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A Longitudinal, Cross-Sectional Case Study of Students' Digital Literacy Learning and Development at the Middle School Using a Blended, Technology-Rich, Project-Based Learning Approach

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by

Hsiao-Ping Hsu

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Dedication

This dissertation is dedicated to my parents, wife and older brother for your unconditional support and unfailing love. Without you, I would not have been able to complete my Ph.D. degree. I would also like to dedicate this dissertation to my always lovely and supportive mentor: Dr. Joan E. Hughes, as your 20th doctoral supervisee.

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Abstract

A Longitudinal, Cross-Sectional Case Study of Students' Digital Literacy Learning and Development at the Middle School Using a Blended, Technology-Rich, Project-Based Learning Approach

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This study examined changes to middle school students' digital literacy after engagement in a learning environment based on a blended, technology-rich, project-based instructional innovation (BTPII). Guided by the social constructivist epistemology and the European Union's DigComp 2.0 framework, this study attempted to understand how students' digital literacy changes and final performance in a BTPII learning environment differed, with respect to participants' multiple engagement, levels of daily Internet access time, and daily Internet usage purposes. Thus, this study applied a cross-sectional, mixed method case study approach to middle-school participants of the BTPII-based after-school program, across the spring and fall semesters of 2017 and 2018. Eighty middle school students completed the whole program and provided valid survey responses. Participants of program iterations in the spring and fall 2017 semesters presented a significant development in digital literacy. However, students enrolled in the spring and fall 2018 semesters exhibited non-significant changes in digital literacy. The results of this study

further include the following findings: (a) relationships between the BTPII learning activities and digital literacy changes differed by semester, (b) impacts of students' multiple engagements on the difference in digital literacy changes and final performance varied by semester, and (c) students' daily Internet access time and Internet usage purposes did not significantly impact DL changes and final performance.

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Chapter 1: Introduction

Background of the Problem

As information communication technologies (ICT) are rapidly changing society, several researchers have been drawn to investigate how best to impart digital literacy to middle school students (Colwell, Hunt-Barron, & Reinking, 2013; Kimbell-Lopez, Cummins, & Manning, 2016; St. John & Von Slomski, 2012). Digital literacy refers to a set of knowledge and skills required to use ICT to effectively perform specific tasks, either in independent or collaborative settings, in order to solve a problem or create a product (Ferrari, 2012). For example, Ng (2012) indicated that a digitally literate individual has the ability to access a broad range of information and make and share meaning in various modes and formats. A digitally literate person is also able to effectively apply digital technologies for collaboration, communication, creation, and problem solving purposes, skills considered essential for interacting with the world by the United Nations Educational, Scientific and Cultural Organization (UNESCO) (Antoninis & Montoya, 2018).

Despite the importance of being digitally literate, the New Media Consortium (NMC) Horizon Report 2011 K–12 Edition (Johnson, Adams, & Haywood, 2011) highlights the rarity of training in teaching digital literacy in teacher education and school district professional development programs. For instance, Hunter (2017) indicated that (a) limited training for pre-service teachers and (b) the lack of dedicated funding for professional development were causing challenges for digital literacy education in

Australia. In addition to lack of training in teaching digital literacy, Neumann (2016) indicated additional challenges, which impact digital literacy instruction, faced by teachers in the classrooms, such as: students' constant distractions by looking up non-educational websites during instruction, trusting information on the Internet without evaluating its reliability, and students not reading required course materials before coming to the classroom. Therefore, effectively teaching digital literacy in the classroom can be challenging to teachers and more investigation is warranted.

As the project-based learning (PBL) approach enables a learning experience that largely overlaps with the core elements of digital literacy in information search and evaluation, communication, creation, and problem solving, an array of studies have been conducted to explore how to employ the PBL approach to facilitate digital literacy in mid-level education by enabling students to practice and develop digital literacy authentically in collaborative learning environments (Price-Dennis, Holmes, & Emily, 2015; Kimbell-Lopez et al.; Petrucco, 2013). Blumenfeld et al. (1991) defined PBL as:

> Project-based learning is a comprehensive perspective focused on teaching by engaging students in investigation. Within this framework, students pursue solutions to nontrivial problems by asking and refining questions, debating ideas, making predictions, de-signing plans and/or experiments, collecting and analyzing data, drawing conclusions, communicating their ideas and findings to others, asking new questions, and creating artifacts. (p.371)

Although previous studies have indicated that students could effectively develop digital literacy in PBL environment contexts, students in these prior studies mainly applied digital literacy to perform tasks in face-to-face settings rather than online environments.

