Use of Tablets to Support Students’ 21st Century Skills: A Look Behind
the Screen at Knowledge Construction, Collaboration, and Skilled
Communication in Language Arts and Science

Rochelle Tkach, B.A., B.Ed.

Department of Graduate and Undergraduate
Studies in Education

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Faculty of Education, Brock University
St. Catharines, Ontario

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Abstract

This study sought to identify how the use of information and communication technologies (ICT), specifically tablets, may foster students’ 21st century skills of knowledge construction, collaboration, and skilled communication and may further support knowledge construction in science, reading comprehension, and vocabulary development. This mixed methods research explored 21 Grade 5 students’ tablet (iPad) screen interactions and audio recordings, blog posts, interview responses, researcher observations, and student artifacts during an interdisciplinary science and language arts unit. Students worked in pairs or small groups on iPads to learn science and language arts concepts. Qualitative data were collected using video and audio monitoring tools (NestCams, 2016). Using NVivo 11.4, qualitative data were coded using the 21 CLD Learning Activity Rubrics (Microsoft Corporation, 2015). Queries were further run to determine data that correlated between the use of tablets for learning and other 21st century skills. Findings showed high instances of 21st century skills while students worked on tablets. The way students used tablets to support their learning seemed to depend on the level of knowledge construction, collaboration, and skilled communication. Quantitative data were also collected using reading comprehension, vocabulary, and science pre- and post-tests. Dependent samples t-tests were run to determine if there was growth from pre-test to post-test. Results indicated statistically significant growth only in science content knowledge. Qualitative findings were triangulated with the quantitative results to illustrate descriptive growth trends in science and language arts. This study highlights the importance of being critical towards multimodal features within apps to support students’ development of 21st century skills and subject-specific knowledge. Recommendations and implications for theory, practice, and methodological approaches are provided for future studies.
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# Table of Contents

Abstract ................................................................................................................................. ii  
Acknowledgements.............................................................................................................. iii  
List of Tables .......................................................................................................................... vi  
List of Figures ........................................................................................................................ vii  

## CHAPTER ONE: INTRODUCTION TO THE STUDY ......................................................... 1  
  Background of the Study .................................................................................................. 1  
  Background of the Problem .............................................................................................. 4  
  Statement of the Problem ................................................................................................. 6  
  Purpose of the Study ........................................................................................................ 6  
  Research Questions ........................................................................................................ 6  
  Rational for the Study ..................................................................................................... 7  
  Definition of Terms ........................................................................................................ 8  
  Overview of the Remainder of the Document ............................................................... 9  

## CHAPTER TWO: REVIEW OF RELATED LITERATURE ............................................. 11  
  Theoretical Framework ................................................................................................... 11  
  Literature Review ........................................................................................................... 16  
  Chapter Summary .......................................................................................................... 46  

## CHAPTER THREE: METHODOLOGY AND PROCEDURES ........................................ 47  
  Research Design ............................................................................................................ 47  
  Pilot Test ......................................................................................................................... 48  
  Present Study ................................................................................................................ 53  
  Data Collection and Analysis ......................................................................................... 56  
  Ethical Review ................................................................................................................ 63  

## CHAPTER FOUR: FINDINGS ....................................................................................... 64  
  Use of Tablets for Learning: Knowledge Construction, Collaboration, and Skilled Communication .......................................................................................................................... 65  
  Use of Tablets for Learning: Knowledge Construction in Science, Reading Comprehension, and Vocabulary ............................................................................................ 116  
  Summary of Findings ..................................................................................................... 132  

## CHAPTER FIVE: DISCUSSION, IMPLICATIONS, LIMITATIONS, AND CONCLUSIONS ................................................................. 134  
  Discussion of the Findings .............................................................................................. 135  
  Implications for Theory .................................................................................................. 153  
  Implications for Practice ................................................................................................. 158  
  Methodological Limitations and Implications for Future Research ......................... 161  
  References ....................................................................................................................... 164
Appendix A: Overview of Seven Competencies of 21st Century Learners ........ 178
Appendix B: Overview of 21 CLD Learning Activity Rubric: Use of ICT for Learning ........................................................................................................................................ 180
Appendix C: Overview of 21 CLD Learning Activity Rubric: Knowledge Construction........................................................................................................................................ 181
Appendix D: Overview of 21 CLD Learning Activity Rubric: Collaboration ..... 182
Appendix E: Overview of 21 CLD Learning Activity Rubric: Skilled Communication ........................................................................................................................................ 183
Appendix F: Exit Interview Questions ................................................................. 184
Appendix G: Sample of Reading Comprehension Test ...................................... 185
Appendix H: Sample of Vocabulary Test ................................................................ 186
Appendix I: Grade 5 eTestSmart Science: Forms of Energy and Conservation of Energy ........................................................................................................................................ 187
Appendix J: Overview of Modified Grade 5 Conservation of Energy Resources and Language Arts Activities ........................................................................................................................................ 191
Appendix K: 21 CLD Learning Activity Rubrics .................................................. 193
# List of Tables

<table>
<thead>
<tr>
<th>Table</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Use of Information and Communication Technologies (ICT) for Learning—Number of Instances Coded</td>
<td>67</td>
</tr>
<tr>
<td>2. Knowledge Construction (KC)—Number of Instances Coded</td>
<td>71</td>
</tr>
<tr>
<td>3. Knowledge Construction (KC) and Use of Information and Communication Technologies (ICT) for Learning—Number of Instances Coded</td>
<td>80</td>
</tr>
<tr>
<td>4. Collaboration (COL)—Number of Instances Coded</td>
<td>93</td>
</tr>
<tr>
<td>5. Collaboration (COL) and Use of Information and Communication Technologies (ICT) for Learning</td>
<td>95</td>
</tr>
<tr>
<td>6. Skilled Communication (COM)—Number of Instances Coded</td>
<td>105</td>
</tr>
<tr>
<td>7. Skilled Communication (COM) and Use of Information and Communication Technologies (ICT) for Learning—Number of Instances Coded</td>
<td>107</td>
</tr>
<tr>
<td>8. Summary of Scores from Reading Comprehension, Vocabulary, and Science Tests</td>
<td>117</td>
</tr>
<tr>
<td>9. Science Test Item Analysis</td>
<td>120</td>
</tr>
</tbody>
</table>
# List of Figures

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Vision for 21st Century Learning in Canada</td>
<td>27</td>
</tr>
<tr>
<td>2.</td>
<td>Tidal Energy app: 3-D view with titles</td>
<td>73</td>
</tr>
<tr>
<td>3.</td>
<td>Popplet app: Mind map on pros and cons of solar panels</td>
<td>75</td>
</tr>
<tr>
<td>4.</td>
<td>EasyBlog app: Blog post on tidal energy</td>
<td>78</td>
</tr>
<tr>
<td>5.</td>
<td>EasyBlog app: Blog post on heat energy</td>
<td>81</td>
</tr>
<tr>
<td>6.</td>
<td>Popplet app: Mind map on good blogs</td>
<td>83</td>
</tr>
<tr>
<td>7.</td>
<td>Popplet app: Mind map on good blogs with pictures</td>
<td>85</td>
</tr>
<tr>
<td>8.</td>
<td>PicCollage app and EasyBlog app: Blog post on types of energy</td>
<td>86</td>
</tr>
<tr>
<td>9.</td>
<td>EasyBlog app: Blog post on energy (Part 1)</td>
<td>89</td>
</tr>
<tr>
<td>10.</td>
<td>EasyBlog app: Blog post on energy (Part 2)</td>
<td>90</td>
</tr>
<tr>
<td>11.</td>
<td>EasyBlog app: Blog post on sources of energy</td>
<td>98</td>
</tr>
<tr>
<td>12.</td>
<td>EasyBlog app: Blog post on wind energy</td>
<td>99</td>
</tr>
<tr>
<td>14.</td>
<td>Popplet app: Mind map on solar energy proposal plan</td>
<td>112</td>
</tr>
<tr>
<td>15.</td>
<td>EasyBlog app: Blog post on coal (Part 1)</td>
<td>114</td>
</tr>
<tr>
<td>16.</td>
<td>EasyBlog app: Blog post on coal (Part 2)</td>
<td>115</td>
</tr>
<tr>
<td>17.</td>
<td>Kids Discover app: Potential vs. kinetic energy text</td>
<td>123</td>
</tr>
<tr>
<td>18.</td>
<td>Kids Discover app: Potential vs. kinetic energy text</td>
<td>124</td>
</tr>
<tr>
<td>19.</td>
<td>PicCollage app and EasyBlog app: Blog post on coal</td>
<td>125</td>
</tr>
<tr>
<td>20.</td>
<td>EasyBlog app: Blog post on solar energy</td>
<td>127</td>
</tr>
<tr>
<td>21.</td>
<td>PicCollage app: Collage on forms of energy</td>
<td>128</td>
</tr>
<tr>
<td>22.</td>
<td>EasyBlog app: Blog post on energy</td>
<td>130</td>
</tr>
</tbody>
</table>
CHAPTER ONE: INTRODUCTION TO THE STUDY

This study explored how the use of tablets for learning can support students’ 21st century skills and further knowledge in subject-specific areas. Education is witnessing a pedagogical shift with the rapid advancements of technology and access to information and knowledge creation platforms (Canadians for 21st Century Learning & Innovation [C21 Canada], 2012). Popular press commentators have been heralding the digital natives (also known as the net generation) as having unique and intuitive abilities to manipulate technology far beyond the capabilities of their predecessors (Oblinger & Oblinger, 2005; Prensky, 2001; Tapscott, 1999); however, this claim has made it difficult for educators and researchers to see beyond a generational divide. Rather than assuming contemporary students know everything about technology and can intuitively construct knowledge through technology because of their date of birth, research recommends that educators and researchers look at the unique affordances of technology to scaffold students’ learning (Kennedy, Judd, Dalgarno, & Waycott, 2010; Thompson, 2013). The purpose of this study was to research how information and communication technologies (ICT), specifically tablets, may foster the 21st century skills of knowledge construction, collaboration, and skilled communication and may further support knowledge construction in science, reading comprehension, and vocabulary development. This chapter outlines the background of the study and problem, the statement of the problem, the purpose of the study, the research questions, the rational for the study, a definition of terms, and an overview of the remainder of the document.

**Background of the Study**

To be positioned for success in the 21st century, it is imperative that students build advanced skills to adapt and become active citizens in their future work and social
environments (C21 Canada, 2012). Since this study was situated within a Canadian school, the current study focused on a framework outlined by C21 Canada (2012). Through the lens of traditional theoretical frameworks, including cognitive constructivism (Piaget, 1963), social constructivism (Vygotsky, 1962), and connectivism (Siemens, 2005), this study expanded upon the C21 Canada framework with respect to the 21st century skills embedded within the competencies, which included: use of ICT for learning, knowledge construction, collaboration, and skilled communication.

This study integrated ICT technologies. Research shows the affordances that digital-touch based mobile ICT like tablets have to support multimodality and students’ development of 21st century skills (Gallagher et al., 2015; Hutchison, Beschorer, & Schmidt-Crawford, 2012; Walsh & Simpson, 2013). The number of educational iPad apps has soared to over 80,000 apps currently in the Apple App Store (Apple Inc., 2017). Considering the volume of apps available at educators’ disposal, tablets such as iPads are considered educational ICT “game changers” due to their unique affordances such as portability, touch-screen interface, wide array of apps, and multimodal features within apps (Falloon, 2014).

Scardamalia and Bereiter’s (1991, 2006) work has informed this study’s understanding of the 21st century skill of knowledge construction by emphasizing the need for knowledge acquisition and knowledge creation. Research also suggests that an interdisciplinary approach to learning has the ability to enhance knowledge construction (Drake & Burns, 2004; Drake, Reid, & Kolohan, 2013). Romance and Vitale (2001) anticipate that through the integration of science and literacy instruction, learners can be conceptualized as active constructors of knowledge and should be the guiding force for integrated instruction. Furthermore, Romance and Vitale (2001) stress the importance of
knowledge acquisition for conceptual understanding that recognizes the different environments students will need to apply knowledge formally inside and informally outside school. Based on these points, the learning activity rubrics used in this study to measure 21st century skills further use the term interdisciplinary learning as a descriptor for the highest instances of knowledge construction (Microsoft Corporation, 2015). For knowledge construction to happen, the interdisciplinary unit needs to centre around big ideas (Drake et al., 2013). In this study, the term interdisciplinary unit was adopted for consistency with the learning activity rubrics. The big ideas that inform the interdisciplinary unit were 21st century literacies including traditional, digital, and environmental literacy. With these literacies in mind, this study situated the analysis of 21st century knowledge construction within an interdisciplinary science and language arts unit. Based on this, students were given the opportunity to apply their knowledge in different learning environments (Romance & Vitale, 2001), which in turn situated students in an authentic learning context with the potential for connections to the real world (Scardamalia & Bereiter, 2006).

Also central to this study were the 21st century skills of collaboration and skilled communication. Presently, learning is strongly rooted in a shared responsibility to collaboratively construct shared objects (Bereiter & Scardamalia, 2014; Paavola, Lipponen, & Hakkarainen, 2004). At the highest levels of collaboration, emphasis is placed on the interdependence of students’ work where there is a balance between individual knowledge and activity and a stream of social activities (Paavola et al., 2004). With regards to 21st century skilled communication, the multimodality in different kinds of texts calls for different forms of meaning making and communicating that stem from the multiple devices and media texts students interact with and learn from (Rowsell &
Walsh, 2011). The emphasis is placed on students’ production of multimodal texts through extended communication and for a particular audience (Microsoft Corporation, 2015).

Given that tablets have become popular in education and are relatively affordable, the current study attempted to determine how the use of tablets may foster the 21st century skills of knowledge construction, collaboration, and skilled communication. This study further attempted to determine how the use of ICT for learning may foster students’ knowledge construction in science concepts, reading comprehension, and vocabulary development.

**Background of the Problem**

Although educators and students are learning in the 21st century, much of education is still dominated by 20th century educational practices. Twentieth century education consisted of knowledge transmission through expert teachers, knowledge organized into neat disciplines, and standardized testing (Drake et al., 2013). Many of these practices are rooted in behavioural and psychological theories (Skinner, 1954, 1968; Thorndike, 1911) where students were seen as blank slates ready for the consumption of knowledge. Progressive educators began to also emerge in the 20th century and focused more on cognitive and social constructivism (Dewey, 1938, 1966; Piaget, 1963; Vygotsky, 1978). Unfortunately, education is notorious for the metaphor of a pendulum swing where learning theories are advocated for and then renounced from one conceptual extreme to the other and back again (Drake et al., 2013). In the 21st century, education cannot abandon 20th century learning practices; instead, there needs to be a balance between the old story and new story of education (Drake et al., 2013).

Scardamalia and Bereiter (2006) have discussed the role of traditional teaching methods in relation to knowledge construction. The value of knowledge about something still dominates education today where students learn facts related to specific subjects and
learn how to apply these facts in subject-specific contexts—that is, taking a test (Scardamalia & Bereiter, 2006). Consistent with fostering traditional learning, acquiring factual knowledge should still be valued, but it should be understood through students’ development of conceptual knowledge (Anderson et al., 2001). Scardamalia and Bereiter (2006) refer to this as knowledge of something where facts, skills, or concepts are not applied to one context, but rather can be applied to multiple contexts.

The main concern with knowledge construction is that education is dominated by the component of knowledge about something and not enough emphasis is placed on the higher-order thinking skills within knowledge of something (Scardamalia & Bereiter, 2006). Learning factual knowledge is not useless; instead, it needs to be conceptualized through invention, theorizing, and the solving of authentic real-world problems (Scardamalia & Bereiter, 2006). Therefore, it was imperative to research knowledge construction as an essential 21st century skill in a learning context where students were not developing subject-specific skills but rather learning skills that are interdisciplinary.

When considering the integration of technology, it is crucial that educators and researchers consider the pedagogy and educational implications of ICT: a purpose for the technology that goes beyond the idea that it is the new hype in the world of education (Falloon, 2014). With respect to this study, there has been limited research looking at how ICT can support students’ development of 21st century skills such as the knowledge construction, collaboration, and skilled communication (Falloon, 2014; Gallagher et al., 2015; Gallagher & Rowsell, in press). It was therefore imperative to investigate the new ICT emerging in the 21st century to better understand if certain features within them could support students’ development of the skills they need to be successful in their future.
Statement of the Problem

Education in the 21st century falls short of moving beyond traditional teaching practices and towards skills students will need to be active citizens in their future (Drew, 2012; Larson & Miller, 2011). Surprisingly, with the hype of new and innovative ICT within 21st century learning frameworks, there is a lack of research to support their pedagogical implications and learning value to scaffold the development of 21st century skills and support knowledge construction in subject-specific content (Falloon, 2014; Gallagher et al., 2015; Groff & Mouza, 2008). This leaves educators challenged with understanding the connectedness between ICT, 21st century learning, and curriculum (Gallagher et al., 2015).

Purpose of the Study

The purpose of this study was to research how information and communication technologies (ICT), specifically tablets, may foster the 21st century skills of knowledge construction, collaboration, and skilled communication and may further support knowledge construction in science, reading comprehension, and vocabulary development. This study anticipated that features within tablets to support learning may foster 21st century skills and elucidate how educators might balance 21st century learning with traditional learning. Perhaps by fostering these 21st century learning practices, students may develop the skills they need to be productive and active citizens (Claxton, 2014).

Research Questions

The following research questions guide this study:

1. How can the use of tablets for learning foster Grade 5 students’ 21st century skills, including knowledge construction, collaboration, and skilled communication?

2. How can the use of tablets for learning build students’ knowledge construction in science concepts, reading comprehension, and vocabulary development?
Rationale for the Study

With a growing number of white papers, policy documents, and popular press publications, teachers are bombarded by blanket terms, buzzwords, and concepts that sound impressive but are often unsubstantiated (Thompson, 2013). Educators often adopt these “innovative” concepts, but do so without considering if they have any research to support them (Falloon, 2014). The rationale for this study was to build upon some of the concepts and frameworks outside of academia, connect these conceptualizations to research-based theories and empirical studies, and then further conduct original research to determine if these frameworks were justified.

The current study referenced the 21st Century Vision of Public Education for Canada (C21 Canada, 2012) framework. This framework was proposed for the Canadian education system and is premised on concepts from cognitive constructivism and social constructivism. The 21st century skills embedded within this framework have been extracted and will be discussed in relation to academic research. This provided a theoretical underpinning to justify the significance of these skills and the study of how the use of ICT for learning may have been able to support these 21st century skills.

To address the problem with schools relying on knowledge transmission to teach specific facts, a focus for this research study was on how students construct knowledge (Scardamalia & Bereiter, 2006) through the use of higher-order thinking skills such as synthesizing, interpreting, analyzing, and evaluating (Anderson et al., 2001). This study also sought to address students’ interdisciplinary learning by researching how tablet use within language arts and science instruction may have enhanced students’ 21st century skill of knowledge construction and subject-specific knowledge. Towards a new story to education embedded with positive aspects from 20th century education, constructivism,
and innovative technology (Drake et al., 2013), this study focused on how tablets could be used as a means to scaffold and support knowledge construction.

With regards to collaboration, studies have looked at how the use of ICT can support students’ collaborative abilities (Rowsell & Walsh, 2011). Pertaining to Falloon’s (2014) point on how tablets specifically pose unique affordances for students, it was rationalized that these affordances may support students’ collaboration. Furthermore, research has not looked specifically at how students build skilled communication through the use of tablets. The C21 Canada (2012) framework emphasized skilled communication as an imperative 21st century skill. However, this study rationalized that with the strong links between ICT and skilled communication (Chelliah & Clarke, 2011), more research needs to be conducted to better understand what features within ICT support students’ skilled communication. Considering the multiple modes offered through tablets, multimodality within skilled communication was therefore used as one of the focal points for this study (Rowsell & Walsh, 2011; Serafini, 2012).

With the growing number of tablets and their available apps (Apple Inc., 2017), it was timely to determine their role in supporting students 21st century skills while also analyzing their role to enhance subject-specific knowledge. It is not enough to integrate ICT without sound research and an understanding of pedagogical implications of tablets specifically. It is imperative for researchers and teachers to take a critical eye towards tablets and the apps embedded in them to determine if they really are useful to support students’ 21st century skills and subject-specific knowledge.

**Definition of Terms**

For the purpose of this study, *digital natives* are identified as the (present) first generation to grow up with ICT and experience the rapid dissemination of ICT (Prensky,
Also referred to as the *net generation*, they are considered to possess sophisticated technological skills and are motivated differently based on their unique learning preferences (Oblinger & Oblinger, 2005; Prensky, 2001; Tapscott, 1999). *Twenty-first century literacies* are the values, attitudes, or behaviours embedded within character strengths (Claxton, 2014; Drake et al., 2013). *Twenty-first century skills* are cognitive, social, and behavioural processes that students will need to be successful productive and active citizens in postsecondary education and their future careers (Claxton, 2014; Sullivan & Downey, 2015). *Multimodality* describes the complex features or modes within ICT that students respond to and construct meaning from in nontraditional ways (Rowsell & Walsh, 2011; Serafini, 2012). *Information and Communication Technologies (ICT)* “encompass a full range of digital tools, both hardware (i.e., computers and related electronic devices such as tablets) and software (including everything from an Internet browser and multimedia development tools)” (Microsoft Corporation, 2015, p. 23).

*Tablets* are mobile devices with unique affordances compared to other ICT such as portability, touch-screen interface, and a wide variety of apps (Falloon, 2014). *Apps* are applications designed for tablets or smart phones to support a single and multiple functions within digital devices (Hutchison et al., 2012). *Interdisciplinary units* are a form of integrated unit that require teachers to cluster curriculum expectations across disciplines and around big ideas, values, attitudes, behaviours, and 21st century skills (Drake & Burns, 2004).

**Overview of the Remainder of the Document**

Chapter 2 provides a review of the literature as it relates to the theoretical framework, digital natives critique, 21st century learning, use of information and communication technologies, knowledge construction, collaboration, and skilled
communication. Chapter 3 presents the mixed methods research design chosen for the current study; specifically, it presents the participant and site selection, procedure, data gathering, recording, and analysis. Chapter 3 further outlines the actions taken to ensure the credibility of the findings and the ethical guidelines that will be followed to ensure participants have been protected. Chapter 4 presents research findings of the study. Chapter 5 offers the conclusions and implications for researchers and educators as they seek to understand, integrate, and evaluate the use of information and communication technologies to support 21st century skills and subject-specific content. Limitations of the study and directions for future research are also outlined in this final chapter.
CHAPTER TWO: REVIEW OF RELATED LITERATURE

This study was designed to explore how students’ use of tablets for learning contributed to their development of 21st century skills, including: knowledge construction, collaboration, and skilled communication. Furthermore, this study was interested in how students’ use of tablets for learning may contribute to their knowledge construction in reading comprehension, vocabulary development, and science concepts. The research questions that guided this study are: (a) How can the use of tablets for learning foster Grade 5 students’ 21st century skills, including knowledge construction, collaboration, and communication? (b) How can the use of tablets for learning build students’ knowledge construction in science concepts, reading comprehension, and vocabulary development? The following review of related literature informed the present study on: constructivist theories; the digital natives debate; 21st century learning; use of information and communication technologies (ICT); knowledge construction; collaboration; and skilled communication. To situate the study, the following section describes the theoretical framework.

Theoretical Framework

The learning theory at the core of this study was constructivism. Constructivist learning theories are composed of both cognitive and social roots (Powell & Kalina, 2009). Cognitive and social constructivism are premised on different theoretical foundations; however, both emphasize that students’ construction of knowledge from experience, and the meaning of this knowledge, is relative to the individual’s personal understanding (Powell & Kalina, 2009). Creating personal meanings through the construction of knowledge is at the centre of a constructivist theoretical framework (Powell & Kalina, 2009). However, within the current digital era, new understandings
about knowledge construction are becoming relevant within education. Constructivism is an important psychological learning theory, but within constructivism, old and new learning theories build off one another to explain learning in the 21st century. In addition to the distinctions of cognitive constructivism and social constructivism, connectivism has evolved more recently as a learning theory (Siemens, 2005).

**Cognitive Constructivism**

Founders of the cognitive constructivist theory are Piaget (1963) and Bruner, Goodenow, and Austin (1956). Cognitive constructivism centres on the premise that individual thought is constructed and interpreted by the learner through personal experiences (Piaget, 1963). Piaget coined six developmental stages and believed that individuals construct knowledge and meaning through these stages. Piaget stated that as students construct knowledge, they do so through two different processes: assimilation and accommodation. Assimilation is when students bring in new knowledge to their already existing schemas, whereas accommodation is when students accommodate new knowledge by changing their schemas (Piaget, 1963). Bruner et al. (1956) further theorized how students need to be ready and motivated to learn within an appropriate learning context. The teacher’s role within the constructivist model is seen as a facilitator of knowledge construction and to provide students with experiences that encourage problem solving and engagement (Bruner et al., 1956; Piaget, 1963).

**Social Constructivism**

The lead founder of social constructivism is Lev Vygotsky (Vygotsky, 1978), who focused on the premise that knowledge is constructed through social interaction among teachers and peers. This theory takes into consideration the personal, critical thinking process in cognitive constructivism, but further emphasizes the importance of knowledge
construction through social interactions (Powell & Kalina, 2009). Vygotsky coined the phrase *zone of proximal development* (ZPD) to describe the context where children capably learn when in a supported context. This supportive process is referred to as *scaffolding*, which occurs when students are provided support from teachers, peers, or other adults to learn a new concept (Wood, Bruner, & Ross, 1976). Social constructivist theory also encourages collaborative learning environments where students learn in pairs or groups to construct knowledge (Vygotsky, 1962). Within this social setting, language usage is imperative as a precursor to develop cognitive thinking and support knowledge construction (Vygotsky, 1962).

Both of cognitive and social constructivist theories emphasize how knowledge construction through cognition and social experiences are integral parts of constructivism. Although these learning theories still apply in today’s education system, limitations to these learning theories are becoming more prominent within the digital era (Siemens, 2005). Cognitive and social constructivist theories are based on the premise that learning and knowledge construction occur within the individual learner; although social constructivism does emphasize that collaborative knowledge is built in pairs or groups and then internalized by the individual learner (Siemens, 2005). By contrast, in the digital era, learning may occur external to an individual where it is stored and manipulated by technological tools (Siemens, 2005). Instead of focusing on what is being learned *in school*, new learning theories stress the importance of learning processes within a digitally networked world (Siemens, 2005).

**Connectivism**

Connectivism is a relatively new learning theory postulated by George Siemens and Stephan Downes in 2005 that reflects a model of education for the digital era
Knowledge is no longer acquired in a linear manner and solely through print-based texts (Rowsell & Walsh, 2011; Serafini, 2012). Students today learn in nonlinear digital platforms through multiple modalities of information transfer (Rowsell & Walsh, 2011). Knowledge construction may be supported through networked processes that occur outside the individual within digital platforms where learners connect large amounts of specialized sources of information (Siemens, 2005). Learning is therefore not controlled by the individual exclusively (Siemens, 2005).

Cognitive functioning no longer takes place solely within the individual learner and/or within groups of learners; rather, connections may take place within digital devices that improve efficiency and task performance (Siemens, 2005). For example, within digital devices, social networking offers an additional dimension to the connectivist learning theory (Siemens, 2005). Social networking is made up of connected hubs of like-minded people who digitally collaborate and construct knowledge together (Siemens, 2005). Therefore, technology may help to scaffold individuals’ networks and cognitive processes through digitally connecting individuals, recommending resources, and storing information.

