2015 - Present
Graduate Student Panel Representative <i>International Technology & Engineering Education Association</i>	2014 – 2015
International Conference Planning Committee <i>International Technology & Engineering Education Association</i>	2013 - 2016
Conference Competitive Event Coordinator - Communications <i>International Technology & Engineering Education Association</i>	2013 - 2015

Regional Robotics Coordinator, Coach, & Representative (VEX)
Utah State Design Academy

2013 - 2014

Conference Presentation Reviewer
Science, Technology, Engineering, & Math Conference

2013

LANGUAGES

English - Native
Tagalog – Fluent
Ilokano - Conversational
American Sign Language – Conversational

MEMBERSHIPS

ACTE Member
UTEE Member
ITEEA Member

2010 – present

2010 – present

2006 – present