As digital literacy refers to competencies required to use ICT fluently in both face-to-face and online environments (Vuorikari, Punie, Carretero Gomez, & Van Den Brande, 2016), some studies have focused on introducing social networking sites (SNS) to support digital literacy development in cyberspace. These investigators verified that SNS provided an online platform for communication and collaboration during group work (Arquero & Romero-Frías, 2013; Magogwe, Ntereke, & Phetlhe, 2015; Pattanapichet & Wichadee, 2015), which enabled similar practices of online communication and collaboration as some of the core elements of digital literacy.

Although the PBL approach has been widely used to support face-to-face digital literacy development and proven its effectiveness, the SNS-based teaching approach was also found to be empirically effective in promoting digital literacy in online spaces (Laakkonen, 2015; Lindstrom & Niederhauser, 2016). However, digital literacy should be a complete skillset weaving face-to-face and online settings (Ng, 2012; Vuorikari et al., 2016). The current study aimed to propose an instructional design framework based on the blended learning approach, enabling middle school students to practice and develop digital literacy through the combination of PBL and SNS-based teaching approaches.

The blended learning approach refers to a combination of face-to-face and online modes of learning, drawing on technology-mediated instruction (Siemens, Gašević, &

Dawson, 2015). Siemens et al. (2015) conducted a comprehensive literature review and indicated a near unanimous agreement on the effectiveness of the blended learning approach in K-12 settings in the scholarly literature despite some issues in causality and generalizability of the research findings.

Along with the popularity of the blended learning approach were some discussions centered around the digital divide in ICT accessibility and its influences on students' online learning experience and outcomes (Basitere & Ivala, 2017; Lynch, 2016). The focus on this digital divide is gradually extending from the gap in ICT accessibility to the gap in digital literacy levels (Buzzetto-Hollywood, Wang, Elobeid, & Elobaid, 2018; Mirazchiyski, 2016). Such extension has raised a debate on the association between students' Internet accessibility/usage patterns and their digital literacy levels. For instance, Livingstone and Helsper (2007) found that middle-class students aged 11 to 19 in the UK had more Internet accessibility and were more skillful at using the Internet compared to their working-class cohorts. By contrast, Li and Ranieri (2010) found that ninth graders' digital literacy was not significantly influenced by their frequency of computer and Internet use. Thus, the debate awaits more empirical studies.

Therefore, this study investigated students' changes in digital literacy influenced by learning activities within a framework involving the blended learning approach, PBL, and SNS. The current study also considered the impact of students' daily Internet usage patterns on the learning environment designed based on the framework. Further, this study explored how students' multiple engagement influences their experience and performance in the learning environment designed based on the framework. The main purpose was to explore the framework's effectiveness of learning transferability on middle school students' digital literacy development. This goal is justified by an experimental study conducted by Demirer and Sahin (2013) to verify the blended learning approach's effect on learning transferability. In their study, college students in the experimental group (learning in a blended environment) were statistically evidenced to be more successful in transferring their theoretical knowledge to their multimedia projects compared to the control group learning in a face-to-face setting.

PURPOSE OF THIS STUDY

The first purpose of this study was to investigate how middle school students' digital literacy levels were impacted after their involvement in a blended technology-rich PBL environment. Secondly, this study also explored how students, with multiple participatory experiences in that environment, performed in subsequent tasks of similar caliber and possibly changed their digital literacy. The third purpose was to identify how the students' daily Internet access time and usage purposes influenced their digital literacy changes and learning performance in that environment.