Connectivism calls for a new design to learning environments that builds off of cognitive and social constructivism (Siemens, 2005). Siemens (2005) believes the current education system has been slow in meeting the expectations of the digital era and realizing the impact digital devices are having on traditional learning theories. Other researchers have suggested that the abrupt application of connectivism into schools may place too much emphasis on the net to foster students’ knowledge construction (Calvani, 2008). For example, when students are given an abundance of autonomy over their learning, there may be implications on critical and deep knowledge construction that is
supported through meaningful transactions with expert teachers (Kop & Hill, 2008).

Critics of Siemen’s (2005) theory of connectivism (e.g., Calvani, 2008) suggest that Siemen is pretentious when he refers to other theories like behaviourism, cognitivism, and constructivism as outdated. Some researchers question whether connectivism is a *developmental theory* (Kop & Hill, 2008). A *theory* should stem from scientific research, use scientific methods, and have previous studies supporting its claims (Miller, 1993). In contrast, a developmental theory is on its way towards becoming a formal theory, but it is still in the stage of idea development, which should engender more empirical research to validate its claims (Kop & Hill, 2008). Therefore, with respect to instructional design and the adoption of connectivism as a theory, it remains controversial to accept connectivism as a formal theory (Kop & Hill, 2008).

Miller (1993) suggests that a developmental theory must describe several aspects of behaviour, change in the relationships within these areas of behaviour, and explain the developmental progression with regards to these areas of behaviour. Siemens (2005) describes connections in relation to nodes or networks where knowledge resides in multiple locations online and information is being inquired about or shared between individuals who have a common interest. However, connectivism is mainly focused on cognitive development rather than how the connections to networks may be interpreted or changed based on a person’s exposure and interactions within the social world. If this is the case, it would not be consistent with constructivism. Furthermore, if learning is reduced to the relationship and connections made through networks, then learning can only be achieved through the properties underlying the networks (Kopp & Hill, 2008). Connectivism places emphasis on the cognitive processes rather than explaining how these underlying networks are interpreted by individuals interacting, socializing, and
making connections (Kopp & Hill, 2008). This is problematic when trying to describe the relationships among several aspects of behaviour and the course of development within these aspects of behaviour (Kopp & Hill, 2008).

Furthermore, a major criticism of connectivism is that there is little explanation regarding the notion that learning happens within nonhuman machines (Gerard & Goldie, 2016). One can argue that the learning is taking place based on the pattern recognitions within machines, and then used by humans (Gerard & Goldie, 2016). With this in mind, connectivism does provide a theoretical underpinning for conceptualizing knowledge and collaboration in digital networks; as such, this research study will also maintain roots in traditional cognitive and social constructivist theories.

Contemporary students are learning in a much different world than their predecessors. Theories such as connectivism attempt to consolidate the widespread notion that suggests the more individuals use technology throughout their lives, the better off they are (Calvani, 2008). Additionally, there are considerations related to common terms—such as millennial learners—which suggest there are characteristics specific to learners based on their generation, and that they do not respond well to traditional teaching approaches (Kop & Hill, 2008). It is important to note the merit of taking traditional learning theories and building concrete understandings of how new learning theories can hold a place in today’s schools and provide students with the skills they need to be successful in the 21st century.

**Literature Review**

The following section provides a review of related literature to situate the research questions within a context based on previous research. The main topics in this section include: (a) the Digital Natives Debate; (b) 21st Century Learning; (c) Use of Information
and Communication Technologies for Learning; (d) Knowledge Construction; (e) Collaboration; and (f) Skilled Communication.

**Digital Natives Debate**

With the evolving technology industry influencing educational settings, it is imperative that researchers understand the theoretical assumptions teachers are adopting to articulate the effects digital technologies have on their learners (Bennett & Maton, 2010). The mainstream press (Helsper & Eynon, 2010) has coined labels to describe the current generation of K-16 learners as *digital natives* (Prensky, 2001) or the *net generation* (Oblinger & Oblinger, 2005; Tapscott, 1999). The following section will provide insight into the current discourses influencing many teachers’ understandings of the current generation of students. It will further provide a comparison between the common discourse and what research is finding with regard to the effects of ICT on student learning.

**Digital natives.** Digital natives have been identified as the first generation to grow up with ICT and the rapid dissemination of this ICT (Oblinger & Oblinger, 2005; Prensky, 2001). The current generation of students are said to be learning, adopting, and manipulating technology to an extent that supersedes practicing teachers (Oblinger & Oblinger, 2005; Prensky, 2007; Tapscott, 1999). It has also been stated that digital natives or the net generation are motivated by: a world of twitch-speed, multitasking, interactivity, random access, graphics-first, connected, fun, fantasy, and quick-pay-off (Prensky & Berry, 2001; Tapscott, 1999). This generation of students are deemed to have an expectation of instant gratification and open access to information readily available at their fingertips (Neumann, 2016). Furthermore, it is believed that most contemporary students have a natural and intuitive ability to navigate new technologies, which leaves
many teachers apprehensive about the use of 21st century ICT (Oblinger & Oblinger, 2005; Prensky, 2007; Tapscott, 1999). Worth noting is that there is a lively critique of the existence of digital natives.

**Digital natives critique.** A growing body of research (e.g., Bennett & Maton, 2010; Bennett, Maton, & Kervin, 2008; Jones, 2012; Helsper & Eynon, 2010; Thompson, 2013) is questioning the validity of the anecdotal evidence that digital natives are a generation of students with a natural intuitive ability to manipulate and be motivated by ICT (Oblinger & Oblinger, 2005; Prensky, 2001; Tapscott, 1999). Researchers have taken a critical stance questioning the body of knowledge that has dominated professionals’ understanding of students’ knowledge, skills, and preferences towards technology.

The debate begins with how the discussion is defined by age; a generational divide has been created between those who have been brought up in the digital era and those who are supposed to teach students in the digital era (Jones, 2012; Kennedy et al., 2010). It is suggested that individuals who have not grown up in the digital age are likely lacking in technological skills and need to appreciate the natural technological abilities of students today (Prensky, 2001). However, this assumption is too general (Helsper & Eynon, 2010) as it attempts to describe this generational divide as a binary distinction between those with technological capabilities and those who are technologically challenged. As a result of this generational divide, there is a presumed distinction or disconnect between students and their teachers (Jones, 2012). If a generational divide determines technological capabilities, then older generations will not be able to combat a solution to the digital disconnect between today’s students and their predecessors (Helsper & Eynon, 2010).

Instead of focusing on age as a distinction between those who are technologically
capable and those who are technologically challenged, research is pointing towards an emphasis on experience with technology instead of date of birth (Helsper & Eynon, 2010). Helsper and Eynon (2010) found that regardless of age, immersion and interaction in a digital environment tends to contribute to the qualities of being technologically savvy. It is worth noting that young people who come from media-rich homes tend to be more confident in their skills towards technology and engage with ICT more frequently (Helsper & Eynon, 2010). The key finding here is that the current generation of students do not necessarily have a more intuitive ability to use technology due to their date of birth; rather, their experiences using technology throughout their life may explain certain skills and comfort.

If research is directing the digital natives debate away from date of birth and relating it to experience, then where should educational research be focused with respect to learning with technology? Recent empirical research has found that although the current generation of students do regularly use ICT to communicate, very few actually create through text, audio, and video (Thompson, 2013). Thomson’s (2013) study found that contemporary students most often use rapid communication technology and Web resources such as social networking, instant messaging, or Web browsing. It may be less pervasive for students to manipulate information and be proficient in the use of all ICT (Thompson, 2013). This implies that educators need to focus their practices on providing more explicit instruction and scaffolding when teaching students through digital platforms (Bennett & Maton 2010; Kennedy et al., 2010; Thompson, 2013). Digital natives may be more familiar and used to technology around them, but this does not mean that they will not misuse or misunderstand technology (Neumann, 2016). Researchers also suggest that there is a disconnect between how students use technology and the use
of technology for academic tasks (Bennet et al., 2008). Technology provides access to a vast amount of information to support quick searches and answers (Thompson, 2013). It is therefore imperative that students’ familiarity with technology is not relied on exclusively to support deep learning and knowledge construction (Thompson, 2013).

For the current study, emphasis was therefore placed on what empirical research has found with regards to the current generation of students and their technological capabilities. The assumption that students have a natural and intuitive ability to manipulate and use technology was not ignored, but it was not the guiding premise of this study. Furthermore, this literature review has underscored the importance of not making broad assumptions about curriculum or instruction based on age alone (Kennedy et al., 2010). When integrating educational technology, educators therefore need to consider the intended learning outcomes for their students (Kennedy et al., 2010) with regards to how the use of technology will support students’ learning of skills and curriculum content.

21st Century Learning

Regardless of the curricular domain, the desired goal of contemporary education goes beyond knowing facts and memorizing lines as emphasis is placed on teaching new literacies and skills (Claxton, 2014; Drew, 2012; Leu, Kinzer, Coiro, Castek, & Henry, 2013; Lewis-Spector, 2016). With this in mind, Drake et al. (2013) emphasize the notion of blending the old story of education (traditional, cognitive, and constructivist approaches) with the contemporary story. The following sections will briefly outline 20th century education, 21st century education, 21st century literacies, and 21st century skills.

20th century education. The traditional approach to education was based on Frederick Taylor’s (1911) work on how to make factories more efficient. The efficient “factory model” of education included curriculum documents with standards, knowledge
neatly organized into disciplines and subjects, students who rotated from class to class based on time, standardized tests providing scores for ranking students, and a competitive nature among students, teachers, regions, provinces, and countries (Drake et al., 2013). The traditional or old story of education was further defined by the theories of Edward Thorndike (1911) and B. F. Skinner (1954, 1968) (Drake et al., 2013). Behavioural psychologist Skinner (1954, 1968) saw humans as tabula rasa where knowledge is transmitted to humans as though they are blank slates. In this traditional approach, teachers are seen as experts, students are seen as passive learners working individually, and learning was shaped by positive or negative reinforcement and punishment (Skinner, 1954, 1968).

Also emerging in the 20th century, theorists such as John Dewey (1938, 1966), Jean Piaget (1963), and Lev Vygotsky (1978) started to view education as a practice about knowledge construction and not about knowledge transmission. John Dewey’s theories were grounded in progressive education and valued democracy, problem solving, and student progress. As previously mentioned in the theoretical framework, Piaget’s work focused on students’ cognitive knowledge construction, whereas Vygotsky emphasized learner interactions to socially construct knowledge.

In the 20th century, there were clearly emerging, influential theories (i.e., constructivism and behaviourism) that contradicted one another. These contradicting theories in education have influenced espoused practices that are opposing, and this flipping back and forth has been like a pendulum (Drake et al., 2013). When considering Drake et al.’s (2013) new story of education, the theories of the old story of education need to be enhanced and understood through the lens of technological innovation and the influence technology is having to accelerate and promote student learning (Drake et al., 2013).
In the new story of education (Drake et al., 2013), education is seen as less confined to brick-and-mortar walls, less focused on the transmission of knowledge, and less fixated on standardized testing than the old story (Claxton, 2014; Sullivan & Downey, 2015). This is not to say that knowledge transmission of true and justified information is not meaningful as it is required during meaningful learning processes (Bereiter & Scardamalia, 2014). Even the traditional teaching and learning practices based on rote memorization are subject to the way students interpret, argue about, and evaluate information (Bereiter & Scardamalia, 2014). Therefore, the current research study places importance on students learning meaningful concepts while they also develop 21st century literacies and skills.

21st century literacies. Literacy in the previous century, when the world was dominated by static book technologies or print literacy, does not fully encompass the massive and multiple types of new literacies in the 21st century digital era (Leu et al., 2013). New literacies typically build upon foundational and traditional literacies rather than replace them completely (Leu et al., 2013). Twenty-first century literacies are the values, attitudes, or behaviours embedded within character strengths (Drake et al., 2013); these are often referred to as character education or key competencies (Claxton, 2014). In general, 21st century literacies are what teachers and school boards want their students to be (Drake et al., 2013) after completing an instructional unit, a course, or a degree.

Twenty-first century literacies build upon traditional teaching and knowledge and may include: digital literacy, global literacy, multicultural literacy, moral literacy, financial literacy, or environmental literacy (Drake et al., 2013; Efe, Ucel, Baran, & Sunkur, 2012; Gilster, 1997). Without abandoning traditional educational approaches and continuing to foster the current curriculum expectations, traditional literacy along with
21st century digital and environmental literacy were the foci for this research study. These three literacies provided the big ideas and values embedded with the research study, which are included in the interdisciplinary curriculum unit.

**Traditional literacy.** It is imperative that 20th century learning and the literacies embedded within this era are not abandoned as students need a foundation in traditional literacies (Morrell, 2012). Traditional literacies can be defined as the three Rs (reading, writing, and arithmetic), which were seen as fundamental to becoming a literate human (Larson & Miller, 2011). Furthermore, traditional literacy encompasses the social practices and elements of literacy that are needed for print-based text reading and writing (Leu et al., 2013). This includes word recognition, vocabulary, comprehension, inferential reasoning, the writing process, spelling, literature responses, and other literacy expectations associated with traditional books or printed materials (Leu et al., 2013).

**Digital literacy.** The term digital literacy was first defined within an educational context and stressed the fundamental skills (e.g., evaluation, searching) needed to navigate the uniqueness of the Internet (Gilster, 1997). A digitally literate student understands technology and possesses the skills to communicate and collaborate effectively through digital platforms (Argentin, Gui, Pagani, & Stanca, 2014). Furthermore, with the unlimited number of multimedia sources and collaborative online environments, it is suggested that students adopt a more critical use of the content available online (Argentin et al., 2014). Researchers agree that the skills students need to be digitally literate include the ability to access and navigate information on the Web, analyze and evaluate this information, compose and create new artifacts, engage in reflective thinking, and share knowledge or collaborate with others through the Web.
Environmental literacy. Environmental education is essential to educate citizens about environmental degradation (Stevenson, Peterson, Bondell, Mertig, & Moore, 2013). In the past, education has responded to the need for environmental education through nature study and outdoor education initiatives as early as the 19th century (Stevenson et al., 2013). The focus of environmental education shifted when the United Nations Education, Scientific, and Cultural Organization (UNESCO, 1976) defined the goal of environmental education as:

The goal of environmental education is to develop a world population that is aware of and concerned about the environment and its associated problems, and which has the knowledge, skills, attitudes, motivations, and commitment to work individually and collectively toward solutions of current problems and the prevention of new ones. (p. 1)

Environmental education is an important facet of environmental literacy, which has the potential to shape students to be environmentally literate citizens (Efe et al., 2012). Consistent with UNESCO’s goal for environmental education, environmentally literate citizens understand ecology, possess caring attitudes towards the environment, identify potential environmental risks, value prevention over remediation, and commit to a collective effort towards sustainability (McBride, Brewer, Berkowitz, & Borrie, 2013; Stevenson et al., 2013). Furthermore, environmental education supports students’ understanding of environmental challenges and activities to further their capacity to take appropriate, responsible action, and influence human behaviour (Efe et al., 2012).

In response to the realities of environmental issues, the Ontario Ministry of
Education (OME, 2009) developed a policy document—*Acting Today Shaping Tomorrow: A Policy Framework for Environmental Education in Ontario Schools*—to stress the importance of environmental education in 21st century schools. Other research has suggested the importance of incorporating published environmental literacy curricula such as Project WILD, Project WET, and Project Learning Tree, which were all effective in enhancing students’ cognitive skills (Stevenson et al., 2013).

Overall, the character education traits (e.g., co-operative, respectful, concern for major contemporary issues, or creative) associated with 21st century literacies provide a starting point for the big ideas overarching an interdisciplinary unit (Drake et al., 2013). Traditional, digital, and environmental literacy together emphasize a balance between the old and new story to education (Drake et al., 2013). Embedded within these literacies are the cognitive and social skills that students need to do (Drake et al., 2013) in order to be literate in the 21st century (Soulé & Warrick, 2015).

21st century skills. In the 20th century, there was a strong emphasis on traditional literacy skills including reading, writing, and arithmetic (Larson & Miller, 2011). However, there have been many fundamental shifts in the economy, industry, and business that require citizens to possess new skill sets (Geisinger, 2015; Hilton, 2015; Soulé & Warrick, 2015). Twenty-first century tasks and problems are not confined to isolated disciplines in which students can use specific subject skills in the subject-specific context. Thus, students need to be able to use certain skills within multiple disciplines in the contemporary world; these skills are the do within interdisciplinary curriculum units (Drake et al., 2013). Interdisciplinary skills are the essential skills students need to be productive and active citizens in the 21st century (Claxton, 2014). Within these new skill sets, cognitive, interpersonal, and intrapersonal skills are valued in the 21st century.
economy along with traditional measures of educational achievement, such as school credentials (Hilton, 2015; Soulé & Warrick, 2015). Furthermore, being literate in the 21st century means one has developed and has the self-determination to utilize 21st century learning skills (Gallagher & Rowsell, in press).

Twenty-first century skills are consistent with Piaget’s (1963) cognitive constructivism and Vygotsky’s (1962) social constructivism. Three of these 21st century skills are embedded within 21st century learning frameworks (Geisinger, 2015; Hilton, 2015): cognitive skills (e.g., reasoning), intrapersonal skills (e.g., self-regulation), and interpersonal skills (e.g., collaborating and communicating). C21 Canada (2012) developed a comprehensive 21st century learning framework that identifies seven specific learning skills or competencies that are embedded within 21st century literacies. These competencies are outlined in the Shifting Minds: A 21st Century Vision of Public Education for Canada document (C21 Canada, 2012) as: creativity, innovation, and entrepreneurship; critical thinking; collaboration; communication; character; culture and ethical citizenship; and computer and digital technologies (see Appendix A for a summary).

This study focused on the higher-order thinking skills embedded within the C21 Canada (2012) framework that are relevant for the knowledge construction process (see Figure 1). Furthermore, computer and digital technologies were examined in relation to knowledge construction, collaboration, and communication. For the purpose of this study, C21 Canada’s concept of computer and digital technologies were referred to as information and communication technologies (ICT) to ensure there was consistency with the Learning Activity Rubrics (Microsoft Corporation, 2015) used in this study.
Figure 1. Vision for 21st century learning in Canada. Source: Canadians for 21st Century Learning & Innovation (2012, p. 16). Copyright 2012 by Canadians for 21st Century Learning & Innovation. Written permission for inclusion of this figure was granted by copyright owner.
It is important to note that within this framework, the competencies are interrelated and have 21st century skills and literacies embedded within them. As illustrated in Figure 1, environmental literacy can be seen in the outer circle, and at the heart of the diagram, fundamental literacies or traditional literacies are identified as literacy, numeracy, and science.

The terms literacies, competencies, and skills can sometimes be misused or used interchangeably. As mentioned above, 21st century literacies are the values, attitudes, or behaviours embedded within character strengths or habits of mind (Claxton, 2014; Drake et al., 2013). The difference between competencies and skills is less clear. Twenty-first century competencies are composed of broader terms (Hilton, 2015) and aligned with competency-based education, which focuses on individualized learning and differentiating instruction based on the specific needs of students (Sullivan & Downey, 2015). In competency-based education, learning is student centred and focused on authentic learning experiences for students to demonstrate authentic application of knowledge and skills (Sullivan & Downey, 2015). For example, in science education, competencies include content knowledge and skills like problem solving and evaluating evidence-based arguments (Hilton, 2015). By contrast, 21st century skills are more focused on the skills students will need to be successful productive and active citizens in college and their future careers (Claxton, 2014; Sullivan & Downey, 2015).

Furthermore, although C21 Canada (2012) uses the term competencies in its framework, two of the principles creating this unifying framework support individualized learning (i.e., competencies) and prepare students for their futures (i.e., skills):

- Principle 1: All Canadians have a universal right to reach their full learning potential and to have a voice in their learning needs.
Principle 2: The primary focus of Canadian education is to position learners for fulfillment and success in the modern world. (p. 4)

These two principles are consistent with the foundation of the current study as it focuses on the skills students need to become productive and active citizens in their future.

Overall, the difference between 21st century competencies and skills can be distilled to what educators are focusing on as learning outcomes. For the purpose of this study, skills were analyzed separately from content knowledge to draw distinct conclusions about the use of tablets for fostering 21st century skills versus the use of tablets for building knowledge construction. This study used the term 21st century skills to describe what students do (Drake et al., 2013) within a 21st century learning framework instead of the broader term competencies. The C21 Canada (2012) framework provides a unified understanding of 21st century learning in Canada and where these skills lie in relation to competencies. The following sections will provide more details on the four 21st century skills under analysis in the present study, which include: (a) Use of Information and Communication Technologies; (b) Knowledge Construction; (c) Collaboration; and (d) Skilled Communication (Microsoft Corporation, 2015).

**Use of Information and Communication Technologies**

Educators are witnessing rapid technological advancements, open access to large amounts of information, and new platforms for the construction of knowledge (C21 Canada, 2012). C21 Canada (2012) articulates the 21st century skill of using ICT for learning as one’s “capacity to use computers and digital resources to access information and create knowledge, solutions, products and services” (p. 12). Furthermore, competent students have the “capacity to use social media for learning” (C21 Canada, 2012, p. 12). In the 21st century, ICT may have the potential to break down the dominant and
constraining path of traditional education and support divergent and multiple learning paths to foster students’ development of 21st century skills (Milman, Carlson-Bancroft, & Boogar, 2014; Walsh & Simpson, 2013). In order for students to be successful in the future, they need specific expertise in ICT as it becomes more prevalent in society (Larson & Miller, 2011). However, ICT should not be used in the classroom to solely gain mastery of the tool; rather, emphasis of ICT should be placed on how students use these tools (Rowsell & Walsh, 2011) to foster other 21st century skills. With the rapid pace of ICT development, many recently created innovative tools are already considered obsolete. Given the fact that less advanced ICT are still the platform for 21st century technology today, the following section provides a brief outline of how early traditional technologies and 21st century ICT were/are used.

Traditional technology. During the 20th century, educational technologies were developed such as overhead and slide projectors, radio broadcasts, and educational videos (Groff & Mouza, 2008; Reiser, 2001). In the 21st century, technology has proceeded to a digital level where technologically advanced devices such as laptop computers and sophisticated computerized communication systems have been integrated into schools (Dyal, Carpenter, & Wright, 2009; Maor, Currie, & Drewry, 2009). Older mainstream technology is still common, such as desktop computers used to enhance students’ learning with their individual work (i.e., presentations or book reports) through programs like PowerPoint (Stanford, Crow, & Flice, 2010). As the digital era has advanced and social networking has exploded, teachers are engaging students in the Web 2.0 interactive instructional atmosphere (Stanford et al., 2010). Overall, traditional technologies are still widely used today, but new innovative devices are changing the way teachers facilitate, mobilize, differentiate, and assess student learning.
Tablets. Education is heralding mobile ICT such as tablets as educational “game changers” and interest in these devices continues to grow in K-16 education (Falloon, 2014; Milman et al., 2014). Tablets, specifically Apple iPads, are mobile computer operating systems that are smaller than laptops but larger than smart phones and look slightly like notebooks with a touch-screen interface (Milman et al., 2014). Apple iPads are unique in their lightweight portability, wide array of apps, unique touch-screen interface, simplicity, intuitive design, speed, and affordability compared to other brands of tablets (Domingo & Garganté, 2015; Falloon, 2014; Hutchison et al., 2012). Tablets are known for their wide variety of apps, which are applications designed for tablets or smart phones to support a single or multiple functions (Hutchison et al., 2012). Different types of apps support different skill development among students. Apps can be separated into learning skill apps, informational management apps, and content learning apps (Domingo & Garganté, 2015). Domingo and Garganté (2015) provide a definition of each app:

Learning Skills Apps: Enable students to create their own knowledge by providing them with the precise atmosphere to build their learning, whereas Informational Management Apps have the ability to work within the specific context and environment of the learning and have the ability to increase the ease of informal learning. Finally, Content Learning Apps are considered to proportionate students’ different activities that allow them to rehearse, reinforce, practice and assess curricular content. (p. 23)

Overall, C21 Canada (2012) indicates that the skill of using ICT should be embedded in all competencies in the framework. Appendix A provides an outline of all the other competencies outlined in the C21 Canada (2012) framework. It is apparent how the use of ICT for learning is embedded within other competencies. For this reason, the
use of ICT for learning was mainly discussed and researched with regard to its relationship to other 21st century skills, including knowledge construction, collaboration, and skilled communication.

**Knowledge Construction**

In the C21 Canada (2012) framework, knowledge construction is embedded within many of the competencies. As mentioned, competencies are a broader term used to stress the importance of content knowledge and skills. Since many higher-order thinking skills are presented within the C21 Canada framework (i.e., analyzing, interpreting, evaluating, and synthesizing), the term knowledge construction will be used to guide the present study.

In the 20th century, most educational institutions were in transition from a didactic educational approach, focused on the transmission of knowledge, towards an active learning approach centred on students’ interests and generative of knowledge and competencies (Scardamalia & Bereiter, 2006). Stone (1996) described this shift from instructivism to developmentalism where students began to be thought of as individuals capable of their own knowledge agency and ability to know what is best for them. The notion of knowledge construction is grounded in cognitive and social constructivist theories. Recently, theories of knowledge construction have been expanded on by Scardamalia and Bereiter (1991, 2006; see also Bereiter & Scardamalia, 2014) who argue that common terms like constructivist learning and inquiry-based learning have made it difficult for educators to see the important knowledge-building processes embedded within and connected to each other. Scardamalia and Bereiter (2006) labelled the knowledge process as knowledge building rather than the more common term knowledge construction. Taking on a strong constructivist view, the current study will not abandon
the term knowledge construction; rather, the notion of knowledge building described by Scardamalia and Bereiter (2006) will be blended with the classic understandings of knowledge construction.

Consistent with active learning, knowledge construction often begins with teachers relinquishing control and allowing students to initiate the direction of their learning based on what they deem relevant and important (Wells, 2007). First, it is imperative that students acquire knowledge not for the purpose of conformity or test performance, but instead, to acquire knowledge as a foundation to enable further conceptual growth (Scardamalia & Bereiter, 2006). They believe that students need to be more knowledgeable about facts and procedures while also developing conceptual tools to expand and construct deeper knowledge of these facts and procedures. Deep learning may then lead to the knowledge creation of new ideas as a result of students’ knowledge acquisition.

**Knowledge acquisition.** Different knowledge structures have implications for students’ learning and their learning processes (Paavola et al., 2004). Students’ knowledge construction processes consist of objects or conceptual artifacts that can be produced, developed, or applied in different contexts (Paavola et al., 2004). According to the revised *structure of knowledge dimension* by Anderson et al. (2001), individuals acquire four types of knowledge: *factual knowledge, conceptual knowledge, procedural knowledge,* and *metacognitive knowledge.* These knowledge dimensions (Anderson et al., 2001) are embedded within the knowledge acquisition and knowledge creation processes proposed by Scardamalia and Bereiter (1991) and the C21 Canada (2012) competencies framework. The following provides an overview of the different types of knowledge construction and cognitive processes associated with them.
Knowledge about. The most basic form of knowledge is explicit knowledge, which is easy to articulate, recognize, and recall formally (Anderson et al., 2001; Nonaka & Takeuchi, 1995). Scardamalia and Bereiter (2006) describe explicit knowledge as knowledge about something as it can be explicitly stated or demonstrated, which currently dominates traditional education. Explicit knowledge is the authoritative knowledge in schools which is to be learned, and it is governed by learning curriculum expectations, textbooks, or subject-specific tests (Scardamalia & Bereiter, 2006). Knowledge about something has a limited usefulness in the sense that unless a particular situation calls for specific knowledge about something (i.e., test taking or trivia games), there is little value to this type of knowledge (Scardamalia & Bereiter, 2006).