These research objectives were inspired by a case study I conducted involving 32 pupils (Hsu, Zou, & Hughes, 2018) engaged in creating augmented reality (AR) content, as a group project, in a blended learning setting. In that study, students were grouped to complete the AR project, which required them to participate in online and face-to-face learning tasks in order to learn necessary knowledge and skills. Before the class hour, students were asked to self-learn teacher-provided course materials of basic technical knowledge and skills required to create AR content. Students used Edmodo (an educational social network site) to exchange information and request peer support online. Bringing what they learned at home to the classrooms, students engaged in individual and group work during the face-to-face class hours. After class, students continued working on incomplete in-class tasks and participated in follow-up learning activities on Edmodo, including teacher-assigned discussion tasks, peer artifact showcases, and peer assessments. Throughout the semester-long program engagement, the student participants exhibited empirically significant digital literacy development attributed to their experiences of creating AR content, as evidenced by quantitative and qualitative data.

However, the focus of that case study examined elementary school students' digital literacy changed through their learning experience of creating AR content, instead of their particular learning experience in a blended learning environment. In other words, it is unclear how the students' digital literacy changed through the cycles of pre-class online learning, in-class project learning, and post-class online follow-up learning activities. Moreover, elementary students and middle school students might have different learning experiences and performance considering the variance in their levels of established digital literacy and experience in using digital tools. Thus, my first research purpose was to investigate how blended technology-rich project-based learning experience impacts middle school students' digital literacy.

Furthermore, in the same case study, I empirically found that some pupils were able to apply what they learned from completing a prior task to subsequent, more complex tasks, which contributed to better learning performance. Thus, the second purpose of this dissertation study was to investigate whether middle school students have a similar degree of learning transferability and its influence on their learning performance and digital literacy changes. The third research purpose originated from my conversation with a teacher interviewee in the same case study. He mentioned that some students' better technical knowledge and skills could be partially explained by their substantial exposure to digital tools. Before participating in the study, they were quite fluent in using various hardware and software to create digital content, such as a video or a digital storytelling product. These students usually had more Internet access time or practice in creating digital content for entertainment. However, in the case study, I did not investigate how elementary students' Internet access time and usage purposes impacted their digital literacy and project performance. Therefore, the third purpose of my dissertation was to identify how middle school students' variances in daily Internet access time and usage purposes impact their digital literacy changes and learning performance in a blended learning environment. Based on these three research purposes, I collaborated with a computer science teacher to initiate an after-school program featuring a blended, technology-rich, project-based instructional innovation (BTPII). I conducted a four-semester, cross-sectional case study in the BTPII after-school program and involved student participants across spring and fall semesters in 2017 and 2018 at his middle school.

SIGNIFICANCE OF THIS DISSERTATION

Although digital literacy is considered an essential skillset to interact with this world by UNESCO (Antoninis & Montoya, 2018), teaching digital literacy is challenging for middle school teachers because of the lack of training (Johnson et al., 2011). As an emerging and widely adopted pedagogical strategy, the blended learning approach has sparked many research efforts investigating its effectiveness on digital literacy education (Atmanegara, Agustina, & Tiara, 2013; Hall, Nix, & Baker, 2013). The first significance of this dissertation is designing an intervention that uniquely verifies the blended learning approach's effectiveness on middle school digital literacy education, on the basis of conceptual frameworks by Jose (2016) and Schwenger (2017). Second, this dissertation empirically broadens the research perspective regarding the blended learning approach's effect on learning transferability by investigating the relationship between students' multiple engagements in a blended learning environment and their performance and learning outcomes in digital literacy. The third significance of this study is to provide more empirical evidence for the debate on the relationship between students' existing Internet usage patterns and their digital literacy levels. Nonetheless, the participants' Internet usage patterns might enable various levels of established digital literacy and further influence the participants' performance and learning outcomes in a blended learning environment that facilitates digital literacy development. In sum, this study will contribute to the existing research and knowledge body on digital literacy education and blended learning approach by verifying its effectiveness in middle school digital literacy education through additional consideration of the research participants' existing Internet usage patterns and multiple engagements. This study adopted a cross-sectional case study approach with a four-semester time frame, thereby offering findings with breadth and depth.