Anderson et al.’s (2001) knowledge dimensions have two types of knowledge about something. First, factual knowledge includes basic facts or elements within a particular topic, subject, or discipline and can be used to solve problems. Second, procedural knowledge is described as the methods, rules, criteria, algorithms, and techniques for how to do something (Anderson et al., 2001). Both of these types of knowledge are governed by the cognitive processes of recognizing and recalling (Anderson et al., 2001).

Knowledge about something is useful knowledge when it is organized and conceptualized around problems rather than specific topics (Bereiter, 1992). Drake et al. (2013) emphasize that students need to have general knowledge about something to be able to move on to deeper learning tasks. However, less emphasis should be placed on top-down instructional approaches of knowledge transmission, and instead factual or explicit knowledge should be learned while engaging in higher-order thinking skills like synthesizing, interpreting, analyzing, evaluating, or creating (Anderson et al., 2001;
Larson & Miller, 2011). It is not sufficient to educate students with explicit knowledge (i.e., scientific laws, causal mechanisms) through knowledge transmission methods since it leaves a gap for the deep knowledge needed to apply knowledge as knowledge about something (Scardamalia & Bereiter, 2006). In general, students need to be able to use acquired knowledge to synthesize, interpret, evaluate, and eventually apply in other contexts.

**Knowledge of.** Knowledge of something goes beyond recall and recognition of factual and procedural knowledge; rather, it is focused on how students use factual and procedural knowledge through the application of this knowledge in other contexts (Scardamalia & Bereiter, 2006). Anderson et al. (2001) describes this type of knowledge as conceptual knowledge where individuals can find relationships among basic facts or elements within broader terms and synthesize and apply this knowledge in a variety of contexts (Anderson et al., 2001). Drake et al. (2013) describe conceptual knowledge as enduring understandings whereby students connect big ideas and show relationships, which are remembered long after the memorization of facts and formal lessons. Other theorists like Nonaka and Takeuchi (1995) see knowledge of something as tacit knowledge. Tacit knowledge is recognized as important for knowledge construction and knowledge creation since it is embedded into individuals’ experiences (Nonaka & Takeuchi, 1995). Overall, knowledge of something goes beyond regurgitation of facts and is the ability to apply and connect knowledge in different situations, fields, or disciplines. While using higher-order thinking skills like synthesizing, interpreting, analyzing, and evaluating to demonstrate knowledge, knowledge of something requires knowledge to be centred on problems so that deeper understandings are formed and students’ cognitive
processes are pushed towards seeking more explanation and eventually innovative knowledge creation (Bereiter & Scardamalia, 2014).

**Knowledge creation.** Consistent with constructivism, *knowledge creation* entails the creation of something new as a function of the learning process (Paavola et al., 2004). Before knowledge creation can take place, students must possess ideas and the skills to transform these ideas into new knowledge (Scardamalia & Bereiter, 2006) and make connections between other ideas (Drake et al., 2013). For students to use higher-order thinking skills and create new knowledge, authentic problems need to be provided (Strimel, 2014). To spark the generation of ideas, lessons should authentically relate to real-life problems, offer hands-on experiences, and incorporate students’ cultural and natural environments so that learning becomes relevant and meaningful to students (Strimel, 2014). In this way, creative knowledge can be seen as a form of knowledge that will advance the knowledge within a community (Scardamalia & Bereiter, 2006).

**Knowledge construction and technology.** Consistent with the theory of connectivism, knowledge construction in the 21st century is happening in digital environments that require learners to have the ability to draw distinctions between nonlinear texts and decide what is and is not important (Siemens, 2005). Scardamalia and Bereiter (2006) stress the importance of integrating technology that fosters deep inquiry and asks questions such as *how* and *why* instead of *what* and *when*.

Some researchers regard technology as an intellectual partner or mind tool to support students through cognitive processes and knowledge construction (Peng, Su, Chou, & Tsai, 2009; Wu, Chen, & Hou, 2016). Through different mobile ICT, students can work within infrastructures designed to support knowledge acquisition, knowledge construction, and knowledge creation (Peng et al., 2009). Rather than focusing solely on
students learning *how* to use ICT, educators should foster the *use* of innovative ICT (Scardamalia & Bereiter, 2006). When utilizing these digital tools, it is also important that teachers realize the balance between offline and online tasks. Online is where the main work takes place, but various offline activities contribute to the overall learning artifacts (Scardamalia & Bereiter, 2006). As students continue to engage in knowledge construction through ICT and create multimedia presentations or visual displays, students are practicing the construction of new knowledge in a way that will foster active citizenship and potentially prepare students for their future careers (Peng et al., 2009).

**Knowledge construction in language arts.** This study adopted the orientation that knowledge construction in language learning resides in Lev Vygotsky’s (1962) theory of social constructivism that emphasizes language development in social environments as a precursor to deep thinking and knowledge construction. Furthermore, within this social process of learning, Vygotsky coined the term *zone of proximal development* (ZPD) to describe how individual students have their own learning needs that can be supported or scaffolded to further construct knowledge and foster higher-order thinking skills (Smagorinsky, Hansen, & Fink, 2013). The current study focused on how the development of reading comprehension and vocabulary outlined in the OME’s (2006) *The Ontario Curriculum Grades 1-8: Language* may be supported within a constructivist learning environment.

Reading literacy is not simply an individual’s ability to read. An individual is considered literate when reading, writing, speaking, and listening are embedded with higher-ordering thinking skills that foster deep knowledge construction (Forster, 2004). In the 21st century, students might be called *readers as designers* as they interpret, analyze, synthesize, and evaluate while navigating multimodal texts (Serafini, 2012; Walsh &
Simpson, 2013). For instance, students could manipulate ICT to construct knowledge through blogging, digital storytelling, video production, screen-casting, or mind-mapping apps (Hutchison et al., 2012). Through the use of ICT, researchers have started to point to the unique affordances apps have to support students’ navigation and knowledge construction through multimodal texts (Hutchison et al., 2012; Walsh & Simpson, 2013).

Overall, whether supported by ICT or not, to be literate in the 21st century goes beyond the most basic reading skills (Forster, 2004). Reading literacy requires students to retrieve information proficiently, understand multimodal texts, and use higher-order thinking skills to conceptualize information (Forster, 2004). Through a relatively unexplored area (Hutchison et al., 2012), research is beginning to demonstrate the potential ICT has to support knowledge construction and foster 21st century reading literacy in language arts.

**Knowledge construction in science.** Scientific literacy is associated with an individual’s ability to make informed decisions about personal and societal scientifically based problems (Lederman, Antink, & Bartos, 2014). Scientific concepts and processes are dimensions of scientific literacy. Scientific concepts often consist of factual knowledge such as scientific terminology or conceptual knowledge of theories, models, and structures (Anderson et al., 2001). When considering knowledge of something (Scardamalia & Bereiter, 2006), these concepts are needed to make sense of the natural world and the changes caused by human impact (Forster, 2004). One of the foci in science instruction is to synthesize, analyze, and evaluate scientific concepts and explanations (Campell, Longhurst, Wang, Hsu, & Coster, 2015; Lederman et al., 2014). Scientific processes consist of finding, interpreting, and acting on evidence (Forster, 2004). This dimension may connect to the dimensions of procedural knowledge and conceptual
knowledge where students use the scientific method to interpret new information (Anderson et al., 2001) and potentially generate ideas (Lederman et al., 2014) or create new knowledge (Scardamalia & Bereiter, 2006).

Research has also demonstrated the potential that ICT have to foster deep understanding of scientific concepts and further enhance authentic learning experiences (Hilton & Hilton, 2013). In Hilton and Hilton’s (2013) study, students interacted within digital simulations, which seemed to help students visualize the type of scientific knowledge and processes being conveyed in class. Hilton and Hilton found that ICT enhanced students’ conceptual understanding and their ability to demonstrate knowledge construction through representational competence and communicate their understanding and explanations. Other researchers have also found that students’ scientific understanding was enhanced when virtual environments were used to teach curriculum (Ketelhut, Nelson, Clarke, & Dede, 2012; Kivinen, Piironinen, & Saikkonen, 2016). Overall, certain ICT may contribute to students’ knowledge construction through a deeper understanding of more abstract and complex concepts (Hilton & Hilton, 2013).

For the present study, within the context of an interdisciplinary unit in language arts and science, the science component will be based on environmental education expectations within the OME’s (2007) *The Ontario Curriculum Grades 1-8: Science and Technology*.

**Interdisciplinary learning.** Interdisciplinary units have the potential to foster knowledge construction through multiple lenses addressing relevant and meaningful concerns or competencies (Drake et al., 2013). As mentioned throughout this literature review, embedded within interdisciplinary units, students need to know (e.g., foundational content/curriculum), do (e.g., 21st century skills), and be (e.g., 21st century literacies).
With regards to this study, environmental, digital, and traditional literacies have been identified as the values and behaviours embedded within the interdisciplinary science and language arts unit.

Overall, interdisciplinary units require teachers to cluster curriculum expectations across the disciplines around a big idea, skills, values, attitudes, or behaviours (Drake & Burns, 2004; Drake et al., 2013). The lines between disciplines are blurred and less defined (Drake & Burns, 2004). For instance, a teacher could choose character literacy as the big idea and have students research bullying to write a report from the perspective of a bully (language arts) and then demonstrate the feelings of being a bully through music, drama, or dance (the arts).

Content areas such as science are foundational for students when reading to learn (Cervetti, Barber, Dorph, Pearson, & Goldschmidt, 2012; Cervetti & Pearson, 2012; Romance & Vitale, 2001). It is assumed that reading, writing, and speaking are core practices embedded within the development of scientific knowledge (Cervetti et al., 2012). Research is pointing towards the affordances of the use of ICT for learning to enhance students’ knowledge construction within science activities (Cervetti et al., 2012). Romance and Vitale (2001) anticipate that through the integration of science and literacy instruction, learners can be conceptualized as active constructors of knowledge and can be a guiding force for integrated instruction. Furthermore, Romance and Vitale stress the importance of knowledge acquisition for conceptual understanding in science that recognizes the different environments students will need to apply knowledge formally inside and informally outside school.

Overall, knowledge construction is a complex process between knowledge about, knowledge of something, and knowledge creation. For the purpose of this study, the use
of ICT for learning was examined in relation to the skills embedded in knowledge construction (i.e., analyzing, interpreting, synthesizing, and evaluating) as a 21st century skill, which includes interdisciplinary learning at the highest level (Microsoft Corporation, 2015). This study examined knowledge construction in relation to science and language arts content knowledge.

**Collaboration**

Grounded in social constructivism, Vygotsky (1962) believed collaboration and social interaction were integral components to learning. Contemporary researchers further recognize social practices as central to developing 21st century literacies and skills (Jones, 2015; Leu et al., 2013; Strimel, 2014). With the development of more innovative technologies, collaboration can take place in both online and offline environments (Larson & Miller, 2011). For collaboration to be meaningful, greater emphasis needs to be placed on authentic learning experiences (Strimel, 2014) and collaboration rather than individual inquiry (Scardamalia & Bereiter, 2006).

The C21 Canada (2012) framework identifies collaboration as a main competency (see Appendix A). Collaboration is described as the process of interacting to create new ideas, develop artifacts together, resolve and manage conflicts, and “collaborate across digital networks using various information and communication technologies” (C21 Canada, 2012, p. 10). Researchers agree that the ability to collaborate is a 21st century skill that students will need to be successful in their future (Claxton, 2014; Greenlaw, 2015; Istance & Kools, 2013; Soulé & Warrick, 2015).

Learning is strongly rooted in a shared responsibility to collaboratively construct shared objects (Bereiter & Scardamalia, 2014; Paavola et al., 2004). For example, within Engeström’s (1999) expansive learning model, students first reconceptualize their own
knowledge through questioning and critique, then collectively reconceptualize shared knowledge concepts or objects. As students are collaborating with shared responsibility over their work, interdependence between students is necessary (Lewis-Spector, 2016). Classroom activities should centre on originating new thoughts and the advancement of communal knowledge (Scardamalia & Bereiter, 2006). Interdependence has a balance between individual knowledge and activity and a stream of social activities (Paavola et al., 2004). In other words, individual and group accountability are necessary. In turn, this balance draws upon the strengths and individual experiences that each student brings to the table during a collaborative activity (Lewis-Spector, 2016).

**Inquiry-based learning.** Collaboration may be enhanced through an inquiry-based learning model. Inquiry-based learning fosters creative problem solving through formulating questions, gathering evidence, and proposing solutions to authentic real-world problems (Drake et al., 2013). Inquiry-based learning further requires students to find connections and build off one another’s ideas through critiquing, hypothesis generation, researching, innovating, and formulating constructive arguments (Drake et al., 2013; Istance & Kools, 2013). As substantive decisions are made through the inquiry process, students support each other to understand and find solutions to problems (Maxwell, Lambeth, & Cox, 2015). While discussing scientific problems or questions, students might support one another to understand a variety of texts, clarify understandings about concepts, share reading strategies such as searching for information and summarizing, and further collaborate to construct a written report about the scientific concept under question (Guthrie, 2004).

**Collaboration and technology.** Students should be able to collaborate in both online and offline environments so that higher-order thinking skills can be enhanced
collaboratively and through technology (Larson & Miller, 2011). In the digital era, students are now networked locally and globally through mobile phones, tablets, social media Web pages, and apps (Jones, 2015; Peng et al., 2009; Rowsell & Walsh, 2011). A study of social networking in the classroom found that problem-solving, negotiation, and knowledge construction happen among students through Web 2.0 technologies (Rowsell & Walsh, 2011). Collaboration through Web 2.0 social networking sites includes: Facebook, Twitter, blogs, wikis, YouTube, Edmodo, Skype, and iMessage (Falloon, 2015; Rowsell & Walsh, 2011; Serafini, 2012). Along with social media, certain Web-based processing apps like Google Docs, allow for students to collaborate simultaneously on the same written project (Falloon, 2015). Collaborative programs like Google Docs and even Skype are considered to be synchronous systems through which users can work simultaneously, share screens, manipulate drawings, and edit written text to create a single product that all group members are mutually responsible for (Falloon, 2015; Hutchison et al., 2012).

Overall, collaboration requires students to work together, share responsibility, make substantive decisions together, and demonstrate a level of interdependence (Microsoft Corporation, 2015). Use of ICT for learning may contribute to students’ development of collaboration skills. This study further examines the relationship between use of ICT for learning and collaboration.

**Skilled Communication**

According to the C21 Canada (2012) framework, skilled communication entails high levels of literacy skills, the use of technology to enhance other competencies in core subjects, the ability to communicate with multimodal technology; access, analyze, and integrate large volumes of information, and use social media to communicate and resolve
challenges. Skilled communication requires complex forms of meaning making (C21 Canada, 2012) that go beyond just a single thought (Microsoft Corporation, 2015). Students need to become well versed in the use of extended communication, which requires students to produce a set of connected ideas (Microsoft Corporation, 2015). In this sense, students are able to communicate their knowledge construction. Students should have the ability to communicate their work through the application of knowledge about something within the conceptual connections made to demonstrate knowledge of something (Scardamalia & Bereiter, 2006). Students also need to manage the validity (Garcia, Elbeltagi, Brown, & Dungay, 2015) and diversity (Lewis-Spector, 2016) of information before publishing skilled communication. Furthermore, students should consider and produce a range of connected ideas and consider multiple perspectives in order to be skilled communicators in the 21st century (Lewis-Spector, 2016).

With this in mind, communication skills have evolved with the advancement of cellular technology and the Internet (Geisinger, 2016). For the purpose of this study, skilled communication was analyzed with respect to students’ ability to use multimodal communication, demonstrate high levels of literacy skills (i.e., connecting more than one idea to communicate), integrate information using evidence, and communicate through social media (i.e., blogging) for a particular audience (Microsoft Corporation, 2015).

Little empirical research has been conducted solely on how students build the 21st century skill of communication. For this reason, a context for skilled communication and the use of ICT for learning will be presented.

**Skilled communication and technology.** The use of ICT for learning has supported changes in the way students communicate in the 21st century. Changes can be seen in the organizational structure and practices of methods for communicating and
information sharing (Chelliah & Clarke, 2011). In the 21\textsuperscript{st} century, students have access to multiple modes. \textit{Multimodality} is a term used to describe the various modes embedded within ICT (Rowsell & Walsh, 2011; Serafini, 2012). Modes can consist of images, sound effects, music, gestures, movements, texts, animations, spatial dimensions, or hyperlinks (Rowsell & Walsh, 2011; Serafini, 2012). Multimodal technologies support the processing of modes in nonlinear ways as compared to a traditionally, linear fashion where text is read from left to right (Rowsell & Walsh, 2011; Serafini, 2012). In the 21\textsuperscript{st} century, \textit{new} or \textit{multi} literacies call for different forms of meaning making and communicating that stem from the multiple devices and media texts students interact with and learn from (Rowsell & Walsh, 2011). Through digital platforms like computer screens, touch pads, game consoles, or other mobile devices, students need to navigate learning paths and communicate information that do not follow the traditional left to right reading practices (Rowsell & Walsh, 2011; Serafini, 2012). Overall, multimodality between different apps and within apps provides students with a nonlinear learning experience and moves away from linear print-based learning (Milman et al., 2014; Walsh & Simpson, 2013).

Through the use of these multiple modes, students should be designing their learning for a particular audience (Microsoft, 2015). Different audiences are determined based on the social media outlet students use. As mentioned above, these may include Web 2.0 social networking sites such as Facebook, Twitter, blogs, wikis, YouTube, Edmodo, Skype, and iMessage (Falloon, 2015; Rowsell & Walsh, 2011; Serafini, 2012).

Overall, skilled communication requires students to produce extended and multimodal communication, evidence to support ideas, and a product designed for a particular audience (Microsoft Corporation, 2015). Use of ICT for learning may
contribute to students’ development of skilled communication. This study therefore examined the relationship between the use of ICT for learning and skilled communication.

**Chapter Summary**

Through the theoretical lens of cognitive constructivism, social constructivism, and connectivism, the current chapter has provided an in-depth literature review of 21st century conceptual learning frameworks. According to the C21 Canada (2012) framework, “in today’s world, youth must be positioned for success with advanced competencies and skills to be able to adapt to an ever changing world and social environment” (p. 3). Students must further build these competencies and skills to be considered literate in the 21st century (Gallagher & Rowsell, in press). It is necessary to determine digital multimodal technologies’ impact on students’ 21st century learning within the traditional curriculum. The literature presented above provides educators with an in-depth review of research-based evidence for 21st century literacies, 21st century skills, technology, knowledge construction, collaboration, and skilled communication. While calling on traditional learning theories and also meeting the demands of 21st century learning, the current mixed-methods study was aimed at furthering an understanding of how the use of tablets for learning supports 21st century skills, including knowledge construction, collaboration, and skilled communication as well as students’ development of scientific concepts, reading comprehension, and vocabulary.
CHAPTER THREE: METHODOLOGY AND PROCEDURES

This chapter outlines the research design and methodological considerations of the present study. The procedures discussed in this chapter were used to address the following research questions: (a) How can the use of tablets for learning foster Grade 5 students’ 21st century skills, including: knowledge construction, collaboration, and skilled communication? (b) How can the use of tablets for learning build students’ knowledge construction in science concepts, reading comprehension, and vocabulary development? The participant and site selection, data collection and analysis, methodological assumptions, and ethical considerations are further included in this chapter. The chapter also presents the steps that were taken to establish credibility and improve the integrity of data collected.

Research Design

The current study took on a mixed-methods approach (Creswell, 2014) to research how the use of tablets for learning may foster Grade 5 students’ 21st century skills, including: knowledge construction, collaboration, and skilled communication. This study further examined how the use of tablets may support students’ content knowledge and knowledge construction in science and language arts. Creswell (2015) emphasizes that the combination of both quantitative and qualitative data provides a better understanding of a research problem than focusing on one method alone. Creswell (2014) defines mixed methods design as “combining or integration of qualitative and quantitative research and data in the research study” (p. 14). Herein, Creswell’s (2014) embedded mixed-methods approach was taken where qualitative data were collected during the intervention (convergent) and after the intervention (sequentially). Qualitative data were collected concurrently during the study by recording students’ conversations, capturing students’
screen interactions, and taking written observational notes. These data were intended to provide insight regarding specific features students were using within tablets to construct knowledge, collaborate, and communicate. Narrative data were also collected at the end of the study to capture participants’ thoughts, behaviours, and knowledge while using tablets throughout the unit. A mixed-methods design has the potential to provide an in-depth understanding of the problem or question without focusing on one method over the other (Creswell, 2014).

With regards to the quantitative data, the current study took on a One-Group Pre-Test–Post-Test Design. This design includes a pre-test followed by a treatment and a post-test for a single group. In order to determine if there were any significant differences between students’ pre- and post-intervention, quantitative data (i.e., pre- and post-tests for reading comprehension, vocabulary, and science) were also collected. The current study triangulated data within the mixed-methods design to seek convergence across the quantitative and qualitative methods (Creswell, 2014). Through the triangulation of data, results are shown as either convergent, inconsistent, or complementary (Creswell, 2012). The quantitative and qualitative datasets carried equal weight, priority, and consideration to answer the research questions (Creswell, 2014). The pre- and post-intervention quantitative data are embedded and presented with the qualitative data (i.e., video screen interaction recordings, audio conversation recordings, and exit interview recordings) in Chapter 4 of this study. Findings from this study might be generalized to a larger population and might be transferred within other school contexts.

**Pilot Test**

A pilot test of the current study was conducted in March 2015 to test the methodological approach with a sample of four Grade 5 students. Ethics clearance was
received from a public school board and Brock University. The intention of this pilot test was to determine if the methodological approach would be appropriate in a larger-scale mixed-methods quantitative and qualitative study.

**Intervention Design**

The context for learning was within a series of interdisciplinary science and language arts lessons. The science instructional focus for this pilot test was from the OME’s (2007) *The Ontario Curriculum Grades 1-8: Science and Technology*’s Grade 5 “Conservation of Energy and Resources” expectations, and was supported by the OME’s (2006) *The Ontario Curriculum Grades 1-8: Language*. Within the latter’s Grade 5 “Language Arts: Reading Strand” (OME, 2006), reading comprehension and vocabulary expectations were embedded within the interdisciplinary unit.

Four students were taken out of their regular class time over a 3-week period to participate in the pilot study. The quantitative pre- and post-tests conducted took two periods (i.e., 100 minutes) at the beginning of the study and one and a half periods at the end of the study for students to complete. Between the tests, the four participants worked in a quiet workspace in pairs on tablets (i.e., Apple iPads). There were six 50-minute sessions for students to work on the tablets and learn through the interdisciplinary science and language arts lessons. This was not a full interdisciplinary science and language arts unit but rather a series of lessons. Lessons were created by the researcher and consisted of language arts activities designed to extend students’ understanding of science concepts within the apps. The pilot research study was designed to test the methodological aspects of data collection and not the effectiveness of the lesson delivery.

App selection and usability was a consideration in the pilot study. Based on Falloon’s (2014) recommendations, the chosen apps had accessible instructions, a clear
learning purpose, multiple options or modes, built-in scaffolds, and formative feedback systems. Not every app in the study met all of these requirements, but these apps had three or more features within them. In the end, six apps were selected by the researcher to enhance science and language arts learning (Energy by Kids Discover, Energy Forms by ScienceWerkz, BrainPOP, News-O-Matic, Energy HD, and Siemens Energy Island), and five apps were selected to support students’ knowledge creation (Popplet, Corkulous, iBrainstorm, iMovie, Educreations, and Penzu). All of the apps in the pilot study were further validated to ensure that they aligned with the OME (2006) curriculum for Grade 5 reading and vocabulary, as well as “The Conservation of Energy and Resources” expectations within the OME’s (2007) *Science and Technology* curriculum.

While working on the tablets, students spent about 30 minutes interacting and manipulating apps to acquire knowledge of scientific concepts through shared reading. The last 20 minutes of the session was spent completing a collaborative literacy-based extension activity using knowledge of and extending conceptual understandings through apps. Each student was given a set of headphones, and the pairs of headphones were connected to the tablets through headphone splitters. These splitters allow two headphones to be hooked up to the headphone outlet on one tablet.

The researcher’s role during this study was to collect data while the students interacted and learned through tablets. The researcher gave no direct teaching of the science or language arts concepts unless it was related to task instruction, technical set-up, or any technical difficulties.

The pilot test provided the opportunity to work out any technical or procedural problems that may have arose during the larger-scale study. As a result of conducting the pilot test, the following sections will outline what the researcher learned with regards to
methodological data connection and app selection.

**Qualitative Data Collection**

The following sections outline the different types of qualitative data collection methods used during the pilot test. These methods include: screen recordings, audio conversation recordings, and exit interviews.

**Screen interaction recordings.** The purpose of trying to capture screen recordings is to avoid intrusive, traditional methods of video capture. Falloon (2014) believes that researchers videotaping students “over the shoulder” to capture screen interactions creates an *observer effect*. Students may feel conscious of a researcher recording them, which may make students act differently while learning than they would if they were not being observed (Falloon, 2014).

To avoid the observer effect, this study modeled Falloon’s (2014) research design where students’ tablet screen interactions were recorded using Air Server. The pilot study used a program called Reflector, which is an advanced wireless airplay receiver, to wirelessly transfer iPad images onto MacBook Pro screens. Two MacBook Pros were used to separately record the tablets. Reflector does not allow two device screens to be recorded at the same time on one MacBook Pro, therefore each MacBook Pro separately recorded the tablet it was wirelessly connected to. Initial trials of this data collection proved to be consistent with Falloon’s (2014) study where trials were met with limited success. Fluctuating Wi-Fi speed, screen lagging, and the inability to record more than one screen at the same time were all problems that occurred. It was quickly apparent that the type of air server did not make a difference.

Alternately, as students worked in pairs, this study utilized video monitoring tools called Dropcams by strategically placing them in front of students to face the tablet
screen. This allowed students’ screen interactions to be captured. The Dropcams were small enough that students could easily maneuver touch interaction with the tablet while the Dropcam sat in front of them. The Dropcams did have limitations because they required an Internet connection and also needed to be plugged in. Dropcam recordings could wirelessly be streamed to the researcher’s secure Dropcam account and then immediately downloaded to the researcher’s password protected folder. Overall, the Dropcam was successful in producing video recordings of screen interactions.

**Audio conversation recordings.** Due to the initial uncertainty of the data collection, every pilot test session was audio-recorded using traditional external audio recorders to capture students’ conversations while working on tablets in pairs. These recorders ensured that even if video data were not captured, some qualitative audio data would be. The audio recorders were secured to the tables with Velcro in front of students. They proved to be reliable and did not interfere with students’ tablet interactions. Furthermore, they produced a much clearer audio recording than the Dropcams.

**Exit interviews.** During exit interviews, students were asked questions about their thoughts, behaviours, and knowledge while using tablets (see Appendix F). These interviews were conducted at the end of the study and in a separate room adjacent to the study’s classroom so that students could answer the questions without other students present. The audio recording app was effective in capturing students’ narrative responses. Furthermore, the questions were comprehensible for the student participants, and they were able to give at least a couple of sentences to answer each question.

Overall, this pilot test confirmed the reliability and effectiveness of Dropcams to produce qualitative video data of students’ complex screen interactions. Furthermore, the use of audio recorders seemed to be an additional, reliable qualitative audio data
collection method. For the purpose of the present study, video recordings were collected through external video monitoring tools such as the Dropcam as well as audio recordings. Additionally, participants’ conversations and exit interview narratives were captured through external audio recorders. This pilot test demonstrated that external video and audio recorders are effective and reliable sources of data collection.

**Quantitative Data Collection**

Students in the pilot test were given pre- and post-intervention tests. The tests were reviewed to ensure alignment to The Ontario Curriculum 1-8: Language (OME, 2006) and The Ontario Curriculum 1-8: Science and Technology (OME, 2007). The Canadian Achievement Tests (CAT-4, Level 15; Canadian Test Centre, 2008) was used to measure reading comprehension (see Appendix G) and vocabulary (see Appendix H). This test comprises two sub-tests for each of reading comprehension and vocabulary.

The Grade 5 eTestSmart Science: Conservation of Energy (Popular Book Company, 2012a) and Grade 5 eTestSmart Science: Forms of Energy (Popular Book Company, 2012b) science tests were administered to measure content knowledge for Grade 5 Ontario science curriculum concepts (see Appendix I). The pilot test was able to provide a time estimate for test administration. As well, the tests seemed appropriately challenging for the four student participants and did not seem to cause any test anxiety or stress. The present study therefore adopted these pre- and post-test instruments.

**Present Study**

The present study received external graduate student scholarship funding through the Social Sciences and Humanities Research Council (SSHRC), which provided significant support for the purchase of the digital data collection tools. The following
sections provide information regarding the context of the present study, intervention design, qualitative and quantitative data collection, and methods of analyses.

**Selection of Site and Description of Participants**

Upon receiving research ethics clearance from the Brock University Research Ethics Board and the Educational Research Committee of the participating school board, the researcher confirmed participation with the principal and teacher of the targeted school. Names of all participants and the participating school name are replaced with pseudonyms. This study was conducted in a public elementary school in middle-to-high socio-economic demography situated in a suburban town in Southern Ontario. There were two Grade 5 classes that the sample could be drawn from. The Grade 5 science teacher (Jarrod) at the participating school was a rotary science teacher and taught both Grade 5 classes. Jarrod arbitrarily selected one of the classes to participate in the proposed study. The sample consisted of 21 student participants (14 females and 7 males aged 10-11). All student participants received and returned parental consent and student assent forms confirming their participation in the current study.

**Intervention Design**

The context for learning with tablets was drawn from an interdisciplinary science and language arts unit. The science unit chosen for this study was based on the OME’s (2007) *The Ontario Curriculum Grades 1-8: Science and Technology’s Grade 5 “The Conservation of Energy and Resources” expectations and the OME’s (2006) *The Ontario Curriculum Grades 1-8: Language’s Grade 5 expectations; specifically, within the latter’s “Language: Reading Strand,” reading comprehension and vocabulary expectations were embedded within the interdisciplinary unit. There were five overarching lessons within the unit with sub-lessons embedded within them. Approximately 20 50-minute
science periods were allotted for the present study to take place. This may have varied depending on field trips, assemblies, and track and field. With the interdisciplinary unit, Jarrod did have to cut out some lessons to ensure that students had time to finish their culminating tasks. This study took place at the end of the school year so the general feeling was more relaxed and less pressure to assess students seemed to be apparent. As the rotary teacher, Jarrod was the one who continued to teach his students while the present study was conducted. The researcher was not involved in content delivery, but rather supported the teacher and students with technology integration and technical support while collecting data.

An inquiry-based unit titled *Connecting With the Natural World: Junior Division Integrated Curriculum—Grade 5 Conservation of Energy and Resources* (see Appendix J) developed by The Science Teachers’ Association of Ontario and the Ontario Teachers’ Federation (STAO/OTF, 2012) was modified and delivered by the classroom teacher. This five-lesson unit was developed to enhance inquiry-based learning and authentic learning experiences, and it is embedded with 21st century technology connections (STAO/OTF, 2012). Appendix J provides an overview for the *Grade 5 Conservation of Energy and Resources* activities. The researcher made enhancements to the unit to embed additional connections to language arts, reading comprehension, and vocabulary expectations and to make explicit technology connections using tablet apps. With regards to technology, the unit integrated blogging initially. A blogging app was therefore embedded into the enhanced interdisciplinary unit.

The participating school provided access to 20 Apple iPads for the proposed study. Based on Falloon’s (2014) recommendations, nine apps were selected by the researcher to enhance science and language arts subject-specific knowledge (Energy by
Kids Discover, Energy HD, BrainPop, and six augmented reality apps), and three apps were selected by the researcher to support students’ conceptual knowledge construction, knowledge creation, and multimodal extended communication (Popplet, PicCollage, and iMovie). Furthermore, a blogging app was used to provide a digital outlet with the possibility of multimodal communicating, collaborating through digital networks, and creating for a particular audience (EasyBlog). The researcher worked with Jarrod, the teacher librarian, and the ICT for Learning representative in the board to ensure all apps required for the current study were downloaded on the iPads. Funding from the SSHRC scholarship supported the purchase of apps at the volume purchase pricing rates within the Apple App Store.

Students worked in pairs or in small groups (one group of three) to complete inquiry-based tasks on the tablets. Each student was given a set of headphones, and the pairs of headphones could be connected to the tablets through headphone splitters. These splitters allowed two headphones to be hooked up to the headphone outlet on one tablet. For the most part, students did not use the headphone splitters because the iPad cases would have had to be taken off for them to plug in. This did not seem to cause issues with noise level.

**Data Collection and Analysis**

In the present study, both qualitative and quantitative data were collected from student participants through pre-, interim, and post-intervention periods. Data collection methods and instruments used in this mixed-methods study included: screen recordings, audio recordings, student interviews, stored student data, researcher observation notes, reading comprehension tests, vocabulary tests, science tests, and 21st century learning activity rubrics.
**Qualitative Data Collection**

Qualitative data were collected through audio and video screen interaction recordings while students worked in pairs on tablets. Out of the 20 50-minute science periods allotted for the present study, the researcher observed nine of these periods to collect qualitative audio and video data. Qualitative interview data were collected by randomly selecting nine students to participate in exit interviews conducted by the researcher at the end of the study.

To reduce the observer effect, audio and screen recordings were used to capture students’ tablet interactions and reduce any uncomfortable or altered behaviours as a result of being taped. Two audio and two video devices recorded two sets of pairs during each qualitative data collection period. The researcher chose different pairs of students to record to ensure qualitative data were collected from a variety of students. At the beginning of the study, there were some issues with Wi-Fi connections. These issues were resolved by the second observation day.

**Screen interaction recordings and audio recordings.** The current study used the most reliable and effective option determined in the pilot test to capture screen interactions. In order to capture video screen interactions while students worked on tablets, two external video monitoring tools called NestCams (previously known as Dropcams) were used. The NestCams were small enough for students to comfortably interact with the tablet while the device was facing the screen in front of them. On days when the Wi-Fi was not working properly, the audio recorders were secured to the tables with Velcro in front of students to capture audio data. During the pilot tests, this practice proved to be a reliable back-up plan and did not interfere with students’ tablet interactions. Overall, 12 screen interaction recordings and audio recordings were
gathered. Letter codes (i.e., Student A) were given to individual participants to demonstrate who is talking. Each type of qualitative data was given at least four codes based on the 21 CLD Learning Activity Rubrics (Microsoft Corporation, 2015): “Use of ICT for Learning,” “Knowledge Construction,” “Collaboration,” and “Skilled Communication.”

**Blog posts.** The EasyBlog app was used on a regular basis for this study. Screenshots of students’ work were gathered from the participating students’ blogs. These screenshots captured students’ written, audio, and video posts. It also captured the work that students were creating in other apps and choosing to share on EasyBlog. Furthermore, screenshots of the comments students posted to one another in EasyBlog were also captured through screenshots within this app. Overall, there were 95 blog posts (including feedback posts).

**Student stored data.** Some work was not captured through the screen interactions or audio recordings since the researcher was only present for 9 instructional days. Furthermore, students did not post every product of their learning through the EasyBlog app. Therefore, to collect student work that was not made public for their class, the researcher downloaded all pictures (e.g., screenshots of mind maps) and videos saved in the camera roll or in the apps used in the present study. Overall, there were 45 pictures and videos of students’ work that were not posted on their blog. Some of the work that was downloaded provided visuals that were superior in quality when compared to the students’ work captured from the NestCam data.

**Researcher observation notes.** Over the course of the 9 days that the researcher was present, typed observation notes were made to provide context for the NestCam clips, blog posts, and stored data.
**Exit interviews.** At the end of the study, one-on-one student interviews were conducted to ask participants about their thoughts, attitudes, behaviours, and experiences while using tablets (see Appendix F). These interviews were conducted in a separate room adjacent to the study’s classroom so that students could answer the questions without other students present. Audio recorders were used to capture students’ narrative responses. The interviews took approximately 10 minutes (each) to conduct. Overall, there were nine student interviews conducted.

**Qualitative Data Analysis**

Through a qualitative data analysis program (NVivo 11.4), audio and video recordings of students’ conversations, narratives, and screen interactions were uploaded into the program. Learning in the 21st century requires the analysis of unique learning rubrics outlined in the *21 CLD Learning Activity Rubrics* (Microsoft Corporation, 2015). The *21 CLD Learning Activity Rubrics* (Microsoft Corporation, 2015) created learning activity rubrics for six rubrics of 21st century learning. Within these rubrics, descriptors have been set to describe the rubrics that are engaged during the learning process (see Appendices B, C, D, & E). Based on the research questions framing this study, the learning activity rubrics for Use of ICT for Learning, Knowledge Construction, Collaboration, and Skilled Communication (Microsoft Corporation, 2015) were used to code all types of qualitative data. With respect to the actual *21 CLD Learning Activity Rubrics* (Microsoft Corporation, 2015), four separate rubrics with embedded descriptors informed coding on 4-point and 5-point scales (see Appendices B, C, D, & E). The Use of ICT for Learning, Knowledge Construction, and Collaboration learning activity rubrics all used a 5-point scale with associated descriptors for each point on the scale (see Appendix K). Skilled Communication used a 4-point scale with associated descriptors on
the scale (see Appendix K). The qualitative data analysis software (NVivo 11.4) was used to code and triangulate the blog posts, video and audio recordings, student interview recordings, researcher observation notes, and pictures and videos of students’ work.

NVivo 11.4 allowed the researcher to code all types of qualitative data based on the learning activity rubrics. With regards to video and audio data, NVivo 11.4 also allowed the researcher to select specific instances within audio or video recordings that are meaningful to the study and then use an adjacent note section to transcribe the data. Once the data were transcribed, the specific audio or video incident and the adjacent transcription notes were selected and coded based on the 21 CLD Learning Activity Rubrics (Microsoft Corporation, 2015) levels embedded within the learning activity rubrics for Use of ICT for Learning, Knowledge Construction, Collaboration, and Skilled Communication. Single codes were given for each individual level within the learning activity rubrics (e.g., Knowledge Construction level 4 or Collaboration level 3). Furthermore, instances of Knowledge Construction were also coded based on the type of higher-ordering thinking skill being used in that instance, which included: synthesizing, analyzing, interpreting, and evaluating.

Once all qualitative data were coded, the NVivo 11.4 program facilitated the triangulation of datasets (Creswell, 2012). After coding, instances under certain codes could be accessed. As such, all instances that were coded with a particular code (e.g., Knowledge Construction level 5) were culled from all datasets including screen interaction recordings and audio recordings, blog posts, researcher observation notes, stored student data, and student interviews. These coded instances were clustered together as their own dataset.
NVivo 11.4 further supported queries to be run between different codes. After coding, instances under two codes could be accessed. This means that all instances pulled from all datasets that were coded for under two particular codes (e.g., Use of ICT for Learning level 4 and Knowledge Construction level 5) were clustered together as a distinct dataset. The Use of ICT for Learning code was run with the other three codes (separately) as a query to align with the research questions. The main objectives of the research questions were to determine how the Use of ICT for Learning supports other 21st century skills and further supports the skill of Knowledge Construction in Science and Language Arts. For this reason, other queries (i.e., Knowledge Construction and Collaboration) were not run as they did not align with the research question. Overall, based on the 5-point or 4-point scales, 75 queries were run. The five levels of Use of ICT for Learning were run with the five levels of Knowledge Construction (25 queries). The five levels of Use of ICT for Learning were run with the five levels of Collaboration (25 queries). The five levels of Use of ICT for Learning were run with the four levels of Skilled Communication (20 queries).

To ensure credibility of the findings, peer debriefers were used. These debriefers included the researcher’s faculty advisor and graduate student who is a certified teacher. During the debriefing process, data samples were reviewed and coded. The researcher was provided with these interpretations and emergent themes were confirmed or disconfirmed as logical or appropriate (Creswell, 2012). The study itself cannot be fully generalizable, but some themes might be transferable to similar educational settings (Lincoln & Guba, 1985). Herein, the triangulation of data provides credibility of the findings through the use of multiple data sources.
Quantitative Data Collection

Pre- and post-tests were administered to the student participants to collect quantitative data. These tests took two periods (100 minutes) at the beginning of the study and two periods at the end of the study.

**Reading comprehension and vocabulary tests.** The *Canadian Achievement Tests* (CAT-4, Level 15; Canadian Test Centre, 2008) was used to measure reading (see Appendix G) and vocabulary (see Appendix H). The reading comprehension test was administered on the first day of quantitative data collection, and the vocabulary test was administered on the second day. These tests were selected due to their alignment with *The Ontario Curriculum 1-8: Language* (OME, 2006). Specifically, the tests align with the “Language: Reading Strand” for reading comprehension and vocabulary (OME, 2006). The CAT-4, Level 15 Reading Comprehension test has a total of 48 multiple-choice questions, while the Vocabulary test has a total of 31 multiple-choice questions (Canadian Test Centre, 2008). See Appendices G and H for sample questions.

**Science test.** The Grade 5 *eTestSmart Science: Conservation of Energy* (Popular Book Company, 2012a) and Grade 5 *eTestSmart Science: Forms of Energy* (Popular Book Company, 2012a) science tests were also administered (see Appendix I) on the second day of the quantitative data collection following the vocabulary test. The test was designed to measure content knowledge for Grade 5 Ontario science curriculum concepts. The test was selected due its alignment with “The Conservation of Energy and Resources” Grade 5 expectations within *The Ontario Curriculum 1-8: Science and Technology* (OME, 2007). Between the Grade 5 *eTestSmart Science: Forms of Energy* and *Conservation of Energy* tests, there were three multiple-choice, five short-answer, 25
fill in the blank or labeling, and seven matching questions. There are 46 questions in total. See Appendix I to view all questions in the science test.

**Quantitative Data Analysis**

The test scores from pre-test were compared to post-test for each of the reading comprehension, vocabulary, and science tests using SPSS 22.0. Specifically, dependent t-tests (Hurlburt, 2003) were conducted with both raw and scale scores to determine whether there was a significant difference in test scores from pre-intervention to post-intervention. Where significant differences existed on the dependent t-tests, the effect sizes were calculated using Cohen’s d (Cohen, 1960). All statistical significance values were set at a 95% confidence level. Further, the individual questions on the science test were further enumerated through an item analysis and then clustered by concepts so that they might be further examined and cross-confirmed with the findings from the qualitative data. As well, qualitative findings were cross-confirmed with the results of the reading comprehension and vocabulary tests.

**Ethical Review**

The current study adhered to the Tri-Council Policy Statement conventions for ethical research. An existing protocol through the Brock University Research Ethics Board (file # 14-123) and the school board’s Educational Research Committee provided formal ethical clearance.
CHAPTER FOUR: FINDINGS

The purpose of this study was to research how information and communication technologies (ICT), specifically tablets, may enhance the 21\textsuperscript{st} century skills of knowledge construction, collaboration, and skilled communication within an interdisciplinary unit. The following research questions guided this study: (a) How can the use of tablets for learning foster Grade 5 students’ 21\textsuperscript{st} century skills, including: knowledge construction, collaboration, and skilled communication? (b) How can the use of tablets for learning build students’ knowledge construction in science concepts, reading comprehension, and vocabulary development?

The first section addresses the first research question and examines the qualitative data findings after analyzing the frequency of occurrence of each 21\textsuperscript{st} century skill and the queries that were run between the following codes: Use of ICT for Learning and Knowledge Construction; Use of ICT for Learning and Collaboration; and Use of ICT for Learning and Skilled Communication (Microsoft Corporation, 2015). Codes that showed the highest frequency of occurrence or a meaningful trend within a query are presented in this chapter. To answer the second research question, the second section presents the findings from the dependent-t tests, which examined the significance between reading comprehension, vocabulary, and science pre- and post-test scores. These findings were then cross-confirmed through an item analysis of the science tests’ individual pre- and post-test questions and examples captured from the qualitative findings. Illustrative excerpts of the video and audio data, student interview recordings, researcher observation notes, and pictures and videos of students’ work are embedded in each section of this chapter.
Use of Tablets for Learning: Knowledge Construction, Collaboration, and Skilled Communication

The 21 CLD Learning Activity Rubrics (Microsoft Corporation, 2015) were modified and used to qualitatively score the frequency of four 21st century skills. The Use of ICT for Learning, Knowledge Construction, and Collaboration learning activity rubrics all used a 5-point scale with associated descriptors for each point on the scale (see Appendix K). Skilled Communication used a 4-point scale with associated descriptors on the scale (see Appendix K). The qualitative data analysis software NVivo 11.4 was used to code and triangulate the blog posts, video and audio recordings, student interview recordings, researcher observation notes, and pictures and videos of students’ work. The findings from the analysis of these data are presented in the following sections to demonstrate the breadth, frequency, and development of students’ 21st century skills over the course of the intervention study.

Use of ICT for Learning

The following section addresses the study’s first research question, which examined how the use of tablets for learning may foster Grade 5 students’ 21st century skills including: knowledge construction, collaboration, and skilled communication. The Use of ICT for Learning activity rubric was used as a set of codes with associated descriptors to indicate the level of ICT use (Microsoft Corporation, 2015). The descriptors associated with Use of ICT for Learning codes were already embedded with links to Knowledge Construction and Skilled Communication. This is an emphasis on constructing knowledge that requires the use of ICT and constructing knowledge for a particular audience through ICT (Microsoft Corporation, 2015). A general summary of the descriptors for each level on the 5-point scale will be provided along with the number of instances each code came up in the qualitative data. These codes are then further
analyzed in relation to how technology, specifically tablets, contributed to students’ level of Knowledge Construction, Collaboration, and Skilled Communication. To reduce repetition when presenting the findings, examples of the Use of ICT for Learning codes will be presented when discussing the queries to demonstrate how tablet use correlated with other 21st century skills. Examples of levels 1-5 Use of ICT for Learning will therefore be presented in relation to the queries with Knowledge Construction, Collaboration, and Skilled Communication that had the highest number of instances. This is to further maintain alignment with the research questions where the focus will not be placed solely on the Use of ICT for Learning, but rather, the Use of ICT for Learning to support Knowledge Construction, Collaboration, and Skilled Communication.

Table 1 outlines the number of instances for the Use of ICT for Learning.

Use of ICT for Learning level 1 described that students do not use ICT for their learning (Microsoft Corporation, 2015). After analyzing the qualitative data, there were 26 instances when students were not using any technology for their learning. Use of ICT for Learning level 2 described that students do use ICT to learn or practice basic skills or reproduce information (Microsoft Corporation, 2015). They are not constructing knowledge (Microsoft Corporation, 2015). After analyzing the qualitative data, there were 71 instances when students were learning foundational knowledge about science concepts through tablets. There was scant data to indicate explicit foundational knowledge of reading comprehension strategies or vocabulary development. Use of ICT for Learning level 3 described that students do use ICT to support knowledge construction but they could construct the same knowledge without using ICT (Microsoft Corporation, 2015). After analyzing the qualitative data, there were 40 instances of students constructing knowledge with tablets that could have also been constructed without the use of technology.
Table 1

*Use of Information and Communication Technologies (ICT) for Learning—Number of Instances Coded*

<table>
<thead>
<tr>
<th>ICT level/code</th>
<th>No. of instances</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>26</td>
</tr>
<tr>
<td>2</td>
<td>71</td>
</tr>
<tr>
<td>3</td>
<td>40</td>
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<tr>
<td>4</td>
<td>90</td>
</tr>
<tr>
<td>5</td>
<td>69</td>
</tr>
</tbody>
</table>

*Note.* Use of ICT for Learning levels/codes based on Microsoft Corporation’s (2015) 21 CLD Learning Activity Rubrics.
Use of ICT for Learning level 4 described that students do use ICT to support knowledge construction and the ICT is required for constructing this knowledge but students do not create an ICT product for authentic users (Microsoft Corporation, 2015). After analyzing the qualitative data, there were 90 instances of students using tablets to construct knowledge in a way that required the technology to support this knowledge construction. However, this knowledge construction was not intended for a particular audience (i.e., to share with their class). Use of ICT for Learning level 5 described that students do use ICT to support knowledge construction and the ICT is required for constructing this knowledge and students do create an ICT product for authentic users (Microsoft Corporation, 2015). After analyzing the qualitative data, there were 69 instances of students using tablets to construct knowledge in a way that required the technology to support this, and the knowledge construction was intended for a particular audience (e.g., to share with their class).

As illustration to distinguish among the levels for the Use of ICT for Learning, some examples will be provided. When asked during a student interview how the Student A made connections to the unit, the student responded, “the book that we read…that’s when I really started getting it.” This book was used as a whole group instruction activity and focused on teaching the different sources of energy. This was coded as Use of ICT for Learning level 1 because technology was not used during this instance.

Another example for the Use of ICT for Learning occurred when students created videos for their peers to view on their blog. One group of students created a commercial with a skit that informed people why they should not use coal as a source of energy. This was coded as a level 5 Use of ICT for Learning since knowledge construction was apparent, the ICT was required for students to record their video, and they created an ICT
product for authentic users (Microsoft Corporation, 2015).

**Knowledge Construction**

The following section further addresses the study’s first research question, which examined how the use of tablets for learning may foster Grade 5 students’ 21st century skills, including: knowledge construction, collaboration, and skilled communication. The Knowledge Construction learning activity rubric was used as a set of codes with associated descriptors to indicate the level of knowledge constructed (Microsoft Corporation, 2015). The descriptors associated with Knowledge Construction emphasized four higher-order thinking skills, including: synthesizing, analyzing, interpreting, and evaluating. The descriptors also emphasized applying knowledge in new contexts and interdisciplinary learning. A general summary of the descriptors for each level on the 5-point scale is provided along with the number of instances each code came up in the qualitative data. Examples of level 1 and level 5 Knowledge Construction are provided to demonstrate the scope between the types of work students were completing at the lowest level of Knowledge Construction compared to the highest level of Knowledge Construction. More examples of level 1-5 will be provided throughout this section with regards to the type of Knowledge Construction skills students were working on and in relation to the query run with the level of Use of ICT for Learning. These codes are then further analyzed to determine if there is a relationship between students’ level of Knowledge Construction and Use of ICT for Learning from the queries run. Examples of these instances and queries will be provided to demonstrate the type of skills students were using while constructing knowledge and how the Use of ICT for Learning intersected with Knowledge Construction.
Table 2 outlines the number of instances of Knowledge Construction. Knowledge Construction level 1 described that students do not construct knowledge; students reproduced information by using familiar procedures (Microsoft Corporation, 2015). After analyzing the qualitative data, there were 83 instances of students reproducing foundational knowledge. Students spent quite a bit of time during their unit in the three-dimensional and augmented reality apps. These apps were intended to teach students about the different structures that turn sources (e.g., the sun) into energy (e.g., solar power). Students were not required to construct knowledge, but rather, they were building knowledge about energy sources. Some students took screenshots to document their learning. Figure 2 provides an example of one of these screenshots. The following provides a conversation between two students while they are manipulating the digital structure for tidal energy:

Student A: Okay, so we are looking at tidal energy.

Researcher observation: The other student lifts up the picture card to show his station.

Student B: We are going to title.

Researcher observation: The student begins pulling the vocabulary titles out of the 3-D view image.

Student A: So that is the rotor head.

Student B: This is the blade.

Student A: That is the foundation.

Student B: Tower.

Student A: This is the nacelle. That’s also the nacelle.

Student B: So yeah, now we are going to take it apart.
Table 2

Knowledge Construction (KC)—Number of Instances Coded

<table>
<thead>
<tr>
<th>KC level/code</th>
<th>No. of instances</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>83</td>
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<tr>
<td>2</td>
<td>52</td>
</tr>
<tr>
<td>3</td>
<td>91</td>
</tr>
<tr>
<td>4</td>
<td>32</td>
</tr>
<tr>
<td>5</td>
<td>38</td>
</tr>
<tr>
<td>Synthesizing</td>
<td>42</td>
</tr>
<tr>
<td>Analyzing</td>
<td>40</td>
</tr>
<tr>
<td>Interpreting</td>
<td>110</td>
</tr>
<tr>
<td>Evaluating</td>
<td>78</td>
</tr>
</tbody>
</table>

Note. Knowledge Construction levels/codes based on Microsoft Corporation’s (2015) 21 CLD Learning Activity Rubrics.
Researcher observation: The student begins to pull apart the 3-D figure.

Student B: It's so cool how you can take it apart.

Student A: Now take a screenshot.

Student B: Okay, so that is what we learned today. Bye!

In this example taken from the NestCam observations, students were also using the video feature where they could embed a video in the 3-D model and record their learning.

Knowledge Construction level 2 described that students do construct knowledge by interpreting, analysing, synthesizing, or evaluating information or ideas even if this is not required (Microsoft Corporation, 2015). This code indicated instances of students developing knowledge about science or language arts concepts and naturally developing knowledge of these science or language arts concepts through synthesis, analysis, interpretation, or evaluation. Developing knowledge of something was not the main goal of learning, but rather, came about in the middle of acquiring knowledge about something. After analyzing the qualitative data, there were 52 instances of students constructing knowledge during activities where knowledge acquisition was the main focus and not knowledge construction.

Knowledge Construction level 3 described that students do construct knowledge because it is required but do not apply their knowledge in a new context (Microsoft Corporation, 2015). After analyzing the qualitative data, there were 91 instances of students constructing knowledge, but not applying this knowledge in a new context.

Knowledge Construction level 4 described that students do construct knowledge and do apply their knowledge in a new context but do not demonstrate learning in more than one subject (Microsoft Corporation, 2015). After analyzing the qualitative data, there were 32 instances of students constructing knowledge in a new context, but this knowledge construction was not interdisciplinary.
Figure 2. Tidal Energy app: 3-D view with titles.
Knowledge Construction level 5 described that students do construct knowledge and do apply their knowledge in a new context and knowledge construction is interdisciplinary (Microsoft Corporation, 2015). They do demonstrate learning in more than one subject through the content, important ideas, or methods (Microsoft Corporation, 2015). After analyzing the qualitative data, there were 38 instances of students constructing interdisciplinary knowledge in a new context.

To present the results of the four higher-order thinking skills coded under Knowledge Construction, the following section provides the descriptors, number of instances, and examples of synthesizing, analyzing, interpreting, and evaluating. The descriptors for each of the higher-order thinking skills were taken from the descriptions presented in the 21 CLD Learning Activity Rubrics (Microsoft Corporation, 2015). It is important to note that some data were coded with multiple higher-order thinking skills.

**Synthesizing.** According to the 21 CLD Learning Activity Rubrics (Microsoft Corporation, 2015), “synthesis means identifying the relationships between two or more ideas” (p. 11). At varying levels of Knowledge Construction, there were 42 instances of students synthesizing to construct knowledge. Figure 3 presents an example of synthesizing to construct knowledge.

Figure 3 depicts a screenshot of a group’s Popplet mind map. Students were asked to research the pros and cons of a source of energy. They demonstrated synthesis by creating a comparison between the pros and cons of using solar panels. This was coded as level 3 Knowledge Construction because students synthesized information, but did not apply their knowledge in a new context.
Figure 3. Popplet app: Mind map on pros and cons of solar panels.
Analyzing. According to the *21 CLD Learning Activity Rubrics* (Microsoft Corporation, 2015), “analysis means identifying the parts of a whole and their relationships to each other” (p. 11). At varying levels of Knowledge Construction, there were 40 instances of students analyzing to construct knowledge. For example, students were asked to analyze the different components of what makes a good blog. Students analyzed to identify the parts of a whole (i.e., what makes up a good blog). This was coded as level 3 Knowledge Construction since students analyzed information, but did not apply their knowledge in a new context. Video and audio data from the NestCam further demonstrates students’ analysis as they formed their mind map in Popplet:

Researcher observation: They are in the mind-mapping app called, Popplet. They are discussing ideas about what makes a good blog and turning these ideas into a mind map.