RESEARCH QUESTIONS

This study was conducted to investigate how the BTPII learning experience influences middle school students' digital literacy changes. These students were involved in a blended, technology-rich, project-based learning environment that aimed to facilitate social-constructivist learning activities inside and outside the classroom in a synergistic manner. This study also compared participants' digital literacy changes and learning performance in the BTPII after-school program based on their repeat participation, aiming to investigate the impact of learning transferability on the students' performance and digital literacy changes. Moreover, to discover how students' varied Internet access time and usage purposes influenced their digital literacy changes and learning performance, this study also respectively compared participant students' changes in digital literacy and final performance scores with respect to their Internet access time and usage purposes. In sum, the research questions guiding this study were as follows:

1. What are the students' learning activities across the four semesters of the BTPII after-school program?
2. How do students' digital literacy change after engagement in the BTPII after-school program?

i. Do the students' pre- and post- digital literacy changes differ with respect to students' repeat participation in the after-school program?

ii. Do changes, if any, differ with respect to levels of students' daily Internet access time?

iii. Do changes, if any, differ with respect to the students' daily Internet usage purposes?

3. How do students' final performance in the BTPII after-school program differ?

   i. Does student performance differ with respect to students' repeat participation in the after-school program?

   ii. Does performance differ with respect to levels of the students' daily Internet access time?

   iii. Does the performance differ with respect to the students' daily Internet usage purposes?

Chapter 2: Review of Literature

This chapter reviews the relevant literature and theoretical foundations of applying blended learning to digital literacy education and justifying this study's emphasis on students' Internet usage patterns and its influence on digital literacy education.

DIGITAL LITERACY

This section covers the definition of digital literacy and the debate on the possession of digital literacy and daily Internet usage patterns, which not only provides this study with a standard to design learning objectives and activities to promote middle school students' digital literacy, but also justifies this dissertation's additional/secondary focus on the association among students' Internet usage patterns, digital literacy levels, and performance in a blended, technology-rich learning environment.

Definition of Digital Literacy

In its traditional definition, literacy is seen as the ability to read and write (Cambridge Assessment, 2013). Gee (2007) specifically defined literacy as the capability to recognize and produce meaning in a specific domain. As multimodal information becomes an ambient part of our world and culture (New London Group, 1996; Roberts & Koliska, 2014), meaning-making now involves utilizing information in various formats, including written, oral, visual, audio, tactile, gestural, and spatial forms (Cope & Kalantzis, 2009). Glister (1997) first defined digital literacy as the ability to understand and use various formats of information from different sources. On the other hand, Jenkins

(2010) articulated that a literate individual should be able to not only read but also write. Thus, a digitally literate person should be able to consume and create meaning by using information in different modes. Moreover, as ICT has profoundly changed the way we communicate and collaborate with people in different professions, a digitally literate person is also expected to be able to effectively adapt to new and emerging technologies for communication and collaboration purposes (Ng, 2012). Ferrari (2012) further indicated that a digitally literate person should have the competence to effectively retrieve, exchange, evaluate, and utilize information to solve problems, while taking into account privacy, safety, and netiquette. As a result of the conceptual development of digital literacy and effort to develop an inclusive framework for citizens of the European Union (EU) countries, the European Commission proposed the DigComp 1.0 framework in 2012 and defined digital literacy as:

> The set of knowledge, skills, attitudes (thus including abilities, strategies, values, and awareness) that are required when using ICT and digital media to perform tasks; solve problems; communicate; manage information; collaborate; create and share content; and build knowledge effectively, efficiently, appropriately, critically, creatively, autonomously, flexibly, ethically, reflectively for work, leisure, participation, learning, socializing, consuming, and empowerment" (Ferrari, 2012, p. 3).

In 2016, the European Commission updated the definition of digital literacy and published the DigComp 2.0 framework (Vuorikari et al., 2016) to define digital literacy as shown in Table 1.

Table 1: European Commission's Digital Competency Framework

Element	Components
1. Information and data literacy	1.1 Browsing, searching, and filtering data, information, and digital content To articulate information needs, to search for data, information, and content in digital environments, to access them, and to navigate between them. To create and update personal search strategies. 1.2 Evaluating data, information, and digital content to analyze, compare, and critically evaluate the credibility and reliability of sources of data, information, and digital content. To analyze, interpret, and critically evaluate the data, information, and digital content. 1.3 Managing data, information, and digital content to organize, store, and retrieve data, information, and content in digital environments. To organize and process them in a structured environment.