Student C: good blog has tones of bold colours, lots of descriptions.

Researcher observation: The one student begins typing and saying the thought they just had out loud.

Student D: A good blog needs to have bold colours, descriptive words, and paragraphs? Okay, good blogs have lots of pictures.

Student C: That goes with the words.

Student D: The picture has to relate to the words, or the words have to relate to the picture. Either, or.

Researcher observation: The student begins typing and reading what they are typing out loud.

Interpreting. According to the *21 CLD Learning Activity Rubrics* (Microsoft Corporation, 2015), “interpretation means drawing inferences beyond the literal meaning”
At varying levels of Knowledge Construction, there were 110 instances of students interpreting to construct knowledge. For example, at the beginning of the unit when students were learning about the different forms of energy, they were asked to go around to the outside of the school and take pictures with the iPad of different forms of energy. Students had to make inferences about what they saw outside and sometimes had to go beyond the literal meaning to explain it. One group took a video to demonstrate light energy. Student A is in the video and Student B is recoding the video. This was coded as level 3 Knowledge Construction since students analyzed information, but did not apply their knowledge in a new context.

Student E: It’s dark and shady down here and it's light and bright out here.

Researcher observation: The student sits under the jungle gym at first and then stands up into the open to show the comparison.

**Evaluating.** According to the *21 CLD Learning Activity Rubrics* (Microsoft Corporation, 2015), “evaluation means judging the quality, credibility, or importance of data, ideas, or events” (p. 11). At varying levels of Knowledge Construction, there were 78 instances of students evaluating to construct knowledge. Figure 4 presents an example of evaluating to construct knowledge. Students evaluated why tidal energy is effective and important to use as a source of energy. This was coded as level 5 Knowledge Construction since students analyzed information and applied their learning in a new context by combining their ideas into a blog post. Students also demonstrated learning in both science and language arts since this was a reading response evaluating scientific concepts.
ISABELLE AND EMILY’S WATER BLOG
Energy made from tidal waves is called, Tidal energy.

We found out that tidal energy is one of the most resourceful source of energy! To make tidal energy they use turbines and that breakers it down into energy. Tidal energy is a renewable energy because it can be used again. And it is better for the earth and people because it does not pollute the earth or the air.

Figure 4. EasyBlog app: Blog post on tidal energy.
Knowledge Construction and Use of ICT for Learning

The intersection of Knowledge Construction and Use of ICT for Learning seemed to illustrate unique relationships. Depending on the level of Knowledge Construction, certain levels of Use of ICT for Learning intersected. This can be seen through the query that was run between the five Knowledge Construction codes and the five Use of ICT for Learning codes (see Appendix K). Codes that showed the most meaningful instances together were: Knowledge Construction level 1 and Use of ICT for Learning level 2; Knowledge Construction level 2 and Use of ICT for Learning level 4; Knowledge Construction level 3 and Use of ICT for Learning level 3; Knowledge Construction level 3 and Use of ICT for Learning level 4; Knowledge Construction level 4 and Use of ICT for Learning level 5; Knowledge Construction level 5 and Use of ICT for Learning level 5. Table 3 outlines the number of instances in these queries.

Knowledge Construction level 1 and Use of ICT for Learning level 2. The query that was run for these two codes resulted in 69 instances. Figure 5 presents an illustration of data that came up when this query was run; two students used the tablet to take a screenshot of the moving fire image from the Kids Discover app. They then shared this image on their blog with a caption in the EasyBlog app. It was a reproduction of the knowledge presented in the Kids Discover app. Reproducing knowledge through screenshots was a common instance under these two codes.

Knowledge Construction level 2 and Use of ICT for Learning level 4. The query that was run for these two codes resulted in 38 instances. In order to provide peer feedback to digital pictures and videos among a large group of students, the EasyBlog app was required for this form of knowledge construction. Student feedback within EasyBlog was one of the highest instances that occurred within this query. For example, one group
Table 3

Knowledge Construction (KC) and Use of Information and Communication Technologies (ICT) for Learning—Number of Instances Coded

<table>
<thead>
<tr>
<th>Queries</th>
<th>No. of instances</th>
</tr>
</thead>
<tbody>
<tr>
<td>KC level 1 and ICT level 2</td>
<td>69</td>
</tr>
<tr>
<td>KC level 2 and ICT level 4</td>
<td>38</td>
</tr>
<tr>
<td>KC level 3 and ICT level 3</td>
<td>16</td>
</tr>
<tr>
<td>KC level 3 and ICT level 4</td>
<td>44</td>
</tr>
<tr>
<td>KC level 4 and ICT level 5</td>
<td>19</td>
</tr>
<tr>
<td>KC level 5 and ICT level 5</td>
<td>26</td>
</tr>
</tbody>
</table>

*Note.* Knowledge Construction and Use of ICT for Learning levels based on Microsoft Corporation’s (2015) *21 CLD Learning Activity Rubrics.*
Figure 5. EasyBlog app: Blog post on heat energy.
of students posted a photograph of air pollution and just labelled it. Another group provided feedback saying, “I can’t believe we are breathing that in, that can’t be good. You didn’t explain what air pollution could do.” Students needed to use ICT to provide evaluative feedback to each other’s videos and pictures. The instances of level 2 Knowledge Construction came about because students were not required to construct knowledge while giving feedback, but this did organically happen in some cases as students evaluated the quality and credibility of others’ work.

**Knowledge Construction level 3 and Use of ICT for Learning level 3.** The query that was run for these two codes resulted in 16 instances. Figure 6 presents an excerpt of data that came up when this query was run. Figure 6 is an example of a group’s Popplet that was used to analyze and evaluate good blogs. This group’s mind map was coded as Use of ICT for Learning level 3 because students used the Popplet app to support their knowledge construction, but such a mind map could have been made without the use of ICT. The mind map that this group created demonstrated Knowledge Construction level 3 because knowledge construction was required, but they did not apply this knowledge in a new context. The Popplet mind map was not created as a blog post or posted on the EasyBlog app. What is especially unique about the Popplet app is that students used the connecting features to demonstrate how some thoughts connected to other thoughts. For example, the one bubble says “a good blog has lots of pictures,” and dragged a line from that bubble to the bubble that says “a good blog has things that match the topic.” This group analyzed the components of a blog that connect and evaluate what makes a good blog. They found a connection between blog pictures that are specifically on a blog to match the topic. This further demonstrated the skill of evaluation since students were judging the quality of different blog posts and the importance of certain features presented within a blog post.
Figure 6. Popplet app: Mind map on good blogs.
**Knowledge Construction level 3 and Use of ICT for Learning level 4.** The query that was run for these two codes resulted in 44 instances. Figure 7 presents a sample of data that came up when this query was run. In comparison to Figure 6, Figure 7 demonstrates how the Use of ICT for Learning was required for this group to present how they evaluated and analyzed different types of blogs. Students were able to communicate their thoughts more effectively with embedded pictures. These pictures were taken from websites and one of them was even cropped to make the focal point just the picture. However, data such as the one above was not developed for authentic users. It was not designed for their blog or posted on their blog. This informed the level of Knowledge Construction as well since students did not apply their learning in a new context (e.g., create a blog post). Knowledge Construction level 3 was therefore coded since knowledge construction was required, but they did not apply this knowledge in a new context.

**Knowledge Construction level 4 and Use of ICT for Learning level 5.** The query that was run for these two codes resulted in 19 instances. Figure 8 presents a sample of data that came up when this query was run. Figure 8 demonstrates a picture collage that a group of students created within the PicCollage app. This app allowed students to upload pictures, use stylistic elements (i.e., boarders and backgrounds), and other multimodal features to communicate (i.e., drawing tools and text boxes). The PicCollage in Figure 8 was saved to the students’ camera roll and uploaded into their EasyBlog page. The following is an occurrence taken in the classroom while the researcher was present and actively observing:

One of the students was looking at another students’ PicCollage. The teacher asked if she knows what energy the basketball picture would show. She said that because of the arrow drawn with the drawing tool by the other group, she can see that it is gravitational energy. (Researcher observational notes)
Figure 7. Popplet app: Mind map on good blogs with pictures.
Figure 8. PicCollage app and EasyBlog app: Blog post on types of energy.
The student is constructing knowledge by interpreting how other students are identifying sources of energy. By constructing knowledge about gravitational energy within another context (e.g., the basketball picture), this instance was coded as Knowledge Construction level 4. This was not coded as Knowledge Construction level 5 because it did not demonstrate interdisciplinary learning. Furthermore, the Use of ICT for Learning level 5 was coded for since students used the real life photographs and digital editing features within PicCollage (i.e., added drawings) to support their knowledge construction. The product supporting students’ interpretation of gravitational energy was also coded as Use of ICT for Learning level 5 since they used a product created for authentic users. The PicCollage (see Figure 8) was created and then posted on EasyBlog for other students to use.

**Knowledge Construction level 5 and Use of ICT for Learning level 5.** The query that was run for these two codes resulted in 26 instances. The following is a NestCam observation that came up within this query:

The one student is still typing a post in the EasyBlog app. There is no dialogue between partners because one student is away today. The student flips screens to go back to the Kids Discover app by double clicking the home button. She scrolls through the text on the first slide and then goes back to the EasyBlog app to keep typing. The student is getting ready to post the response. Before posting, she is prompted to upload a video or picture. She double clicks the home button to return to the Kids Discover app. She scrolls through the three pages of digital text that they were assigned to read today. She chooses the picture of a waterfall and holds down the power button and the home button to take a screenshot. She quickly flips back to the EasyBlog app and uploads the picture from the camera roll. She then publishes
the written post and picture on her blog. She returns to the EasyBlog app and opens the post she just published to make sure everything showed up.

Figures 9 and 10 present the blog post that the student in the above example was working on. When coding for Knowledge Construction level 5, this was evident in how the student analyzed and interpreted the meaning of energy. The student was required to construct knowledge and apply learning in a new context by creating a blog post for the rest of the class. This instance was further coded as level 5 Knowledge Construction because it demonstrated interdisciplinary learning. This is apparent since the researcher observed the student analyzing information in the Kids Discover app and then constructing knowledge in the EasyBlog app to create a reading response. This demonstrated interdisciplinary methods for Knowledge Construction since students understood the process of reading to collect evidence in science. This then supported the students’ reading responses on scientific concepts as the student analyzed and interpreted the information through a reading response (i.e., blog post).

The Use of ICT for Learning was apparent in the student’s fluidity between the two apps. The tablet seemed to support the student’s knowledge construction by making it easier to move between the content-based app and the creation-based app. As seen in the researcher observations above, this student was able to efficiently flip back into the content-based app, take a screenshot, and upload this photograph into the post. Some students took this step further, as seen in Figure 9, by cropping the picture to make it more aesthetically appealing and relevant to their post. The Use of ICT for Learning also supported this students’ construction of knowledge since the student created a product for authentic users with a real-life photograph. The student included information in the blog post that demonstrated a level of interpretation to support other students’ learning, which would occur when peers view this group’s blog.
Figure 9. EasyBlog app: Blog post on energy (Part 1).
Wednesday May 11 2016

We were at the first station today and we learned that energy, you can't see it but you can hear the results. Like a CD when you put in your CD in you can hear the music but can't see the sound waves. You can't touch it either. Most energy comes from the sun, the sun is the main source of energy. Without the sun people and animals and plants can't live.

Figure 10. EasyBlog app: Blog post on energy (Part 2).
Overall, the above section demonstrated how students used tablets while constructing knowledge. Depending on the level of Knowledge Construction and the level of Use of ICT for Learning, certain unique intersections were uncovered.

Collaboration

The following section addresses the study’s first research question, which focuses on how the use of tablets for learning may foster Grade 5 students’ 21st century skills, including: knowledge construction, collaboration, and communication. The Collaboration learning activity rubric was used as a set of codes with associated descriptors to indicate the level of collaboration (Microsoft Corporation, 2015).

Throughout the current study, students worked in pairs on tablets (iPads). There was one group of three. They shared responsibility for their work on the iPads, but the level of collaboration greatly depended on the types of decisions students were making together regarding the content, process, and product of their work and whether their work was interdependent (Microsoft Corporation, 2015). For the most part, it was difficult to measure the interdependence level because individual accountability was difficult to see in some data samples. A general summary of the descriptors for each level on the 5-point scale is provided along with the number of instances each code came up in the qualitative data. These codes were then further analyzed to see the relationship between students’ level of Collaboration and Use of ICT for Learning from the queries run. Examples of these instances and queries are provided to demonstrate how the Use of ICT for Learning correlated to Collaboration.

Table 4 outlines the number of instances of Collaboration. Collaboration level 1 described that students do not work together in pairs or groups (Microsoft Corporation,
After analyzing the qualitative data, there were 38 instances of students not working together in pairs or groups. Since students did have a shared responsibility for their work and worked in pairs every class, level 1 often came about due to student absences or during student interviews when they were just talking about what they learned. Collaboration level 2 described that students do work together but they do not have shared responsibility (Microsoft Corporation, 2015). After analyzing the qualitative data, there were 47 instances of students working together even if they do not have shared responsibility. Instances of working together without shared responsibility came about when students gave feedback to each other through the EasyBlog app.

Collaboration level 3 described that students do have shared responsibility but they do not make substantive decisions together about the content, process, or product of their work (Microsoft Corporation, 2015). Substantive decisions required students to work together to discuss and resolve important issues that shaped the content, process, or product of their work. After analyzing the qualitative data, there were 67 instances of students working together with shared responsibility but not making any substantive decisions. Collaboration level 4 described that students do have shared responsibility and they do make substantive decisions together about the content, process, or product of their work but their work was not interdependent (Microsoft Corporation, 2015). Interdependence refers to when work was divided fairly among students who shared responsibility for the work, and there is usually individual and group accountability (Microsoft Corporation, 2015). After analyzing the qualitative data, there were 80 instances of students working together interdependently and with shared responsibility.
Table 4

*Collaboration (COL)—Number of Instances Coded*

<table>
<thead>
<tr>
<th>COL level/code</th>
<th>No. of instances</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>38</td>
</tr>
<tr>
<td>2</td>
<td>47</td>
</tr>
<tr>
<td>3</td>
<td>67</td>
</tr>
<tr>
<td>4</td>
<td>80</td>
</tr>
<tr>
<td>5</td>
<td>65</td>
</tr>
</tbody>
</table>

*Note.* Collaboration levels/codes based on Microsoft Corporation’s (2015) 21 CLD Learning Activity Rubrics.
Collaboration level 5 described that students *do* have shared responsibility *and* they *do* make substantive decisions together about the content, process, or product of their work *and* their work is interdependent (Microsoft Corporation, 2015). A level of interdependence meant that all students participated equally with individual and group accountability. After analyzing the qualitative data, there were 65 instances of students working together interdependently, with shared responsibility, and with substantive decisions made together.

**Collaboration and Use of ICT for Learning**

The intersection of Collaboration and level of Use of ICT for Learning demonstrated a unique relationship. Depending on the level of Collaboration, certain levels of Use of ICT for Learning were correlated. This can be seen through the query that was run between the five Collaboration codes and the five Use of ICT for Learning codes (see Appendix K). Codes that showed the most meaningful instances together were: Collaboration level 1 and Use of ICT for Learning level 1; Collaboration level 2 and Use of ICT for Learning level 4; Collaboration level 3 and Use of ICT for Learning level 2; Collaboration level 4 and Use of ICT for Learning level 3; Collaboration level 5 and Use of ICT for Learning level 4; Collaboration level 5 and Use of ICT for Learning level 5. Table 5 outlines the number of instances in these queries.

**Collaboration level 1 and Use of ICT for Learning level 1.** The query that was run for these two codes resulted in 20 instances. Many instances of this query came up when students were talking about the connections or inferences they made to the unit. These were individual connections and many students did not make reference back to how technology supported making these connections or inferences.
Table 5

**Collaboration (COL) and Use of Information and Communication Technologies (ICT) for Learning—Number of Instances Coded**

<table>
<thead>
<tr>
<th>Queries</th>
<th>No. of instances</th>
</tr>
</thead>
<tbody>
<tr>
<td>COL level 1 and ICT level 1</td>
<td>20</td>
</tr>
<tr>
<td>COL level 2 and ICT level 4</td>
<td>35</td>
</tr>
<tr>
<td>COL level 3 and ICT level 2</td>
<td>43</td>
</tr>
<tr>
<td>COL level 4 and ICT level 3</td>
<td>29</td>
</tr>
<tr>
<td>COL level 5 and ICT level 4</td>
<td>25</td>
</tr>
<tr>
<td>COL level 5 and ICT level 5</td>
<td>28</td>
</tr>
</tbody>
</table>

*Note.* Collaboration and Use of ICT for Learning levels based on Microsoft Corporation’s (2015) *21 CLD Learning Activity Rubrics.*
Researcher: How did you make connections to the unit…connections to yourself, to things that are going on in the world, or things that you read or made inferences about that you learned?

Student F: Well I've heard my sister come home and talk about energy a lot so I made some connections to what she said. She is older...grade 7.

During this interview, the student is not demonstrating how working in pairs or groups or a shared responsibility contributed to making connections in the unit. Furthermore, there was no mention of how technology contributed to their connection. This is what informed a code for Use of ICT for Learning level 1.

Collaboration level 2 and Use of ICT for Learning level 4. The query that was run for these two codes resulted in 35 instances. The highest instances of Use of ICT for Learning level 2 and Collaboration level 4 were when students gave feedback to one another in the EasyBlog app. For example, a pair of students wrote “the light there is not electricity energy it is light energy.” A pair of students were providing feedback on another group’s interpretation of forms of energy. In this instance, students were working together. However, giving feedback was not considered Collaboration level 3 because students did not have shared responsibility over producing a common product (i.e., their own blog posts), and they did not make substantive decisions together about the content, process, or product of their own work. They were giving some helpful feedback to other groups. The Use of ICT for Learning was coded as level 4 because the tablet provided the opportunity for students to work together and provide constructive feedback to multimodal posts. In this case, students were providing feedback on another students’ blog page and evaluating the credibility of a photograph in a PicCollage.
Collaboration level 3 and Use of ICT for Learning level 2. The query that was run for the co-existence of these two codes resulted in 43 instances. Figure 11 shows a blog post from a pair of students that presents a sample of the data that came up when this query was run. After manipulating the augmented reality apps to explore different structures that transform sources of energy into energy, this group posted about what they learned. This blog post was coded as Collaboration level 3 because the students did have shared responsibility for their blog and what was posted on it. However, they were not making a substantive decision together.

This pair of students just listed the different structures that they explored that day instead of making a substantive decision about the content, process, or product of more complex work. The Use of ICT for Learning level 2 informs this because the pair did not construct knowledge using ICT. They reproduced information by posting the names of the different augmented reality apps they used that day.

Collaboration level 4 and Use of ICT for Learning level 3. The query that was run for the intersection of these two codes resulted in 29 instances. Figure 12 shows an example of a blog post written about the pros and cons of using wind energy that presents data that came up when this query was run. This blog post was coded as Collaboration level 4 because students had shared responsibility for their blog and made substantive decisions about what they considered pros and what they considered cons. This required taking a stance towards wind energy by evaluating and synthesizing facts about it. However, after analyzing the interdependence between this particular group from the NestCam data, it was apparent that two students took more of a lead role in producing the work. The third participant in this group was an English Language Learner (ELL).
We have learned about energy. We learned about windmills, solar panels, and hydro dams. Hydro is electricity, solar is sun, and windmills are also electricity.

**Comments**

Please enter your comment here.

*Figure 11.* EasyBlog app: Blog post on sources of energy.
We learned when we were searching all about wind energy that there are pros and cons about wind. Some of the pros are wind, solar, and hydroelectric systems. They generate electricity with no associated air pollution emissions and a down side of wind energy are threats to wildlife, noise disturbances, visual impact, and suited to particular. These are some of the facts about wind energy we learnt.

*Figure 12.* EasyBlog app: Blog post on wind energy.
The other students asked this student (ELL) questions to engage her, but for the most part, this groups’ work was not interdependent. With regards to the Use of ICT for Learning level 3 code, this work could have been collaboratively constructed without the use of a tablet. The fact that it was posted on a blog, did not contribute to the content or level of Knowledge Construction in the written post itself.

**Collaboration level 5 and Use of ICT for Learning level 4.** The query that was run for the intersection of these two codes resulted in 25 instances. The following provides an example of data that came up when a query was run for these two codes. This example presents an instance during the student interviews when the student was asked about how she collaborated.

Researcher: How did you learn any of the following skills: Problem solving, critical thinking, collaborating, or environmental awareness?

Student G: Um, collaborating.

Researcher: Okay, how did you collaborate?

Student G: Well, [it’s] kind of hard to explain.

Researcher: Like, how did you collaborate with your partner to work on your projects and assignments?

Student G: Well we both kind of got ideas, we talked about them, then we agreed on one together, then we started to work on that…

Researcher: Was there a way that you collaborated with your whole class…like communicated and talked to your whole class?

Student G: Um, through EasyBlog.

Researcher: How so?
Student G: They would come on our blog and see what we wrote and everything, they would give us advice on what we needed to work on and things and we would take that advice and edit it.

Student E provides insight into how some students collaborated between different groups and within their own group and further how these informed one another. Student E’s feedback was coded as Collaboration level 5 because students worked together. However, in this interview, the student gave insight into how interdependent the learning process was between students at the whole group level and at the paired group level. In this instance, the student discussed how feedback was used to inform and make more substantive decisions together about their own collaborative content and products. There was individual and group accountability because they talked about their ideas and agreed upon decisions (Microsoft Corporation, 2015). This seemed to be supported by the use of feedback from other groups’ evaluations and interpretations of their work.

Considering the degree to which this student saw value in using the feedback feature within EasyBlog to inform their work, the Use of ICT for Learning level 4 code was given. The EasyBlog feedback feature to support collaboration would not have been possible without the use of the app because students were evaluating and interpreting multimodal texts (i.e., videos and pictures).

**Collaboration level 5 and Use of ICT for Learning level 5.** The query that was run for the intersection of these two codes resulted in 28 instances. As an example of data that came up under these two codes, the following presents the researcher observations and transcription of a video that two students developed. This video was developed as a commercial for part of their culminating task.

Researcher observation: Student runs around back and forth.
Student H: I need the lights. I don’t even need the lights! I need my iPad.

Researcher observation: The video then skips to her jumping up and down.

Another student walks up to her.

Student I: Wow, calm down. Why are you wasting all this energy?

Student H: I don’t know...because I guess energy grows on rainbows.

Student I: That’s not true. Why aren’t you using solar panels instead?

Student H: What are solar panels?

Student I: Solar panels are usually blue and you put them on top of your house or in a garden or something to power something. It takes the sun and turns it into energy.

Student H: That’s smart!

Based on this text excerpt from their video, Collaboration level 5 was coded since the students had shared responsibility for their learning, made substantive decisions about the lines and facts they were going to say in the video, and further took an interdependent role in the production of their final product (i.e., the commercial). The video demonstrated individual and group accountability. Both students individually contributed by scripting and saying their respective lines, which influenced the overall group project. With regards to the Use of ICT for Learning level 5, the camera itself was necessary to create this collaborative video. The Use of ICT for Learning further allowed this group to create an authentic product (i.e., the commercial) that demonstrated their interpretation of solar energy. This authentic product was further created for a particular audience (i.e., their class). With regards to supporting knowledge construction, the video allowed students to document their interpretations of solar energy, but the knowledge construction itself was not very meaningful.
Overall, the above section demonstrates how students used tablets while collaborating. Depending on the level of Collaboration and the level of Use of ICT for Learning, certain unique intersections were uncovered such that there were high instances of Collaboration where students had shared responsibility and made substantive decisions together, but their work was not deemed interdependent.

**Skilled Communication**

The following section addresses the study’s first research question, which examined how the use of tablets for learning may foster Grade 5 students’ 21st century skills including: knowledge construction, collaboration, and skilled communication. The Skilled Communication learning activity rubric includes a set of codes with associated descriptors to indicate the level of skilled communication (Microsoft Corporation, 2015). The descriptors associated with Skilled Communication codes were already embedded with links to Knowledge Construction and Use of ICT for Learning through an emphasis on producing extended communication (Microsoft Corporation, 2015). Students had to connect more than one idea or use multimodal communication (Microsoft Corporation, 2015). A general summary of the descriptors for each level on the 4-point scale is provided along with the number of instances each code came up in the qualitative findings. These codes were then further analyzed to see the intersection between students’ level of Skilled Communication and Use of ICT for Learning from the queries run.

Examples of these instances and queries will be provided to demonstrate how the Use of ICT for Learning intersected to Skilled Communication.

Table 6 outlines the number of instances of Skilled Communication. Skilled Communication level 1 described that students do not produce extended or multimodal communication (Microsoft Corporation, 2015). Extended communication refers to
producing work with connected ideas and not a single thought (Microsoft Corporation, 2015). Multimodal communication refers to when students use more than one mode or tool to produce their work (Microsoft Corporation, 2015). After analyzing the qualitative data, there were 130 instances of students not producing extended or multimodal communication. Skilled Communication level 2 described that students do produce extended communication or multimodal communication but they do not provide supporting evidence or design their work for a particular audience (Microsoft Corporation, 2015). After analyzing the qualitative data, there were 48 instances of students demonstrating just extended or multimodal communication.

Skilled Communication level 3 described that students do produce extended communication or multimodal communication and provide supporting evidence: they explain their ideas or support a thesis with facts examples or they’re designing their communication for a particular audience but not both (Microsoft Corporation, 2015). After analyzing the qualitative data, there were 67 instances of students demonstrating extended or multimodal communication along with supporting their ideas or designing their work for a particular audience (i.e., their whole class). Skilled Communication level 4 described that students do produce extended communication or multimodal communication and provide supporting evidence (Microsoft Corporation, 2015). They also design their communication for a particular audience (Microsoft Corporation, 2015). After analyzing the qualitative data, there were 49 instances of students demonstrating extended or multimodal communication along with supporting their ideas and designing their work for a particular audience (i.e., their whole class).
Table 6

*Skilled Communication (COM)—Number of Instances Coded*

<table>
<thead>
<tr>
<th>COM level/code</th>
<th>No. of instances</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>130</td>
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<tr>
<td>2</td>
<td>48</td>
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<tr>
<td>3</td>
<td>67</td>
</tr>
<tr>
<td>4</td>
<td>49</td>
</tr>
</tbody>
</table>

*Note.* Skilled Communication levels/codes based on Microsoft Corporation’s (2015) *21 CLD Learning Activity Rubrics.*
Communication and Use of ICT for Learning

It was often the case that students’ Use of ICT for Learning intersected with Skilled Communication with regards to producing multimodal work and producing work for a particular audience. The levels with these descriptors embedded in them overlapped in the two learning activity rubrics. Depending on the level of Skilled Communication, certain levels of Use of ICT for Learning co-existed. This can be seen through the queries that were run between the four Skilled Communication codes and the five Use of ICT for Learning codes (see Appendix K). Codes that showed the most intersections were: Skilled Communication level 1 and Use of ICT for Learning level 2; Skilled Communication level 1 and Use of ICT for Learning level 4; Skilled Communication level 3 and Use of ICT for Learning level 2; Skilled Communication level 3 and Use of ICT for Learning level 5; Skilled Communication level 4 and Use of ICT for Learning level 3; Skilled Communication level 4 and Use of ICT for Learning level 5. Table 7 outlines the number of instances in these queries.

Skilled Communication level 1 and Use of ICT for Learning level 2. The query that was run for these two codes resulted in 51 instances. There were many instances of students reproducing knowledge through blog posts (i.e., posting screenshots without any extended communication) that were not multimodal and did not demonstrate a set of connected ideas. Furthermore, when students were communicating with one another in their pairs, instances of reading, practicing vocabulary words, and giving very minimal feedback through EasyBlog (e.g., good job!) were coded as Skilled Communication level 1. Use of ICT for Learning level 2 was coded when the tablets were used to support their learning, but during many instances of Skilled Communication level 1, students were using the tablet to practice basic skills or reproduce knowledge (Microsoft Corporation, 2015).
Table 7

*Skilled Communication (COM) and Use of Information and Communication Technologies (ICT) for Learning—Number of Instances Coded*

<table>
<thead>
<tr>
<th>Queries</th>
<th>No. of instances</th>
</tr>
</thead>
<tbody>
<tr>
<td>COM level 1 and ICT level 2</td>
<td>51</td>
</tr>
<tr>
<td>COM level 1 and ICT level 4</td>
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<td>26</td>
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<tr>
<td>COM level 4 and ICT level 3</td>
<td>12</td>
</tr>
</tbody>
</table>

*Note.* Skilled Communication and Use of ICT for Learning levels based on Microsoft Corporation’s (2015) 21 CLD Learning Activity Rubrics.
Skilled Communication level 1 and Use of ICT for Learning level 4. The query that was run for these two codes resulted in 64 instances. Within this query, students still presented Skilled Communication level 1. They communicated through a single thought instead of connected ideas (Microsoft Corporation, 2015). However, through the Use of ICT for Learning, students demonstrated a level of knowledge construction that required the tablet. One type of data that was of high frequency during this query was when students gave feedback that demonstrated some interpretation or evaluation of others’ work. For example, one group questioned another group’s interpretation of gravitational energy by commenting, “for gravity, you just stood on a rock?” Another group of students evaluated a post by saying, “good job, it seems like you learned a lot, but I got confused which were the pros and which were the cons.” The feedback posts such as these were still a single thought, but ICT was used to provide feedback to other groups’ posts. Technology was needed to provide efficient feedback within such multimodal posts.

Skilled Communication level 3 and Use of ICT for Learning level 2. The query that was run for these two codes resulted in 15 instances. Figure 13 presents a sample of data when this query was run. Figure 13 is a blog post that was coded as Skilled Communication level 3 because it demonstrates multimodal communication through the picture, hyperlink, and caption and it was intended for a particular audience. This group decided to design a post that would provide students with a resource. This example was further coded as Use of ICT for Learning level 2 because even though technology is required to take a screenshot of a website and provide an audience with an active Web link, these multimodal features did not visibly support this group’s level of knowledge construction. The level of multimodal communication for a particular audience was higher than the use of this multimodal technology to support knowledge construction for a particular audience.
Coal.
If you want to learn about coal visit
https://www.studentenergy.org/topics/coal?gclid=CPaWiKK1-MwCFQwPaQoddcPfg

Figure 13. EasyBlog app: Blog post on coal.
**Skilled Communication level 3 and Use of ICT for Learning level 5.** The query that was run for these two codes resulted in 26 instances. The NestCam videos captured students recording videos within the augmented reality apps. These instances were coded as Skilled Communication level 3. These screen-cast videos depicted the 3-D view of structures that turn different sources into energy (e.g., nuclear power plants) while also embedding another video into this screen recording so that students could see themselves in the screen-cast video.

The following is a transcript and the researcher’s observations from the NestCam recordings of students producing one of these screen-cast videos.

Student J: Is it nuclear energy? Yeah, nuclear.

Student K: Record this fun lesson...Hi!

Researcher observation: The group has created a video of the 3-D view. The student explains that they were highlighting the titles during the video.

Student J: Let’s put this on our blog.

Researcher observation: They turn on the recording feature again that’s embedded into the virtual reality video.

Student K: Record this fun lesson. This is fun alright.

Researcher observation: One student is interacting with the 3-D view and is pulling out the titles.

Student J: We are preparing. Let’s record it.

Researcher observation: They take a screenshot.

Student K: This is the downstream. The dam. Powerhouse. Upstream.

Researcher observation: They are going through the different features of the hydro energy so that their video records it all.
Student J: So what does the powerhouse do?

Student K: I have no idea, what does the powerhouse do?

Student J: Maybe it controls everything that is happening in it.

Researcher observation: Students are interacting with the tablet and pulling out the titles within the 3-D view of the hydro plant.

This transcript and the researcher’s observations demonstrate Skilled Communication level 3 because students were able to manipulate a 3-D figure, view text within the figure, and verbally express the different parts of the structure. They are further able to document all of these different types of multimodality through the recording feature. Skilled Communication level 3 was also coded for because students were producing a recording for a particular audience. This was evident in the way they were speaking while recording and when students mentioned uploading this to their blog. With regards to the Use of ICT for Learning, students often started to question and interpret what they were viewing within the augmented reality and 3-D view structures. At the end of this NestCam observation, students started to question and interpret what the powerhouse does. Since this instance of knowledge construction required the use of technology (i.e., manipulating the different parts of a hydro plant) while they were creating a product for authentic users, it was coded as Use of ICT for Learning level 5.

**Skilled Communication level 4 and use of ICT for Learning level 3.** The query that was run for these two codes resulted in 12 instances. Figure 14 presents an example of data that came up when this query was run. This mind map was posted on this group’s blog. The photograph was downloaded from their blog. In Figure 14, students
Figure 14. Popplet app: Mind map on solar energy proposal plan.
Demonstrated Skilled Communication level 4 through extended communication. Students connected more than one idea to explain why solar power is the best energy source to use. This group further researched facts and provided evidence to support their thesis. Finally, their work was developed as a proposal plan for the government to try and convince them to fund their source of energy production. Their work was in the beginning stages of being designed for a particular audience. However, the Popplet was further shared with on their blog so it could have been designed as a rough draft for other groups to view and provide feedback on. With regards to Use of ICT for Learning, this group did use the mind mapping app, Popplet to support their level of knowledge construction. However, all of these points could have been developed and presented without the use of technology. The Use of ICT for Learning code would have been higher if they had embedded pictures or videos into their blog post.

Figures 15 and 16 demonstrate Skilled Communication level 4 because students show a set of connected ideas regarding the pros and cons of using coal as a source of energy. Students further produced this extended communication in a multimodal way by including a picture and hyperlink. This picture and link informed the Use of ICT for Learning level 5 code because students would not have been able to provide a real-life photograph without technology and would not have been able to embed a link into their text efficiently. Furthermore, Skilled Communication level 4 and Use of ICT for Learning level 5 were coded because students communicated and produced a product for authentic users/audience (e.g., their class).

Overall, the above section demonstrated how students used tablets while communicating. Depending on the level of Skilled Communication and the level of Use of ICT for Learning, certain intersections existed. There were no meaningful intersections between Skilled Communication level 2 and Use of ICT for Learning. Students tended to produce work with multiple modes or extended communication for a particular audience, which indicated Skilled Communication level 3.
Coal is a fossil fuel. It is non-renewable because it takes hundreds of years to be made and people use it like it takes thirty seconds to be made. Coal is transformed into energy by

Figure 15. EasyBlog app: Blog post on coal (Part 1).
crushing it up so it burns faster. The negative effects are that it pollutes the earth. Positive effects are that it is use for a lot of things here on earth e.g factories and lots of other things. I think that people need to stop using it because of the earth and a better future. Please watch this video on this website!

https://www.studentenergy.org/topics/coal?gclid=CPaWlKK1-MwCFQwPaoQoddrcPfg

*Figure 16.* EasyBlog app: Blog post on coal (Part 2).
Use of Tablets for Learning: Knowledge Construction in Science, Reading Comprehension, and Vocabulary

The following section addresses the study’s second research question to determine if the use of tablets for learning could build students’ knowledge in science concepts, reading comprehension, and vocabulary development. The results of the dependent t-tests (Hurlburt, 2003) for both raw and scale scores from pre to post-intervention are presented (see Table 8). Where significant differences existed on the dependent t-tests, the effect sizes were calculated using Cohen’s d (Cohen, 1960). Questions on the science test were further enumerated through an item analysis, then clustered by concepts and cross-confirmed with findings from the different levels of Use of ICT for Learning and Knowledge Construction.

Reading Comprehension Test

A dependent t-test generated the following results for the reading comprehension raw scores: \( t(20) = -1.82, p = 0.084 \). There was no statistically significant improvement from the pre-test raw scores (M=25.14; SD=7.36) to post-test raw scores (M=26.57; SD=7.74) following the interdisciplinary science and language arts unit.

A dependent t-test generated the following results for the reading comprehension scale scores: \( t(20) = -1.46, p = 0.162 \). There was no statistically significant improvement from the pre-test raw scores (M=508.38; SD=33.62) to post-test scale scores (M=516.48; SD=30.05) following the interdisciplinary science and language arts unit.

Vocabulary Test

A dependent t-test generated the following results for the vocabulary raw scores: \( t(20) = -0.132, p = 0.896 \). There was no statistically significant improvement from the pre-test raw scores (M=25.81; SD=4.98) to post-test raw scores (M=25.90; SD=5.67) following the interdisciplinary science and language arts unit.
Table 8

*Summary of Scores from Reading Comprehension, Vocabulary, and Science Tests*

<table>
<thead>
<tr>
<th>Test</th>
<th>N</th>
<th>M</th>
<th>SD</th>
<th>t</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pair 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Comp. raw score T1</td>
<td>21</td>
<td>25</td>
<td>7.36</td>
<td>-1.82</td>
<td>.084</td>
</tr>
<tr>
<td>Comp. raw score T2</td>
<td>21</td>
<td>26</td>
<td>7.74</td>
<td>-1.82</td>
<td>.084</td>
</tr>
<tr>
<td>Pair 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Comp. scale score T1</td>
<td>21</td>
<td>508.38</td>
<td>33.62</td>
<td>-1.46</td>
<td>.162</td>
</tr>
<tr>
<td>Comp. scale score T2</td>
<td>21</td>
<td>516.48</td>
<td>30.05</td>
<td>-1.46</td>
<td>.162</td>
</tr>
<tr>
<td>Pair 3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vocab. raw score T1</td>
<td>21</td>
<td>25.81</td>
<td>4.98</td>
<td>-.132</td>
<td>.896</td>
</tr>
<tr>
<td>Vocab. raw score T2</td>
<td>21</td>
<td>25.90</td>
<td>5.67</td>
<td>-.132</td>
<td>.896</td>
</tr>
<tr>
<td>Pair 4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vocab. scale score T1</td>
<td>21</td>
<td>505.81</td>
<td>32.72</td>
<td>-.29</td>
<td>.780</td>
</tr>
<tr>
<td>Vocab. scale score T2</td>
<td>21</td>
<td>507.19</td>
<td>38.58</td>
<td>-.29</td>
<td>.780</td>
</tr>
<tr>
<td>Pair 5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Science raw score T1</td>
<td>21</td>
<td>10.29</td>
<td>4.68</td>
<td>-7.99</td>
<td>.000</td>
</tr>
<tr>
<td>Science raw score T2</td>
<td>21</td>
<td>17.10</td>
<td>6.95</td>
<td>-7.99</td>
<td>.000</td>
</tr>
</tbody>
</table>

*Note.* Comp. = comprehension; Vocab. = vocabulary.
A dependent t-test was conducted and generated the following results for the vocabulary scale scores: \( t(20) = -0.29, p = 0.780 \). There was no statistically significant improvement from the pre-test raw scores (M=505.81; SD=32.72) to post-test scale scores (M=507.19; SD=38.58) following the interdisciplinary science and language arts unit.

**Science Test**

A dependent t-test was conducted and generated the following results for the science test raw scores: \( t(20) = -7.99, p = 0.000 \). There was a statistically significant improvement from the pre-test raw scores (M=10.29; SD=4.68) to post-test raw scores (M=17.10; SD=6.95) following the interdisciplinary science and language arts unit.

Cohen’s \( d \) was run to determine the effect size of significant growth in the science raw scores following the interdisciplinary science and language arts unit. There was large effect size (McGraw & Wong, 1992), \( d = 1.15 \) (17.1 - 10.29), \( p < 0.0005 \) indicating strong growth is science test performance from pre- to post-intervention.

**Science Test Item Analysis**

To deconstruct the questions on the science test and determine if there were distinct growth trends in students’ science performance, an item analysis was conducted. Each question item on the science test was coded for the concept that it was querying. The eight codes for the concepts in this item analysis included: Definition of Energy; Potential vs. Kinetic Energy; Identifying Forms of Energy and Giving Examples; Type of Energy Sources; Renewable vs. Non-Renewable Identifications; Renewable vs. Non-Renewable Definition; Law of Conservation of Energy; Energy Transformations. The codes were culled as a means of identifying if there were apparent growth trends in the raw scores in certain concepts. The four concepts each had growth percentages in raw scores from pre-test to post-test Potential vs. Kinetic Energy, Types of Energy Sources, Renewable vs. Non-
Renewable Identifications, and Renewable vs. Non-Renewable Definition. See Table 9 for the percentage of increase results.

Overall, many of the apps used in this study were content specific. Students learned knowledge of scientific concepts and were able to access features within the apps to support this knowledge construction. In one of the student interviews, a student identified how the tablets were able to help support his knowledge of these scientific concepts:

Researcher: Anything about the technology itself that was exciting for your or different?

Student L: Um, not really.

Researcher: Did it help you in a certain way?

Student L: Well it did because um because there was a help button in some apps if you needed help explaining it. …When we weren’t sure of something or if we didn’t understand what they were saying or my [partner] or I would explain to my partner or she would explain to me what that means. If we didn’t know and we still didn’t know, we would ask the teacher.

Researcher: So what kind of help did it give you?

Student L: It explained the words sometimes because we did not know what the words meant. It might have been BrainPop.

This instance in the qualitative data was coded as Use of ICT for Learning level 4 because the tablet was required to provide a help button feature and the technology supported students’ knowledge construction. This help button seemed to make it easier for students to spark conversation and contextualize their understanding of scientific concepts. Since the student mentioned how the help button supported their explanation to one another, this contributed to a level of synthesis and interpretation.
### Table 9

*Science Test Item Analysis*

<table>
<thead>
<tr>
<th>Science concept</th>
<th>(% increase)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potential vs. kinetic</td>
<td>13</td>
</tr>
<tr>
<td>Types of energy sources</td>
<td>31</td>
</tr>
<tr>
<td>R vs. RN identification</td>
<td>20</td>
</tr>
<tr>
<td>R vs. RN definition</td>
<td>57</td>
</tr>
</tbody>
</table>

*Note.* R = renewable; RN = non-renewable.
With regards to growth trends, students seemed to develop their vocabulary of specific words within the interdisciplinary unit. It is important to point this out because even though students’ overall vocabulary development did not increase, their vocabulary development with science specific words may have been enhanced through the use of help buttons embedded within apps.

**Potential vs. kinetic energy.** The growth trend for this section of questions might be attributed to the fact that multiple groups of students found a particular activity in the Kids Discover app to be useful. Two groups of students took a screenshot similar to those shown in Figures 17 and 18 from the Kids Discover app.

This picture was coded as Knowledge Construction level 1 and Use of ICT for Learning level 2 because students were reproducing knowledge while using the tablet. They were not constructing their own knowledge and the Use of ICT for Learning was not required for this task. However, since this post was available for other groups to view in the EasyBlog app, it could have contributed to the growth trend when students applied their knowledge of potential vs. kinetic energy on the science test. Furthermore, Kids Discover is multimodal, and students were able to manipulate a slingshot to better understand the difference between potential vs. kinetic energy. Students can use their fingers to pull the slingshot back and then watch the stone “crash” the tablet screen (see Figure 18).

**Types of energy sources.** The growth trend associated with types of energy sources could have been attributed to students’ exploration with the augmented reality and 3-D view apps. There were eight different apps and each focused on a different structure that turned a source (e.g., solar) into energy (e.g., solar panels). These
included augmented reality apps for a: wind turbine, windmill, hydro power plant, nuclear power plant, solar panels, etc. Many of the video recordings that students made showed students manipulating these structures by viewing them from different angles and even taking the structure apart. When students had to then identity the source of energy that the structure uses in the science test, students may have applied their knowledge from the augmented reality and 3-D structure apps. These videos were recorded as Use of ICT for Learning level 2 or level 3 depending on whether the structures sparked a level of knowledge construction. The instances of using these apps were often coded under Knowledge Construction level 1 or level 2 because students were either reproducing knowledge or constructing knowledge when it is not required in the lesson. In other words, students were learning knowledge about something or they were learning knowledge about something and beginning to conceptualize knowledge of something. The knowledge construction was not the main purpose of student learning in these instances.

**Renewable vs. non-renewable identification.** When students viewed different pictures and had to identify the source of energy on the science test, they also had to identify if it was renewable or non-renewable. Students further had to provide a definition of renewable vs. non-renewable energy. One of the tasks that students had to complete in the science unit was to compare and evaluate the pros and cons of a source of energy. When students worked on this task, they had to further identify if it was renewable vs. non-renewable. Figure 19 shows an example of a PicCollage posted on the EasyBlog app that one group of students created to compare and evaluate the pros and cons of coal as a source of energy.
You can think of energy as something that can be stored (potential energy) or something that flows from place to place (kinetic energy). A slingshot stretched to its limit has potential energy. That is, it has the capability of doing work in the future. Once the elastic is released, the stone has kinetic energy, the energy of something in motion.

*Drag the bar to pull the elastic back and maximize the slingshot’s potential energy.*

*Figure 17. Kids Discover app: Potential vs. kinetic energy text.*
Figure 18. Kids Discover app: Potential vs. kinetic energy text.
Figure 19. PicCollage app and EasyBlog app: Blog post on coal.
When instances of this task came up in the qualitative data, it was often coded as Knowledge Construction level 5 because students created a visual that demonstrated interdisciplinary learning (i.e., reading comprehension with scientific facts), and they further applied their learning in a new context by synthesizing their work into a blog post. The Use of ICT for Learning was therefore informed and coded as level 5 since these visuals were created for a particular audience and were multimodal, which required the Use of ICT for Learning.

The growth trend in the science test could have been a result of students posting these visual products for other students to learn about different renewable vs. non-renewable energy. Figure 20 shows a less multimodal example of another group’s comparison and evaluation of solar energy. This task also demonstrates how students would have had to understand the difference in definition between renewable and non-renewable energy.

With respect to the other codes for the science test item analysis, there was no significant growth in the overall Definition of Energy section because students for the most part got that section right during the pre- and the post-test. The Forms of Energy Section did not show much growth. This could be due the amount of time students spent on interpreting forms of energy instead of consolidating this learning more concretely. Students were given some explanation about different forms of energy, but when they were asked to identify different forms of energy, there was a discrepancy between their vocabulary use and their interpretations. This discrepancy can be seen in Figure 21, which depicts one of the PicCollages that students were required to make after identifying different types of energy outside in the schoolyard. The water tower is not a type of energy. After analyzing the qualitative data, there were no instances of students learning or discussing why the water tower is not a type of energy.
We decided to do solar energy because we knew a lot about it.

It is a renewable energy because it is the sun so it will never run out and every hour the sun shines has enough energy to last the whole world for a year.

Solar panels are expensive to buy and put on a roof so not many people have them. Most people will use nonrenewable energy.

The government should support our company because solar energy is better for the earth. Other resources for example, coal and oil, will some day run out.

*Figure 20.* EasyBlog app: Blog post on solar energy.
Figure 21. PicCollage app: Collage on forms of energy.
The qualitative data also demonstrated very few instances where students discussed the item analysis code, Energy Transformations. This was a topic covered in the Kids Discover and Energy HD app. However, this was not documented in the qualitative data and might be the reason why there was little growth in this section. With regards to the item analysis code, Law of Conservation of Energy, this concept was not addressed anywhere in the qualitative data and is probably why no students answered these questions well.

**Growth Trends in Language Arts**

Although the pre- and post-tests for vocabulary and reading comprehension did not show any statistically significant growth, triangulation of qualitative data may help explain this. As seen in Figure 19, students used reading comprehension skills to synthesize, analyze, interpret, and evaluate different scientific concepts. The teacher did not provide any explicit instruction in reading comprehension skills to support their knowledge construction. However, some groups, as seen in Figure 19, were able to produce quality work that demonstrated reading comprehension. They were able to demonstrate interdisciplinary knowledge with regards to the content, important ideas, and method from both academic subjects (Microsoft Corporation, 2015).

Some instances within the qualitative data were coded as Knowledge Construction because students were still interpreting or evaluating ideas. However, there was not a high level of reading comprehension within some students’ work. Figure 22 presents an example of a students’ reading response interpreting and evaluating energy. There was not a high degree of synthesis to connect ideas and use facts to analyze his overall understanding of energy. This could have been a result of the lack of emphasis on explicit student learning of these higher-order thinking skills embedded in the lessons. Figure 22. does not present interdisciplinary learning of content or important ideas.
Energy is cool. I wonder when it started? If solar is natural why did that dude Thomas something, have to invent it. Also we don't need electricity why isn't everything solar powered. It would SOOOOO easy because we wouldn't need wifi and stuff we would need the sun. We could build solar panels into the iPads then the sun could give us power. The sun is everywhere so it would be a walk in the park. Or we could find the earths core and like inject wifi into it so EVERYONE CAN HAVE WIFI!!!!!! Yayyy! But we don't even need screens. Also why is there pollution. It wrecks our all natural world. And the smoke and other poop doesn't even help us. After this I hope you agree with me.-Sam

Figure 22. EasyBlog app: Blog post on energy.
The vocabulary pre- and post-test also resulted in no significance growth after the intervention. The qualitative data generally demonstrated students’ learning and application of science specific vocabulary. There were no instances of students explicitly learning about different vocabulary words or how to understand words within other contexts. In many of the science content apps, students were able to access help buttons to support their science vocabulary development. This may have therefore contributed more to the growth in the science test items that relied on vocabulary understanding rather than the standardized vocabulary test.

Overall, the item-analysis provided more insight into growth trends among different sections within the science test. Based on the triangulation of qualitative and quantitative data, students seemed to have had more opportunity to learn and explore topics about Potential vs. Kinetic Energy, Types of Energy Sources, Renewable vs. Non-Renewable Identification, and Renewable vs. Non-Renewable Definition. Furthermore, the instances of where students used multimodal features within apps seemed to be linked to students’ level of understanding. In other words, the science concepts that students showed the most growth on seemed to be the concepts that students learned through multimodal texts, conceptualized through multimodal features embedded within apps, or reproduced through their blog for others to learn about. With regards to vocabulary development, some growth trends were observed in science specific vocabulary (on the science test), which seemed to happen when students were developing vocabulary in this specific context (science). Furthermore, students seemed to demonstrate reading comprehension skills with regards to the interdisciplinary methods they used to construct and communicate their knowledge of scientific concepts through reading responses in the science unit of study (not on the reading comprehension test).
Summary of Findings

With regards to the first research question, “How can the use of tablets for learning foster Grade 5 students’ 21st century skills including: knowledge construction, collaboration, and skilled communication?” the Use of ICT for learning level 2 (71 instances) and level 5 (69 instances) were the most pervasive. This means that there were high instances of students using tablets to support the reproduction of knowledge. Furthermore, there were high instances of students constructing knowledge in a way that required the use of ICT, and this ICT was used to create a product for authentic users.

With regards to constructing knowledge, the most instances (91) were coded under level 3 Knowledge Construction where students had to construct knowledge, but not apply this knowledge in a new context. With regards to collaborating, the most instances (80) were coded under level 4 Collaboration where students had shared responsibility and made substantive decisions together, but their work was not deemed interdependent. Furthermore, when looking at the Skilled Communication code, instances within the four levels for Skilled Communication showed that there were 130 instances of students not producing skilled communication. With regards to skilled communication, the most instances (130) were coded under level 1 Skilled Communication where students did not produce extended or multimodal communication. Furthermore, through the queries run in this study, it is apparent that the way students use tablets has a relationship to the quality of Knowledge Construction, Collaboration, and Skilled Communication. This corroborates that the use of ICT for learning can support students’ development of 21st century skills.

With regards to the second research question, “How can the use of tablets for learning build students’ knowledge construction in science concepts, reading
comprehension, and vocabulary development?” the dependent t-tests run for students’ raw scores and scale scores in reading comprehension and vocabulary did not find statistically significant changes from pre-test to post-test. The dependent t-test conducted for the science test did yield a statistically significant growth in students’ scores. Through the item analysis of sections embedded within the science test, Potential vs. Kinetic Energy, Types of Energy Sources, and Renewable vs. Non-Renewable Identifications and Definitions showed the most growth among students. Qualitative data showed that certain apps provided multimodal diagrams for students to manipulate and understand these concepts.

After analyzing the insignificant results from the vocabulary and reading comprehension tests, it seems that students’ lack of growth could have been a result of less time focused on understanding the vocabulary and content embedded within the interdisciplinary unit. Instances of students reading in content learning apps and producing reading responses in learning creation apps or informational management apps, engendered interdisciplinary learning that was not measured through the standardized pre- and post-tests. Overall, growth trends do not corroborate that students were able to construct knowledge in language arts and reading comprehension.
CHAPTER FIVE: DISCUSSION, IMPLICATIONS, LIMITATIONS, AND CONCLUSIONS

Education in the 21st century falls short of moving beyond traditional teaching practices and towards skills students will need to be active citizens in their future (Drew, 2012; Larson & Miller, 2011). Surprisingly, with the hype of new and innovative ICT within 21st century learning frameworks, there is a lack of research to support their pedagogical implications and learning value to scaffold the development of 21st century skills and support knowledge construction in subject-specific content (Falloon, 2014; Gallagher et al., 2015; Groff & Mouza, 2008). This leaves educators challenged with understanding the connectedness between tablets, 21st century learning, and curriculum (Gallagher et al., 2015). It is imperative that educators and researchers consider the educational implications of ICT.

It is therefore timely to investigate the new technologies emerging in the 21st century to better understand if certain features within them can support students in developing the essential skills they need to be successful in their future. The current study references the 21st Century Vision of Public Education for Canada (C21 Canada, 2012) framework. The 21st century skills embedded within this framework have been discussed in relation to academic research as a means to provide a theoretical underpinning for why the use of ICT for learning may be able to support these 21st century skills. With the pervasive use of tablets and their available apps (Apple Inc., 2017), it was central to this study’s rationale to determine the role tablets play in supporting students’ 21st century skills while also analyzing their role in constructing subject-specific knowledge.
Discussion of the Findings

The purpose of this study was to research how information and communication technologies (ICT), specifically tablets, may foster the 21st century skills of knowledge construction, collaboration, and skilled communication and may further support knowledge construction in science, reading comprehension, and vocabulary development. This study anticipated that features within tablets support the learning of 21st century skills. Hopefully by fostering these 21st century learning practices, students will develop the skills they need to be productive and active citizens (Claxton, 2014).