Table 1 (continued)

Element	Components
2. Communication and collaboration	2.1 Interacting through digital technologies To interact through a variety of digital technologies and to understand appropriate digital communication means for a given context. 2.2 Sharing through digital technologies To share data, information, and digital content with others through appropriate digital technologies. To act as an intermediary, to know about referencing and attribution practices. 2.3 Engaging in citizenship through digital technologies To participate in society through the use of public and private digital services. To seek opportunities for self-empowerment and for participatory citizenship through appropriate digital technologies. 2.4 Collaborating through digital technologies To use digital tools and technologies for collaborative processes and for co-construction and co-creation of resources and knowledge.

Table 1 (continued)

Element	Components
2. Communication and collaboration	2.5 Netiquette To be aware of behavioral norms and know-how while using digital technologies and interacting in digital environments. To adapt communication strategies to the specific audience and to be aware of cultural and generational diversity in digital environments. 2.6 Managing digital identity To create and manage one or multiple digital identities, to be able to protect one's own reputation, and to deal with the data that one produces through several digital tools, environments, and services.
3. Digital content creation	3.1 Developing digital content To create and edit digital content in different formats, to express oneself through digital means. 3.2 Integrating and re-elaborating digital content To modify, refine, improve, and integrate information and content into an existing body of knowledge to create new, original, and relevant content and knowledge.

Table 1 (continued)

Element	Components
3. Digital content creation	3.3 Copyright and licenses To understand how copyright and licenses apply to data, information, and digital content. 3.4 Programming To plan and develop a sequence of understandable instructions for a computing system to solve a given problem or perform a specific task.
4. Safety	4.1 Protecting devices To protect devices and digital content, and to understand risks and threats in digital environments. To know about safety and security measures and to have due regard to reliability and privacy. 4.2 Protecting personal data and privacy To protect personal data and privacy in digital environments. To understand how to use and share personally identifiable information while being able to protect oneself and others from damages. To understand that digital services use a "Privacy policy" to inform how personal data is used.

Table 1 (continued)

Element	Components
4. Safety	4.3 Protecting health and well-being To be able to avoid health-risks and threats to physical and psychological well-being while using digital technologies. To be able to protect oneself and others from possible dangers in digital environments (e.g., cyber bullying). To be aware of digital technologies for social wellbeing and social inclusion. 4.4 Protecting the environment To be aware of the environmental impact of digital technologies and their use.
5. Problem solving	5.1 Solving technical problems To identify technical problems when operating devices and using digital environments, and to solve them (from troubleshooting to solving more complex problems). 5.2 Identifying needs and technological responses To assess needs and to identify, evaluate, select, and use digital tools and possible technological responses to solve them. To adjust and customize digital environments to personal needs (e.g., accessibility).

Table 1 (continued)

Element	Components
5. Problem solving	5.3 Creatively using digital technologies To use digital tools and technologies to create knowledge and to innovate processes and products. To engage individually and collectively in cognitive processing to understand and resolve conceptual problems and problem situations in digital environments. 5.4 Identifying digital competence gaps To understand where one's own digital competence needs to be improved or updated. To be able to support others with their digital competence development. To seek opportunities for self-development and to keep up-to-date with the digital evolution.

The DigComp 2.0 framework provides a clear guidance for digital literacy education by categorizing digital literacy into five elements: *information and data literacy*, *communication and collaboration*, *digital content creation*, *safety,* and *problem solving*. These elements serve as clear learning objectives that foster digital literacy. An educator can view the five elements as a basic standard to decide students' learning objectives and activities when teaching digital literacy. For instance, to promote the element of *information and data literacy*, a learning activity such as digital storytelling using multimodal information would allow students to practice and gain competency in searching, filtering, evaluating, and managing data, information, and digital content. Similarly, to develop the element of *safety*, learning activities can be designed to involve students in reflecting on their digital behaviors related to device protection, privacy and personal data protection, health and well-being protection, and environmental protection. Furthermore, these five elements could be used as a reference to design assessment tools for students' digital literacy. For instance, the Ministry of Education and Research, Republic of Estonia (2014), through its policy of Estonian Lifelong Learning Strategy 2020, planned to use the DigComp 1.0 framework as a foundation to develop national assessment models to evaluate citizen's possession of digital literacy. In sum, the DigComp 2.0 framework provides a basis for digital literacy education comprising students' learning objectives and activities as well as assessment tools.