The Role of Tablets to Support Learning

Knowledge is no longer acquired in a linear manner and solely through print-based texts (Rowsell & Walsh, 2011; Serafini, 2012). C21 Canada (2016) stresses the importance of using technology for learning to support 21st century skills; this competency is referred to as the Use of ICT for Learning. To answer the current study’s first research question—“How can the use of tablets for learning foster Grade 5 students’ 21st century skills, including: knowledge construction, collaboration, and skilled communication?”—findings are drawn from students’ activities that involved the Use of ICT for Learning. With reference to the learning activity rubrics for this skill (Microsoft Corporation, 2015), level 2 (71 instances) and level 5 (69 instances) were the most pervasive. With respect to level 2, this suggests that there were many instances of students using tablets to support the reproduction of knowledge. This might be attributed to the fact that students spent a great amount of time on content learning apps (e.g., Energy by Kids Discover) where students rehearse, reinforce, practise, and assess curricular content (Domingo & Garganté, 2016). Furthermore, with respect to level 5, there were high instances of students constructing knowledge in a way that required the
use of ICT to create a product for authentic users. Students also spent a lot of time during the intervention using informational management apps where they were able to collate information within a specific context and provide a more informal learning environment (Domingo & Garganté, 2016). This was most often seen when students used the EasyBlog app as a form of social media to share their knowledge construction.

Thompson’s (2013) study found that contemporary students often use rapid communication technology and Web resources such as social networking, instant messaging, or Web browsing. By contrast, it is less often the case that students manipulate information and are proficient in the use of all ICT (Thompson, 2013). It has been suggested that teachers need to provide students with more scaffolding and explicit instruction on how to use digital platforms (Bennett & Maton 2010; Kennedy et al., 2010; Thompson, 2013). This call to action is rooted in Vygotsky’s (1962) concept of the zone of proximal development where students’ learning is scaffolded, when students are provided support from teachers, peers, or other adults to learn a new concept (Powell & Kalina, 2009). In the current study, the high number of instances of students’ use of the tablets as a digital platform to share knowledge on the blog could be attributed to the time dedicated to teach these students about what makes a good blog. During the intervention, students were given time to explore and interpret blogs on the Web, evaluate them, and then analyze and synthesize information through a mind map. The high level of instances where students constructed knowledge (at level 5 for the Use of ICT for Learning) through the EasyBlog app may have been as a result of this scaffolding provided at the beginning of the unit.

To fully appreciate how the use of ICT for learning supported students’ learning in the other 21st century skills, the following sections provide a discussion of the findings
in light of literature in response to the first research question, “How can the use of tablets for learning foster Grade 5 students’ 21st century skills, including: knowledge construction, collaboration, and skilled communication?” The role of tablets to support each of these three 21st century skills will be discussed in separate subsections.

**The Role of Tablets to Support Knowledge Construction**

With reference to Cognitive Constructivism (Piaget, 1963), the findings suggest that students constructed knowledge through the tablets using higher-order thinking skills such as analyzing, interpreting, synthesizing, and evaluating. Students *analyzed* information during learning activities when they had to determine what makes a good blog. Students demonstrated their knowledge of the parts that make up a whole blog and the relationship these parts have to one another—that is, how the pictures match the text (Microsoft Corporation, 2015). There were activities in which students demonstrated the *interpretation* of information by taking videos to document their understanding of scientific concepts (i.e., forms of energy) beyond the literal meaning—that is, finding their own examples outside in the school yard (Microsoft Corporation, 2015). Students demonstrated the *synthesis* of information by comparing and contrasting the pros and cons between using different sources of energy. Further, both synthesis and analysis were supported with the use of digital mind mapping tools (e.g., Popplet). Finally, students engaged in the *evaluation* of information by appraising the quality and importance (Microsoft Corporation, 2015) of certain sources of energy. Through the EasyBlog app and Popplet app, students often organized and represented their evaluative thoughts.

However, there are some distinctions when interpreting the findings in light of the theory of Connectivism (Siemens, 2005). The connectivist learner is seen as nurturing and maintaining connections to facilitate continual learning and works toward developing
the ability to synthesize and recognize connections among fields, ideas, and concepts (Thota, 2015). In the present study, there were not enough instances of students synthesizing information within the networked blog (i.e., EasyBlog) in the way that is consistent with practices of the connectivist learner. There were some instances where students did express how they used other students’ feedback to edit their own work. After careful analysis, students did not seem to make significant changes to their work based on feedback that would constitute synthesis in keeping with Connectivism.

The findings from the current study suggest that when students were not constructing knowledge, they tended to be reproducing knowledge from within texts. Students used tablets to reproduce screenshots (some were captioned) taken from content learning apps. Students spent a lot of time during the intervention developing the most basic forms of explicit knowledge, which are easy to articulate, recognize, and recall formally (Anderson et al., 2011; Nonoka & Takeuchi, 1995). This presents such that there was less emphasis on higher-ordering thinking skills throughout the intervention that contributes to knowledge construction. However, even traditional teaching and learning practices based on rote memorization are subject to the way students interpret, argue about, and evaluate information (Bereiter & Scardamalia, 2014). In other words, the acquisition of factual knowledge is still useful as it is necessary for students to see connections within other disciplines (Scardamalia & Bereiter, 2006). Content-based knowledge is the basis for students’ application of knowledge to solve problems in other contexts (Scardamalia & Bereiter, 2006).

Instances of students not constructing knowledge of something, but rather, constructing knowledge about something does not mean that a conceptual understanding of factual knowledge will not be sparked (Anderson et al., 2011; Bereiter & Scardamalia,
Instances of students manipulating augmented reality and 3-D apps were intended to build students’ knowledge of scientific factual knowledge. Further, instances of students interpreting and creating embedded videos in the screen-casts seemed to happen as a function of students using technology to build content knowledge. This confirms what research (Walsh & Simpson, 2013) suggests that built-in features like hyperlinks or Web links, photo diagrams, or graphics on digital screens have the potential to scaffold students’ interpreting, analyzing, synthesizing, and evaluating skills to determine what information is most important.

At level 2 of Knowledge Construction, students used tablets for the EasyBlog app to comment and provide feedback on each other’s blog posts. Some of the posts students responded to were multimodal. With the unlimited number of multimedia sources and collaborative online environments, it is suggested that students adopt a more critical use of the content available online (Argentin et al., 2014). Students need to be digitally literate to access and navigate information on the Web, analyze and evaluate this information, compose and create new artifacts, engage in reflective thinking, and share knowledge or collaborate with others through the Web (Green et al., 2014; Hobbs, 2011; Istance & Kools, 2013; Meyers et al., 2013). As students used the EasyBlog app, they became familiar with attempting to evaluate and comment on their peers’ work through multimedia sources. However, the students’ critiques did not demonstrate depth of evaluation and were not always expanded on.

When students engaged in activities that represented Knowledge Construction level 3 they were evaluating, analyzing, and synthesizing using mind maps. This is consistent with the use of higher-order thinking skills to support knowledge construction (Anderson et al., 2001; Larson & Miller, 2011), but not the application of this knowledge
in other contexts (Scardamalia & Bereiter, 2006). At this level of knowledge construction, students used tablets for the Popplet app where they were able to efficiently connect ideas and embed real-life photographs to support the text. The use of mind maps are deemed a cognitive tool to help students keep their learning succinct and focused on the main topic (Wu et al., 2016). While using mind-mapping apps, students were often synthesizing and analyzing information. These higher-order thinking skills required students to make connections between ideas and analyze these connections as part of a whole (Microsoft Corporation, 2015). Consistent with other studies, students used the Popplet app to support knowledge construction by moving notes (i.e., bubbles), adding notes, deleting notes, and connecting notes. Representations of students’ knowledge were therefore concentrated (Wu et al., 2016) and efficient.

Findings that relate to students’ Knowledge Construction at level 4 were instances in which students interpreted the work of others in relation to what they learned in a new context. This is consistent with knowledge of learning as students applied their conceptual knowledge in other contexts (Anderson et al., 2001). At this level of knowledge construction, students used tablets to access other’s work in the EasyBlog app. Students used PicCollages to understand how other students interpreted the forms of energy and these interpretations were exemplified by students comparing and contrasting information between their PicCollages. The features embedded within these apps offered affordances for students to not only communicate their ideas, but to also support each other’s interpretations and conceptual understandings (Anderson et al., 2001). The multimodal intuitive logic within apps may suggest why students are able to interpret their peers’ work (Gallagher et al., 2015). The built-in features embedded within the app, PicCollage, facilitate certain interpretations to be made from the original photographs.
Instances of Knowledge Construction at level 5 were evident in students’ reading responses about scientific concepts. At this level of knowledge construction, students demonstrated their conceptual knowledge by applying their learning in another context (Scardamalia & Bereiter, 2006) and also by demonstrating knowledge construction in more than one subject—that is, language arts and science (Microsoft Corporation, 2015). There were a number of instances where students used tablets to support the skills necessary for interdisciplinary learning (Drake et al., 2013). Students used tablets to fluidly flip back and forth between content learning apps (e.g., Kids Discover) and informational management apps (e.g., EasyBlog). This seemed to support an interdisciplinary method to learning where the lines between disciplines were blurred (Drake & Burns, 2004). Furthermore, students also represented their typed reading responses with embedded pictures in their posts. These pictures were usually screenshots taken from content learning apps where students read information and then uploaded into their EasyBlog page. Overall, students demonstrated a level of knowledge construction that resembles interdisciplinary learning in language arts and science. This is consistent with findings from a study of elementary teachers who integrated multimodal texts, hands-on science activities, and literacy skills (Gallagher & Fazio, 2016). This study determined that when there were opportunities to build science knowledge through collaboration, communication, and multimodal literacy enhancements, Grade 5 students showed statistically significant cognitive gains in science, vocabulary, and reading comprehension (Gallagher & Fazio, 2016).

However, overall, at the highest level of Knowledge Construction (level 5), there were very few instances of students creating something new as a function of their learning (Paavola et al., 2004). Some digital platforms that may provide creative digital
working spaces are apps like iMovie, iStop Motion, and BookCreator (Milman et al., 2014). Some students did create commercials in iMovie as part of their final culminating task. However, these commercials did not always demonstrate deep learning and conceptual knowledge. Most knowledge creation artifacts were not embedded with enough evidence to demonstrate content knowledge in scientific concepts. Although the activities in the unit did provide students with ill-defined and ill-structured problems for students to interpret, analyze, synthesize, and evaluate (Antonenko, Jahanzad, & Greenwood, 2014), students did not seem to reach the stage of creating new artifacts. This could be because there was not enough instructional emphasis placed on assessing and monitoring students’ idea improvement (Scardamalia & Bereiter, 2006) during the creation of their culminating task—there was little emphasis on design thinking. Bereiter and Scardamalia (2014) use the term *design mode* to describe the activities associated with knowledge creation. Theorizing, invention, design, generating ideas, and idea searching are considered key activities within a design mode (Bereiter & Scardamalia, 2014). Overall, the use of tablets for learning supported students’ knowledge construction through the conceptualization of ideas within other contexts and interdisciplinary methods of learning, but they did not enter a design mode.

### The Role of Tablets to Support Collaboration

Encouraging student collaboration in learning is grounded in the theoretical framework of Social Constructivism with the premise that learning happens through social interactions (Vygotsky, 1962). In the digital era, learning may occur external to an individual where it is stored and manipulated by technological tools (Siemens, 2005). Instead of focusing on what is being learned in school, contemporary learning theories highlight the importance of learning within a digitally networked world (Siemens, 2005).
Given that knowledge construction may no longer take place solely within the individual learner, but rather, learning may be part of a networked process that occurs outside the individual within digital platforms where learners need to connect specialized sources of information (Siemens, 2005). The connection of specialized sources of information may happen through social networking where like-minded people digitally collaborate and construct knowledge together (Siemens, 2005), which makes it imperative that 21st century collaboration is critically examined in relation to the use of ICT like social media apps in tablets.

The findings from the present study indicated that there were instances of students not collaborating and of them not using tablets during learning activities. This seemed to happen most when students were making connections to concepts during the instructional unit, but it was not apparent that technology was used to support these connections to text, self, and the world. Consistent with Cognitive Constructivism (Piaget, 1953), these are instances where individual thought is constructed and interpreted by the learner through (connections to) personal experiences.

The findings that related to Collaboration level 2 were demonstrations of the students working together to give feedback to other groups. At this level of collaboration, students used tablets for the EasyBlog app to comment and provide feedback on each other’s blog posts. Some of the posts students responded to were multimodal, however, most of the feedback posts were minimal and did not require deep conceptual thought. This level of collaboration entailed students working together, but they did not have shared responsibility over a common product (Microsoft Corporation, 2015). However, when there were instances of students providing feedback, it demonstrated how collaboration can happen in both online and offline environments through the use of
tablets (Larson & Miller, 2011). Although minimal, tablets supported a level of collaboration only possible with the use of ICT as students were commenting and posting on multimodal texts that are not able to be viewed and commented directly on without the use of ICT.

At level 3 Collaboration, there were examples of the students sharing the responsibility of writing or reproducing information together as a group. At this level of collaboration, students used tablets to type responses in the EasyBlog app. These were sometimes supported by photographs embedded in the posts. Other research substantiates the importance of a shared responsibility as students conceptualize their own knowledge through questioning and critique, then collectively reconceptualizing shared knowledge concepts or objects (Engeström, 1999). As simple as typing a post on the EasyBlog app, students were required to share the responsibility of expressing while working on the tablets. There were a large number of these instances due to the fact that students were required to share a tablet and share their own blog page. Through this model, students had to collectively reconceptualize their work (Engeström, 1999), even if the learning task did not require making substantive decision.

Examples from the findings for Collaboration at level 4 are students producing complex reading responses that required decisions to be made about the content, process, or product of their work. Substantive decisions often came about as a result of inquiry-based learning activities. Other researchers concur that students can successfully support each other to understand and find solutions to problems (Maxwell et al., 2015). At this level of collaboration, students used tablets to type these posts in EasyBlog. During the inquiry-based learning process, it was also observed that students were working together to use content learning apps to research information for their inquiry projects. An
example of one of these inquiry projects included students choosing a source of energy and researching the pros and cons of its use. However, the findings showed that at this level, students did not necessarily have individual accountability (Paavola et al., 2004) because some students in the group took control of the writing more than others.

There were findings for Collaboration level 5 when students described how they worked together to make decisions. At this level of collaboration, students used tablets to access feedback and ideas from other groups in the EasyBlog app. This indicates that there was a decision-making process (Maxwell et al., 2015) that was considered over the content in their work and a level of interdependence (Paavola et al., 2004). Furthermore, students were able to not only collaborate offline by working together to create products for their blog, but they were further able to collaborate online by sending and receiving feedback (Larson & Miller, 2011). The use of social media confirms the value in apps like EasyBlog to support problem-solving, negotiation, and even knowledge construction among students through Web 2.0 technologies (Rowsell & Walsh, 2011).

The findings for Collaboration at level 5 also indicated that there was interdependence within groups. Students often made videos with iMovie to demonstrate their learning, which further demonstrated individual accountability by the roles they held. This speaks to the use of learning skills apps where students benefit from designing their own creative knowledge (Domingo & Garganté, 2016). When students were given freedom to produce authentic products, higher frequencies of interdependent collaboration were present.

Overall, students seemed to use tablets to support collaboration offline. The only instance of online collaboration was when providing evaluative feedback in the EasyBlog app. Collaboration through digital networks to create products together did not come to
light in this study. However, high instances of collaboration offline while working on
learning tasks were supported by the use of tablets for learning.

**The Role of Tablets to Support Skilled Communications**

It is said that students today are digital natives and are motivated by: twitch-speed, random access, graphics first, and quick-pay off (Prensky & Berry, 2001; Tapscott, 1999). Furthermore, it is believed that students today have a more natural and intuitive ability to navigate and manipulate new technologies compared to their predecessors (Oblinger & Oblinger, 2005; Prensky, 2007; Tapscott, 1999). However, more recent studies have found that very few students actually create through text, audio, and video (Thompson, 2013). Research seems to be uncovering a discrepancy between what students are thought to be capable of doing and what they can do with ICT for learning.

Instances of students not producing skilled communication were very high in this study. This means students did not demonstrate extended communication through the synthesis and analysis of ideas (Microsoft Corporation, 2015). Students often shared screenshots on the EasyBlog app without any extended communication to demonstrate learning or evidence to support this communication. Researchers stress the validity (Garcia et al., 2015) and diversity (Lewis-Spector, 2016) of information before publication. This was not apparent during these instances. Students did provide feedback to one another through the EasyBlog app; however, it was minimal (e.g., “good job!”) or evaluative (e.g., “I got confused which were the pros and which were the cons”) and did not show extended or multimodal communication.

Why the lack of skilled communication? Perhaps, it is because students are encountering a world of twitch-speed access to social media like Facebook and Twitter where users are in the hundreds of millions (Morrell, 2012) and less thought is dedicated
to why and what they are posting online. With social media pages like Instagram, Facebook, SnapChat, and Twitter, students are used to a world of sharing pictures with little explanation or even purpose. This could potentially explain the high instance of knowledge sharing with the absence of skilled communication.

There were findings related to Skilled Communication at level 3 in which students posted pictures that were multimodal and intended for a particular audience (Microsoft Corporation, 2015). At this level of skilled communication, students used tablets to share screenshots of websites and embed active hyperlinks so that other students could use their post as a resource for information on energy. This example is consistent with what researchers describe as different modes that students have access to through ICT like tablets; this method of communicating knowledge follows a nonlinear path (Rowsell & Walsh, 2011; Serafini, 2012). In order to create and read this type of text, students used tablets to share and access information through hyperlinks to other Web pages instead of flipping a page in a book. During this level of skilled communication, students in the study also used tablets to communicate for a particular audience (Microsoft Corporation, 2015). Groups of students in the study were assigned different sources of energy to research. They were then tasked with producing products for other students to access and learn from. When sharing pictures with hyperlinks, students were able to produce a multimodal resource within the EasyBlog app that considered the perspectives of the people who will be accessing this resource (Lewis-Spector, 2016). The tablet provided students with an efficient way of sharing multimodal texts for the purpose of supporting others’ knowledge development in their area of expertise.

Skilled communication at level 3 was also present in the findings when students were interacting with augmented reality and 3-D view apps. Initially, the augmented
reality and 3-D view apps were not intended for students to use as a learning skills app. Rather, they were intended for students to use as a content learning app. Students were assigned the task of rotating to different iPad stations where they could view different structures (e.g., solar panels) that turned different sources (e.g., the sun) into energy (e.g., solar energy). However, embedded within these apps, students discovered a feature where they could video record the screen-cast of their interactions within the 3-D view of the structure while also embedding a video of themselves into the screen-cast. This led students to naturally start communicating to explain what they were learning about. Many instances of this led students to save the video and upload it to their blog. This example demonstrates how students were producing a multimodal and nonlinear text through the screen-cast, embedded video, and audio recordings (Rowsell & Walsh, 2011; Serafini, 2012). They further produced these screen-cast videos for an intended audience, which in this case was their class. Overall, the tablet itself was very valuable during this instance. The multimodal touch-screen interaction of the tablet allowed students to pull out the titles of the different parts of the structure where just the screen was recorded, which made the video focus on just the app content. Furthermore, students were able to overlay their voices saying the vocabulary words and during some instances, interpreting what the different parts were. This demonstrated a very nontraditional way of communicating information (Rowsell & Walsh, 2011; Serafini, 2012).

Findings for Skilled Communication at level 4 included the students’ production of extended or multimodal products supported with evidence and for a particular audience in mind (Microsoft Corporation, 2015). Most often students communicated through blog posts or proposal plans. At this level of skilled communication, students not only embedded multimodal texts such as hyperlinks and pictures, but they further extended
communication through the synthesis and analysis of information gathered from these hyperlinks. Students also used mind-mapping apps to document the synthesis and analysis of connected ideas (Lewis-Spector, 2016) and provided supporting evidence for their thoughts. These videos were then posted on their EasyBlog page. This finding suggests that when tablets are used in this manner to support knowledge construction, there is evidence of how skilled communication in 21st century has changed and become significantly influenced by the multimodal features embedded within technology. Students are conceptualizing their communication, sharing their communication, and even accessing others’ communication in nonlinear ways (Milman et al., 2014; Walsh & Simpson, 2013). To produce skilled communication in the 21st century, students are indeed navigators and producers of multimodal texts.

The Role of Tablets to Support Knowledge of Science Concepts

With regards to the second research question, “How can the use of tablets for learning build students’ knowledge construction in science concepts, reading comprehension, and vocabulary development?” this study looked at how knowledge (Bereiter & Scardamalia, 2014) was developed during meaningful learning processes in science. Based on the results from the dependent t-tests, students demonstrated growth from pre-test to post-test in science content knowledge. There was a high effect size for this growth. An item analysis of the concepts embedded within the science test suggest that the following concepts showed the most growth: Potential vs. Kinetic Energy, Types of Energy Sources, and Renewable vs. Non-Renewable Identifications and Definitions.

Qualitative findings suggest that certain apps provided built-in help buttons and multimodal diagrams for students to manipulate and understand these concepts. This is consistent with other research that describes how features within apps may also play a
role in scaffolding students and how immediate, corrective feedback supports the development of subject-specific knowledge (Falloon, 2014). Other researchers (e.g., Hutchison et al., 2012; Walsh & Simpson, 2013) state that certain features within apps may scaffold students’ knowledge construction, such as: hearing text read to them through audio support; word-by-word tracking or highlighting sentences; picture animation; hyperlinked words with definitions built-in; hyperlinks to access Web pages; and, using finger actions to move, enlarge, or reduce images on the touch-screen interface. The current study uncovered similar findings where features like help buttons, could provide immediate clarification of concepts. Furthermore, other students were able to click on certain vocabulary words embedded within apps to immediately support their science vocabulary development. There were no additional steps needed to access this information (i.e., looking the word up in a dictionary). Also consistent with others (Hutchison et al., 2012; Walsh & Simpson, 2013), the current study found that the growth trends in certain scientific concepts were connected to specific instances of students manipulating interactive digital texts to understand these concepts. These interactive digital texts were accompanied by text to support students’ understanding.

Other knowledge was gained through students’ interaction and manipulation of virtual environments. The augmented and 3-D view apps provided students with a unique opportunity to become familiar with structures that would be very difficult to view in the real world. Other researchers agree that there is value in using virtual environments to enhance science curriculum (Ketelhut et al., 2010) and create more authentic learning experiences.

Furthermore, science concepts often include factual knowledge such as terminology, theories, models, and structures (Anderson et al., 2001). One of the foci in
science instruction includes the conceptualization of scientific facts within the natural world (Forester, 2004) leading to knowledge of these scientific concepts (Scardamalia & Bereiter, 2006). Results from the item-analysis of the science test found distinct growth trends in certain question clusters—students were demonstrating their understanding of conceptual knowledge. For example, some students created PicCollages to organize their synthesis and evaluation of different energy sources. Students learned factual knowledge about scientific concepts through content learning apps and then conceptualized their understanding of these facts through the synthesis and evaluation of these ideas (i.e., identifying pros and cons to energy sources) in PicCollage. Therefore, beyond 21st century learning, even the traditional teaching and learning practices based on rote memorization (i.e., learning factual knowledge about scientific concepts) were subject to the way students interpreted and evaluated their conceptualization of this information (Bereiter & Scardamalia, 2014).

The Role of Tablets to Support Reading Comprehension and Vocabulary Development

Traditional literacy encompasses the social practices and elements of literacy that are needed for print-based text reading and writing (Leu et al., 2013). This includes word recognition, vocabulary, comprehension, inferential reasoning, the writing process, spelling, literature responses, and other literacy expectations associated with traditional books or printed materials (Leu et al., 2013). With regards to the second research question, “How can the use of tablets for learning build students’ knowledge construction in science concepts, reading comprehension, and vocabulary development?” the results of the dependent t-tests indicated that there were no statistically significant gains in students’ reading comprehension and vocabulary scores from pre-test to post-test. This
suggests that reading comprehension and vocabulary were not explicitly taught in ways that are consistent with an integrated instructional approach to disciplinary literacy. Other research substantiates that reading, writing, and speaking are core practices embedded within the development of scientific knowledge (Cervetti et al., 2012). Engaging with scientific concepts is foundational for students when reading to learn and learning to read (Cervetti et al., 2012; Cervetti & Pearson, 2012; Romance & Vitale, 2001). Further, research suggests that literacy in the 21st century consists of the ability to read, write, speak, and listen through the use of higher-order thinking skills (Forster, 2004). Although students demonstrated the ability to interpret, analyze, synthesize, and evaluate while navigating multimodal texts (Serafini, 2012; Walsh & Simpson, 2013), they were not applying these skills to read for meaning in science learning contexts. This finding is not consistent with other studies (Cervetti et al., 2012; Fang, 2008; Moje, 2008; Shanahan & Shanahan, 2008).

Although students did not demonstrate growth in reading comprehension and vocabulary as measured on a standardized test, this does not mean that students did not build interdisciplinary skills within science and language arts. Reading in the 21st century requires students to retrieve information proficiently, understand multimodal texts, and use higher-order thinking skills to conceptualize information (Forster, 2004). These were not measured through the quantitative data collected.

The method (Microsoft Corporation, 2015) in which students gained scientific knowledge seemed to demonstrate interdisciplinary learning. For instance, an example of an interdisciplinary learning activity in literacy and science might consist of gathering scientific evidence to support arguments within a reading response. In this study, there were instances of students switching from science texts (e.g., Kids Discover App) to their
blog in order to post a reading response. Students used ICT to efficiently flip between content-based apps to content-creation apps—these activities contributed to the finding of 38 instances of students engaging in interdisciplinary learning.

The findings of this study are consistent with other research that contends that ICT can facilitate and scaffold students towards deeper reading comprehension (Hutchison et al., 2012; Leu et al., 2013; Milman et al., 2014; Rowsell & Walsh, 2011; Serafini, 2012; Walsh & Simpson, 2013). Students are required to become active participants while reading since digital texts are nonlinear paths and require the navigation of multiple modes to acquire information (Serafini, 2012). While reading online, students use the higher-order thinking skills embedded within the construction of knowledge such as evaluating information through a critical lens and synthesizing information to bring multiple sources of information together (Leu et al., 2013).

Although students did not make any statistically significant gains in vocabulary as measured on the standardized tests, students did show growth in science specific vocabulary words when an item analysis was completed on the science test questions. This could have been a result of features within the content learning apps where students could access help buttons to support their vocabulary development. It appears to be the case that students’ vocabulary development was supported while reading with hyperlinked words leading to definitions or online dictionaries (Walsh & Simpson, 2013), or digital graphics to represent words. Overall, qualitative findings point to the instances of students’ development of interdisciplinary methods of learning within language arts and science.

Implications for Theory

The theoretical foundation for this study was grounded on the C21 Canada (2012) framework. This framework was further interpreted through the learning theories of
Cognitive Constructivism (Piaget, 1963), Social Constructivism (Vygotsky, 1962), and Connectivism (Siemens, 2005). The 21st century learner possess seven key competences (C21 Canada, 2012); from these competencies, the present student analyzed four 21st century skills embedded within this framework: Knowledge Construction, Collaboration, Skilled Communication, and the Use of ICT for Learning (C21 Canada, 2012). This study further investigated whether the use of tablets for learning could support students’ development of these 21st century skills as well as knowledge construction within science and language arts.

**Recommendations for the Study of 21st Century Skills**

A concept that has been associated with knowledge construction is the term *knowledge creation*. Consistent with Constructivism, knowledge creation entails the formation of something new as a function of the learning process (Paavola et al., 2004). Before knowledge creation can take place, students must possess ideas and the skills to transform these ideas into new knowledge (Scardamalia & Bereiter, 2006) and make connections between other ideas (Drake et al., 2013). For students to use higher-order thinking skills and create new knowledge, authentic learning and problems need to be provided (Strimel, 2014). To spark the generation of ideas, lessons should authentically relate to real-life problems, offer hands-on experiences, and incorporate students’ cultural and natural environments so that learning becomes relevant and meaningful to students (Strimel, 2014). In this way, knowledge creation can be seen as a process to form knowledge that will advance the knowledge within a community (Scardamalia & Bereiter, 2006). In this study, the students’ use of tablets to support their knowledge construction did not demonstrate many instances of students creating new knowledge. When students did create new knowledge, it did not seem to be grounded in concrete
evidence to support this new knowledge. For instance, students created commercials to support why a certain type of energy should be used. However, their deep understanding of this type of energy was not present in the video.

The lack of meaningful knowledge creation activities could have been a result of students requiring the opportunity to focus on idea improvement. Idea improvement is a guiding principle to push students towards challenging their conceptions and understandings of knowledge (Scardamalia & Bereiter, 2006). Generating ideas throughout life is a typical activity, but a constant and sustained effort to improve ideas is not pervasive (Scardamalia & Bereiter, 2006). If students are to think like scientists, engineers, scholars, and designers, generating and revising ideas needs to be a goal of 21st century education (Scardamalia & Bereiter, 2006). Anderson et al. (2001) identified creating as the highest form of cognitive processing, and within creation, individuals need to be able to generate ideas, plan, and then eventually produce.

In traditional education models, students tend to think that the more they learn and understand, the less they need to learn and understand in the future (Scardamalia & Bereiter, 2006). In the 21st century classroom, students strive to develop the skills to continue to want to improve ideas and progress knowledge (Scardamalia & Bereiter, 2006). One way for students to move beyond idea improvement and towards more concrete knowledge creation is through design thinking. To expand intellectual capabilities, educators should foster the construction of new artifacts as a means to enhance knowledge construction among students (Paavola et al., 2004). Bereiter and Scardamalia (2014) use the term design mode to describe the activities associated with knowledge creation. Theorizing, invention, design, generating ideas, and idea searching are considered key activities within a design mode (Bereiter & Scardamalia, 2014).
Design thinking uses the higher-order thinking skills associated with knowledge of something to apply knowledge to a full range of problems (Bereiter & Scardamalia, 2014). For students, design thinking could mean the creation of knowledge that is new to them and not necessarily a whole new discovery. Therefore, future research should look more closely at examining idea improvement and design thinking to enhance knowledge creation as an important component to the 21st century skill of knowledge construction.

With regards to collaboration, collaborative programs like Google Docs and even Skype are consider synchronous systems where users can work simultaneously, share screens, manipulate drawings, and edit written text to create a single product that all group members are mutually responsible for (Falloon, 2015; Hutchison et al., 2012). In the current study, the only form of a synchronous system was when students provided feedback to one another within the EasyBlog app. Future research should more closely examine how students can collaborate to create products where they have shared responsibility, make substantive decisions together, and further demonstrate interdependence (Microsoft Corporation, 2015) through these synchronous systems.

More research needs to be conducted to uncover why students use communication to share knowledge, even when this knowledge is not extended communication or multimodal communication. Why are students pushing out information that does not always have a meaning or purpose? There was a high level of instance of students publishing pictures such as screenshots. However, this work was not justified with any evidence or expansion on ideas. There was no development of communication skills to elucidate that these instances were for a particular purpose or audience. Could this form of communication be a by-product of the experiences that students are having with technology outside of school? Research should examine this further.
Overall, with reference to frameworks such as the one proposed by C21 Canada (2012), future research should examine the how and why students are developing these 21st century skills. This study was premised on the notion that the use of 21st century technologies can support the development of other 21st century skills. Future research should continue to look at how the use of ICT may support the 21st century skills beyond the ones used in the current study.

**Recommendations for the Study of Interdisciplinary Learning with Tablets**

The current study demonstrated many instances of students’ development of interdisciplinary methods for learning and statistically significant gains in their content knowledge in science. The current study did adopt an interdisciplinary curricular approach to integrate science and language arts instruction based on Drake et al.’s (2013) work. However, other integrated curricular approaches could be explored in future studies. Disciplinary (digital and print-based) texts such as those in science are foundational for students when reading to learn (Cervetti et al., 2012; Cervetti & Pearson, 2012; Romance & Vitale, 2001). Research is pointing towards the affordances of multimodal texts and inquiry-based learning to enhance students’ knowledge construction with inquiry-based learning activities in science (Cervetti et al., 2012). Multimodal texts have the ability to deepen students’ understanding of content-area concepts and provide opportunities to then apply this knowledge through literacy-based activities (Cervetti et al., 2012).

There has been little research demonstrating the potential of multimodal technologies to support an interdisciplinary approach to science and language arts. Findings from a study of middle-school teachers who integrated multimodal texts, hands-on science activities, and literacy skills found that when opportunities to build science knowledge
through collaboration, communication, and multimodal literacy enhancements, that Grade 5 students realize statistically significant cognitive gains in science, vocabulary, and reading comprehension (Gallagher & Fazio, 2016). Cervetti et al. (2012), Guthrie (2004), and Romance and Vitale (2001) have proposed models for science and language arts integration. Future research could examine how the use of ICT within these models for science and language arts integration may enhance students’ knowledge construction.

Furthermore, more research based on teachers’ own knowledge and practice of interdisciplinary learning may guide future studies. The current study adopted an interdisciplinary unit based on more recent work (Drake et al., 2013), but this unit was not fully developed by the teacher in the Grade 5 class. Drake et al.’s (2013) work is much more comprehensive with regards to the teachers’ own planning and understanding of interdisciplinary learning. Therefore, future studies are encouraged to place more emphasis on teacher professional development for interdisciplinary learning when adopting Drake et al.’s model.

Implications for Practice

Given the findings of the current study, some suggestions can be made with regards to the implications for best practices and exercising caution when using tablets to support 21st century skills and knowledge construction within science and language arts.

Use of Tablets: Cautions and Concerns

With over 80,000 educational iPad apps in the Apple App Store (Apple Inc., 2017), educators are advised to be selective when downloading and purchasing apps. Considerations should be made regarding the apps’ ability to support content knowledge, informational management, or learning skills (Domingo & Garganté, 2016). Furthermore, it is imperative that teachers review particular features embedded within these apps. Teachers
should look for certain features within apps that may scaffold students’ knowledge construction by hearing text read to them through audio support, word-by-word tracking or highlight sentences, picture animation, hyperlinked words with definitions built-in, hyperlinks to access Web pages, and using finger actions to move, enlarge, or reduce images on the touch-screen interface (Hutchison et al., 2012; Walsh & Simpson, 2013).

Teachers also need to ensure that more explicit instructions are given to emphasize the relationship between these types of apps. In the current study, although students understood the method of transferring knowledge from content learning apps to learning skills or informational management apps, the knowledge transferred may not have been as deep as it could have been. More instructional time should be spent on teaching students how to read and comprehend multimodal texts in order to demonstrate their knowledge within learning skills or informational management apps.

**Implications for Teaching 21st Century Skills**

Students’ development of 21st century skills came as a result of working within groups on tablets. Therefore, teachers need to understand the value of assuming the role of a learning guide to support students’ connections to the real-world while also learning foundational concepts (Domingo & Garganté, 2016). Within groups, students should work together to become co-constructors of their own knowledge (Domingo & Garganté, 2016). With the Internet at their fingertips, educators do not need to be positioned as the bearers of all knowledge. Furthermore, students’ reliance on the teachers’ knowledge limits them to the possibilities of discovering knowledge beyond the curriculum. In the 21st century, students need to be positioned for success in careers that may require interdisciplinary skills or may not even exist yet. The acquisition of 21st century skills
should therefore be prioritized in relation to the standard curriculum.

**Implications for Teaching an Interdisciplinary Unit in Language Arts and Science**

Teachers should strive to provide more explicit instruction for reading comprehension and vocabulary within an interdisciplinary instructional unit of study. In the current research, it was not enough to have students practising interdisciplinary methods. This could have been a result of the study’s heavy reliance on technology to support learning in both language arts and science. According to Greenlaw (2015), teachers need to adopt a balanced perspective towards the content and process within their instructional approaches. Greenlaw (2015) suggests that by separating traditional teaching of content knowledge acquisition from instructional processes, teachers run the risk of “leaving their students adrift on a sea of information with no compass to guide them” (p. 899). The intervention in the current study tried to create a balance, but it was the implementation reality that more time was spent learning through tablets. Students were not given much traditional teaching of content knowledge in science and language arts; rather, they were given more time to explore this content knowledge on their own through tablets. The results of the current study should guide future research towards more of a “balance between teacher-driven activities and student-centred online learning activities” (Greenlaw, 2015, p. 899).

Therefore, to ensure that language arts skills are being taught through evidence-based instructional methods, a blended learning approach to the integration of tablets may be adopted by educators. Blended learning is an instructional approach that allows students to learn through traditional practices while also integrating the use of ICT (Means, Toyama, Murphy, & Baki, 2013). Blended learning is a combination of online
learning and face-to-face interaction (Means et al., 2013). In other words, students spend time learning through the use of ICT, which is then balanced with the equivalent amount of time spent learning through face-to-face interaction. Research suggests that a combination of online and traditional learning produces greater academic success (Means et al., 2013). With regards to the current study, interdisciplinary learning was difficult to achieve with the limited amount of time to carry out the full unit of study. A great deal of time was spent on the use of the tablets because the class only had them for one period a few times per cycle. There was not much flexibility. A meta-analysis of 45 studies supports the benefits of a great deal of dedicated learning time through a blended learning approach (Means et al., 2013). Learning time could be derived from the flexibility of tablets (Means et al., 2013) or other mobile ICT (i.e., smart phones) to take learning outside of the classroom and foster anytime and anywhere learning that adopts Drake et al.’s (2013) interdisciplinary curricular approach.

**Methodological Limitations and Implications for Future Research**

Although this study set out to ensure that effective methodological approaches were taken, there were methodological limitations that can inform implications for future research. First, the current study was a one group pre-test–post-test design. A general rule of thumb for quantitative research is that the larger the sample size, the less likely potential error will occur between the sample and the general population (Creswell, 2015). This study fell short of reaching the optimal number of participants with n=21. Since the current study used a statistical test (dependent t-test) to determine whether there were significant differences between the means of the pre- and post-tests, the current study should have had a slightly larger number of participants (approximately 30) for greater statistical power (Creswell, 2015). The participating school allowed for one class
to participate in the study, which limited the number of participants to invite. It is recommended that future studies attempt to recruit a larger sample size to carry out this type of quasi-experimental research.

Even though a mixed-methods approach was used, one limitation to the study is that the quantitative data were not collected through an experimental design (Creswell, 2015). The study was not able to compare the outcome or dependent variable (subject-specific knowledge) to a control group (Creswell, 2015). By conducting an experimental design, the current study may have been able to determine if it was the independent variable (use of tablets) that contributed to students’ growth in scientific knowledge or lack of growth in reading comprehension and vocabulary development. Through the dependent t-test statistical analysis, the relationship between variables could be explained, but it is still unclear if the tablets were the only variable contributing to students’ growth in scientific knowledge and lack of growth in reading comprehension and vocabulary. Controlling all of the variables in the study that might influence the outcome (Creswell, 2015) may inform future research with respect to whether it was the tablet that influenced students’ subject-specific knowledge growth.

With regards to the growth in scientific knowledge and lack of growth in reading comprehension and vocabulary development, one variable that may have contributed to this was the lack of dedicated, integrated instructional time allotted for the current study. In an ideal classroom, the regular classroom teacher would utilize the 100-minute literacy block and the 50-minute science block to carry out an interdisciplinary language arts and science unit. However, the school participating in the study selected the teacher who seemed to be most familiar with technology. This teacher happened to be the rotary teacher. Therefore, this teacher did not teach language arts to the Grade 5 class
participating in the study. The interdisciplinary unit was therefore only allotted the time
given for students’ science periods and not the time given for their language arts periods.
Science periods ran for 50 minutes, seven times per 10-day cycle. Students therefore did
not work on their units every day. This may have further created a disconnect between the
language arts tasks with their regular classroom teacher and the language arts tasks in
science class. Students may not have valued these language arts tasks as much since they
knew that they were not part of their regular language arts programming. This may have
further contributed to the lack of growth shown in the reading comprehension and
vocabulary post-tests. The lack of time also may have contributed to the over emphasis on
integrating technology instead of fostering more of a balance between online and offline
tasks. This would have informed a more blended learning approach within the
interdisciplinary unit (Means et al., 2013). Future studies should therefore try to look at
how the progression of this interdisciplinary unit and integration of tablets may differ if
more time were allocated for language arts tasks.

The current study focused more on how students were learning 21st century skills
and subject-specific knowledge through the use of tablets. After conducting this study, it
did not seem to be enough to ask a teacher to implement the modified STAO/OTF unit
and integrate the researcher selected iPad apps throughout the unit. Although the study
did demonstrate high instances of 21st century skills through the use of tablets, there was
no growth in the reading comprehension and vocabulary tests. Future studies may want to
look at the perspectives of teachers as they progress throughout the implementation of an
interdisciplinary unit with tablets. This may further inform whether the use of tablets for
learning is logistically practical and academically meaningful based on teachers’
professional knowledge.
References


doi:10.1080/02103702.2014.929863


doi:10.1111/bjet.12184


doi:10.1080/08957347.2016.1209207


doi:10.1108/10748120110424816


doi:10.1108/10748120110424843


doi:10.1080/095006901300069101


doi:10.1371/journal.pone.0059519


processing, and knowledge construction. *Interactive Learning Environments*, 24(8), 1778-1794. doi:10.1080/10494820.2015.1057740
Appendix A

Overview of Seven Competencies of 21st Century Learners

1. Creativity, Innovation and Entrepreneurship
   • Creativity: The ability to apply creative thought processes to create something of value.
   • Innovation and Entrepreneurship: The capacity to create and apply new knowledge in innovative and entrepreneurial ways to create new products or solve complex problems.

2. Critical Thinking
   • A deep understanding of and capacity to apply the elements and processes associated with critical thinking and problem solving.
   • The ability to acquire, process, interpret, rationalize and critically analyze large volumes of often conflicting information to the point of making an informed decision and taking action in a timely fashion.

3. Collaboration
   • The ability to interact positively and respectfully with others in creating new ideas and developing products.
   • The ability to lead or work in a team and to relate to other people in varying contexts, including capacity to resolve and manage conflict.
   • The capacity for sensitivity to the issues and processes associated with collaborating across cultures.
   • The ability to collaborate across networks, using various information and communication technologies.

4. Communication
   • High level literacy skills, including strength in a person's mother tongue with multilingual capacity a definite asset.
   • The ability to use technology to develop 21st Century competencies in the context of core subjects.
   • The capacity to communicate using a variety of media and technologies.
   • The ability to access, analyze, integrate and manage large volumes of information.
   • The capacity to effectively use social media to communicate and resolve challenges.
   • The ability to critically interpret and evaluate ideas presented through a variety of media and technologies.
   • Highly developed cooperative interpersonal capabilities.

5. Character
   • Life-long learner
   • Leadership, responsibility and accountability
• Self-directed, adaptable and resilient
• Tolerant, ethical and fair
• Personal productivity
• Interpersonal (people) skills
• Mental and physical well being
• Proficiency in managing personal
• Relationships

6. Culture and Ethical Citizenship
• The capacity to comprehend Canada's political, social, economic and financial systems in a global context.
• The ability to appreciate cultural and societal diversity at the local, national and global levels.
• The ability to critically analyze the past and present and apply those understandings in planning for the future.
• The capacity to understand key ideas and concepts related to democracy, social justice and human rights.
• Disposition and skills necessary for effective civic engagement.
• The ability to understand the dynamic interactions of Earth's systems, the dependence of our social and economic systems on these natural systems, our fundamental connection to all living things, and the impact of humans upon the environment.
• The capacity to consider the impact of societal and environmental trends and issues.

7. Computer and Digital Technologies
• The capacity to use computers and digital resources to access information and create knowledge, solutions, products and services.
• The capacity to use social media for learning.

Appendix B

Overview of 21 CLD Learning Activity Rubric: Use of ICT for Learning

Use of ICT Opportunities

- It is considered ICT use if the students are required to use ICT or can use ICT to complete an activity.

Use of ICT for Learning for Knowledge Construction

- Students use ICT directly for the knowledge construction part of a learning activity.
- Students use ICT to indirectly support knowledge construction, by using ICT to complete one step of an activity, and then using information from that step in the knowledge-building part of the activity.
- The knowledge building supported by ICT must be about the learning goals of the activity; learning to use the ICT does not qualify.
- ICT is required for the knowledge building when it allows students to do knowledge building activities that would be impossible or impractical without the use of the ICT.

Use of ICT for Learning to Design ICT Products

- Students are designers of ICT products when they create ICT products that others can use.
- Students must have an authentic audience in mind.

Appendix C

Overview of 21 CLD Learning Activity Rubric: Knowledge Construction

Knowledge Construction as Interpretation, Analysis, Synthesis, & Evaluation

- Knowledge construction happens when students do more than reproduce what they have learned; they go beyond knowledge reproduction to generate ideas and understandings that are new to them.
- Activities that require knowledge construction ask students to interpret, analyze, synthesize, or evaluate information or ideas.
  - **Interpretation** means drawing inferences beyond the literal meaning.
  - **Analysis** means identifying the parts of a whole and their relationships to each other.
  - **Synthesis** means identifying the relationships between two or more ideas.
  - **Evaluation** means judging the quality, credibility, or importance of data, ideas, or events.

Knowledge Construction as Main Requirement

- The **main requirement** is the part of the activity that students spend the most time and effort on and the part that *teachers focus on when grading*.

Knowledge Construction as Interdisciplinary Learning

- **Interdisciplinary** learning activities have **learning goals** that involve, content, important ideas, or methods from different academic subjects.
- Subjects that are **typically taught together** in your country do not count as interdisciplinary.

Appendix D

Overview of 21 CLD Learning Activity Rubric: Collaboration

Collaboration as Working with Others

- Students **work together** when the activity requires them to work in **pairs** or **groups** to:
  - discuss an issue
  - solve a problem
  - create a product
- Students working in pairs or groups might also include people from outside the classroom, such as students in other classes or schools, or community members or experts.
- Students can work together face to face or by using **technology to share ideas or resources**.

Collaboration as Shared Responsibility

- Students **have shared responsibility** when they work in pairs or groups to develop a common product, design, or response.
- Shared responsibility is more than simply helping each other: students must collectively own the work and be mutually responsible for its outcome.

Collaboration as Making Substantive Decisions Together

- Students **make substantive decisions together** when they must resolve important issues that will guide their work together.
- Substantive decisions are decisions that shape the content, process, or product of students’ work:
  - **Content**: Students must use their knowledge of an issue to make a decision that affects the academic content of their work together, such as taking a stance on a topic they will then write about, or deciding on the hypothesis they will test.
  - **Process**: Students must plan what they will do, when to do it, what tools they will use, or the roles of people on the team.
  - **Product**: Students must make fundamental design decisions that affect the nature and usability of their product.

Appendix E

Overview of 21 CLD Learning Activity Rubric: Skilled Communication

Skilled Communication as Extended Communication

- Extended communication is required when students must produce communication that represents a set of connected ideas, not a single simple thought

Skilled Communication as Multi-Modal

- Communication is multi-modal when it includes more than one type of communication mode or tool used to communicate a coherent message

Skilled Communication as Requiring Supporting Evidence

- Communication requires supporting evidence when students must explain their ideas or support their thesis with facts or examples

Skilled Communication as Designing Communication for a Particular Audience

- Students are required to design their communication for a particular audience when they must ensure that their communication is appropriate to the specific reader, listeners, viewers, or others with whom they are communicating
- They must have in mind a specific group with specific needs in order to shape their communication appropriately

Appendix F

Exit Interview Questions

1. What have you learned over the past few weeks?

2. Describe how you communicated on the iPad through reading, writing, or talking?

3. How did you learn any of the following skills: problem solving, critical thinking, collaborating, communicating, or environmental awareness?

4. How did you make connections to the unit or make inferences about what you learned?

5. How did you organize all of your ideas after reading through the iPad?

6. What got you excited about working on the iPad?

7. Do you want to learn more about the Conservation of Energy and Resources?
Appendix G

Sample of Reading Comprehension Test

Before the discovery of insulin, doctors could do little to help people who had the disorder known as diabetes. However, in 1921, insulin was discovered by Fred Banting and Charles Best at the University of Toronto. The first tests on a human, which were done on Leonard Thompson in 1922, were a great success. Word of this spread quickly around the world, and there was a great and urgent demand for insulin. Since then, insulin has saved millions of lives.

Why was there a “great and urgent demand for insulin” (line 7)?

A Insulin was successful in treating diabetes.
B People were afraid that they might get diabetes.
C Many drug companies wanted to be the first to make this new drug.
D Many professors wanted to be the first to learn about this new discovery.

Appendix H

Sample of Vocabulary Test

Samples A, B and C

Read the following paragraph. Then do Items A and B. For each blank, there is a list of words. Choose the word from each list that best completes the meaning of the paragraph.

Some students are nervous about playing team sports, so they hesitate to join a team. They really should not worry. An enthusiastic coach will soon help young ______ (A) ______ to feel confident. On a good sports team, people encourage each other to learn and to have fun. It doesn’t matter if the team never wins a ______ (B) ______. The important thing is to make an effort to play as well as possible.

A friends
B athletes
C leaders
D partners

F team
G trophy
H second
J referee

Read the incomplete sentences. Then, choose the one word that correctly completes both sentences.

Susan forgot to ______ her friend.
What do you ______ your kittens?

A call
B write
C thank
D remind

Appendix I

Grade 5 eTestSmart Science: Forms of Energy and Conservation of Energy

Test 5

• forms of energy

A. Check the correct answers. (5 marks each)

1. What is energy?
   - Energy is the ability to do work.
   - Energy is the ability to go to work.
   - Energy is visible work.

2. How many forms of energy are there?
   - one form
   - six forms
   - many forms

B. Write whether each picture shows “kinetic energy” or “potential energy”. Then explain what these two energies are. (10 marks each)

1. [Image]
   - __________ energy

2. [Image]
   - __________ energy
C. Identify the form of energy being described. Then give one example from everyday life of how that energy is used. (10 marks each)

1. __________ energy; e.g. __________
2. __________; e.g. __________
3. __________; e.g. __________

4. the energy that hot objects have more of than cold objects
   __________; e.g. __________

5. the energy that an object has because it is above the Earth’s surface
   __________; e.g. __________

6. the energy that is produced by the vibrations of an object
   __________; e.g. __________

7. the energy that allows us to see things
   __________; e.g. __________
Test 6

- conservation of energy

A. Label the source of energy in each picture. Then write whether it is renewable "R" or non-renewable "NR". (5 marks each)

1. [Diagram of oil rig]  
2. [Diagram of solar panels]  
3. [Diagram of wood]  
4. [Diagram of wind turbine]  
5. [Diagram of coal]  
6. [Diagram of hydroelectric power]  
7. [Diagram of oil spill]  

B. Write the meaning of each term. (7 marks each)

1. renewable energy source:

2. non-renewable energy source:

3. Law of Conservation of Energy:
C. Write the change of energy in each situation. (8 marks each)

1. 

2. 

3. 

4. 

D. Answer the question. (12 marks)

Describe how the energy in a stretched elastic changes when it is released.


Write one useful and one useless energy output of a car.

useful: 

useless: 

Source:
Appendix J

Overview for Modified Grade 5 Conservation of Energy and Resources and Language Arts Activities

Lesson #1: Conservation of Energy and Resources Blog

Students will create a blog by posting articles, news, responses, and reflections of what and how they have learned about the Conservation of Energy and Resources. Electronic pictures of outdoor learning will also be included in the blog. The blog could include a variety of records of student learning, specific activities completed by students, and the new ideas they came away with after each lesson, students’ educated opinions of different sources of energy and what the average citizen could do to help conserve energy and resources. This activity will occur over the length of the unit and be added in continually as their learning progresses. Students will be provided with time to respond to postings on the blog through their own postings.

Lesson #2: Defining and Collecting an Inventory of Energy in the Community

Students will take a community walk in order to identify and discuss different energy forms and how energy is harnessed. Using the iPads, students will take pictures of the different forms of energy they see inside and outside of the school. Students will then work in partners to create a pic collage on the iPad of the different energy sources and start to label the types of energy that they know of. Students will use their collective wisdom to construct new learning to their prior knowledge about what energy is and how it is harnessed using concrete examples they see in the school community.

Lesson #3: Gather Perspectives on Using Different Energy Sources

Students will examine and evaluate different energy sources and from different perspectives. They will share the positive and negative aspects of each energy source and compare the environmental impact. Students will first listen to a story about renewable and nonrenewable energy and then conduct an inquiry-based learning activity to explore one source of energy with their partner. This research will take place for the most part inside some of the energy apps. This is sometimes set up as a rotation. Students will then compile all of their research to write a blog post on their group’s EasyBlog page. The lesson will consolidate with a period of students’ reading each other’s’ blog posts and providing feedback towards their peers’ blog posts.

Lesson #4: Solar, Wind, and Water Energy Inquiries

Students will first explore the structures behind renewable energy transformation through augmented reality stations. Students will then deconstruct a variety of other inquiry projects linked to solar, wind, or water powered energy in order to build an understanding of what others have done to test these renewable resources, and then create their own inquires on either solar energy, wind energy, or water energy. Students will
review information in BrainPop, the Kids Discover app, and their peers’ blog posts and then design an experiment to test out. Testing of these inquiries is best completed outside. Students will reflect on what energy source their company will focus on based on the scenario proposed at the beginning of the study. They will start to reflect on what their plan of action will be to develop an energy company for a certain energy source and energy structure.

Lesson #5: Energy Company Plan of Action to Support the Environment: Culminating Activity

Students will use their knowledge and understanding they have gained around the Conservation of Energy and Resources and higher order thinking skills gained from Reading Comprehension and Vocabulary development to apply a Plan of Action. Students will craft a way to support why their Energy Company has chosen to invest and support the development of a certain energy source. This lesson will take several class periods.

Appendix K

21 CLD Learning Activity Rubrics

Collaboration: Rubric

1. Students DO NOT work together in pairs or groups

2. Students DO work together BUT they DO NOT have shared responsibility

3. Students DO have shared responsibility BUT they DO NOT make substantive decisions together

4. Students DO have shared responsibility AND they DO make substantive decisions together about the content, process, or product of their work but their work is not interdependent

5. Students DO have shared responsibility AND they DO make substantive decisions together about the content, process, or product of their work AND their work is interdependent

Skilled Communication: Rubric

1. Students DO NOT produce extended OR multi-modal communication

2. Students DO produce extended communication OR multi-modal communication BUT they DO NOT provide supporting evidence OR design their work for a particular audience

3. Students DO produce extended communication OR multi-modal communication AND provide supporting evidence: they explain their ideas or support a thesis with facts examples OR they’re designing their communication for a particular audience BUT NOT BOTH

4. Students DO produce extended communication OR multi-modal communication and provide supporting evidence AND they design their communication for a particular audience
Use of ICT for Learning: Rubric

1. Students DO NOT use ICT for their learning

2. Students DO use ICT to learn or practice basic skills or reproduce information. They are NOT constructing knowledge

3. Students DO use ICT to support knowledge construction BUT they could construct the same knowledge without using ICT

4. Students DO use ICT to support knowledge construction AND the ICT is required for constructing this knowledge but students DO NOT create an ICT product for authentic users

5. Students DO use ICT to support knowledge construction and the ICT is required for constructing this knowledge AND students DO create an ICT product for authentic users

Knowledge Construction: Rubric

1. Students DO NOT construct knowledge. Students reproduce information by using familiar procedures

2. Students DO construct knowledge by interpreting, analysing, synthesizing, or evaluating information or ideas even if this is not required

3. Students DO construct knowledge because it is required BUT DO NOT apply their knowledge in a new context

4. Students DO construct knowledge AND DO apply their knowledge in a new context BUT they DO NOT demonstrate learning in more than one subject (not interdisciplinary)

5. Students DO construct knowledge AND DO apply their knowledge in a new context AND the knowledge construction is interdisciplinary. They do demonstrate learning in more than one subject.