Impacts of Internet Usage Patterns on Digital Literacy

Students' technological access and experiences today vary widely (Poll, 2015). Thus, their competency at using ICT might vary (Livingstone & Helsper, 2007). Livingstone and Helsper (2007) found that Britain's middle-class children aged between 11 to 19 had significantly more access to the Internet and were accordingly skillful in using the Internet for broad and deep purposes, compared to the working-class children within the same age range. However, there is an ongoing debate regarding the association between students' Internet usage patterns and their levels of digital literacy and its component elements. For example, Li and Ranieri (2010) indicated that ninth graders' digital literacy was not significantly influenced by their frequency of computer and Internet use. Šorgo, Bartol, Dolničar & Both Podgornik (2017) also found that undergraduate students' experience with the Internet use did not statistically predict their information and data literacy. By contrast, however, is a study conducted by Alkan and Meinck (2016) using data collected from 60,000 14-year-old students from 21 countries, or education systems within countries, in 2014, by the International Association for the Evaluation of Educational Achievement (IEA). Alkan and Meinck (2016) concluded that students' frequent ICT use for communication significantly contributed to a relatively high level of computer and information literacy (similar to the concept of digital literacy applied in this study).

Summary of Digital Literacy

To investigate how the engagement in a blended, technology-rich, and project-based learning environment impacts middle-school students' digital literacy changes, this dissertation study used the five elements of digital literacy (information and data literacy, communication and collaboration, digital content creation, safety and problem solving) as a standard based on which students' learning objectives and activities as well as assessment tools were created for the BTPII after-school program. Moreover, inspired by the debate on the association between digital/information literacy and Internet usage (ICT) patterns, this study also investigated the association between students' daily Internet usage patterns and digital literacy. This study additionally examined the relationship between students' Internet usage patterns and learning performance in a blended learning environment, as less investigative efforts were expended on this aspect in the studies mentioned above. In other words, this study investigated if students' learning performance in a blended, technology-rich learning environment differed with respect to their daily Internet use time and usage purposes.

APPROACHES TO TEACHING DIGITAL LITERACY

In this section, first I discuss the application of the social-constructivist approach with digital artifact creation as a mainstay in digital literacy education. Later, I review how technology-enhanced PBL has been widely applied in digital literacy education, particularly at the middle-school level. I also review the effectiveness of SNS on digital literacy education and justify the need to conduct a study that investigates the application of SNS to K-12 digital literacy education. In the last section, I review the relationship between the blended learning approach and digital literacy education and describe how to use blended learning approach as a bridge, combining use of SNS and PBL.

A Social-Constructivist Approach for Digital Artifact Creation

As literacy practices are socially constructed and situated (Gee, 2015), Reynolds (2016) proposed the concept of social-constructivist digital literacy and regarded human beings as autonomous agents with productive purposes driving their technology use. Digital literacy, as a learned knowledge domain, can be effectively cultivated by using task-driven practices in a social-constructivist environment, such as digital artifact creation through group work (Greenhow & Gleason, 2012; Ranker, 2015). For instance, Hobbs and Coiro (2016) directed a collaborative and creative work experience. At a teacher professional development workshop aimed at codesigning technology-rich interdisciplinary teaching plans, in-service teachers learned from one another while they worked together and shared digital literacy skills and creative thoughts on accessing, analyzing, and creating with digital media. This collaborative experience also enabled individuals with lower digital literacy levels to learn from those with higher digital literacy levels through peer interactions. A recent study has further shown that situating digital literacy learners in a collaborative learning environment has become the mainstream in digital literacy education (Sharp, 2018).

In a collaborative digital artifact creation setting, learners are situated in an authentic context and use their own ICT experience and expertise to solve technical problems and come up with creative ideas, concurrently taking into account safety, copyrights, and netiquette. Moreover, practices of communication and collaboration are naturally embedded into the collaborative work setting (Hafner, 2014; Kimbell-Lopez et al., 2016; Price-Dennis et al., 2015). Based on the literature reviewed above, the collaborative learning approach, aimed at creating a digital artifact, involves learners in practicing and developing the various elements of digital literacy as defined by the EU's DigComp 2.0 framework. Notably, the collaborative learning approach involving digital artifact creation has been widely associated with the PBL approach, as evidenced by literature described above.

Technology-Rich Project-Based Learning Approach in Digital Literacy Education

The PBL approach involves students in multi-phased, student-centered investigations (Blumenfeld et al., 1991; English & Kitsantas, 2013). A typical PBL activity often involves students creating an artifact, a sharable representation of their learned knowledge and skills (Blumenfeld et al., 1991). For instance, in a study conducted by De La Paz and Hernández-Ramos (2013), 87 middle school students were grouped and involved in a six-week project-based learning activity to create multimedia presentations, which represented their learned knowledge of American history as well as their historical thinking ability.

Students' PBL experience and outcomes have been extensively investigated. By presenting students with an authentic task that they might encounter later in life, the PBL approach engages students in testing and evaluating their ideas, developing critical thinking skills, information literacy, and deeper understanding of the topic (Blumenfeld et al., 1991, p. 373). Bower, Howe, McCredie, Robinson, and Grover (2014) found that creating AR content in a PBL context significantly helped high school students develop information management ability, collaboration and communication, creativity, and critical thinking skills. Participants of this dissertation contextually managed and critically selected multimodal information (e.g., text, video, audio, and music) necessary for building their AR content in a creative and meaningful manner. As the students repeatedly used the same AR content creation platform (Aurasma) to complete projects, they were likely to improve their AR technical knowledge and skills. Their ability to communicate and collaborate was also impacted by this shared work experience.

In the current digital era, the integration of technology with the PBL approach further supports students in creating digital artifacts and, thus, developing their capacity to obtain, analyze, and share information (Blumenfeld et al., 1991). For instance, in a case study conducted by Petrosino (2004), students from grades 9 to 12 were involved in an project-based curriculum called Hands on Universe (HOU). In this case study, students were able to not only request specific observational information from professional observatories, but also download telescope images to visualize and analyze the data. Furthermore, students wrote webpages to describe and share their understanding of the learning content. This study's findings evidence how technology-supported PBL developed students' abilities in obtaining, analyzing, and sharing information.

Mathews (2010) involved high school students in an AR-based game design project and empirically demonstrated that participants' digital literacy improved as a result of the technology-enhanced PBL experience. Students collected and analyzed information about authentic community issues and connected it to their learning in AR-based game development. They used a real-world scenario along with interactive and multimodal representation AR features in game development. Ultimately, students developed technology-based information management, collaboration, communication, and problem solving skills through the situated, collaborative game development project.

The research findings of Bower et al. (2014), Mathews (2010), and Petrosino (2004) empirically exhibit how technology-supported PBL experiences benefit students' technology-based capacities, in line with the elements of digital literacy (information and data literacy, communication and collaboration, digital content creation, and problem solving), as defined by the DigComp 2.0 framework (Vuorikari et al., 2016). Moreover, their findings also reveal how students' digital literacy can be promoted by task-driven practices in a social-constructivist environment (Bell, 2010) and directly verified the concept of social-constructivist digital literacy proposed by Reynolds (2016). Although the effectiveness of PBL on digital literacy has been widely recognized, its practices primarily center on the face-to-face setting. With the development of Web 2.0 technology, the integration of SNS into online education is increasingly attracting educators and researchers.

Using Social Network Sites to Develop Digital Literacy

SNS refers to a web-based service and a bounded system where users create public or semi-public profiles of themselves before connecting and exchanging information with fellow users (Boyd & Ellison, 2007). Examples of SNS include Facebook, Twitter, Instagram, and Edmodo. SNS have been widely adopted to support social-constructivist learning, particularly in higher education (Al-Rahmi, Othman, & Yusuf, 2015; Churcher, Downs, & Tewksbury, 2014) and has been evidenced to increase students' critical thinking ability, collaboration, communication, creativity, and problem solving abilities in the online setting (Arquero & Romero-Frías, 2013; Chao, Lai, Liu, & Lin, 2018; Frydenberg & Andone, 2016).

To gauge SNS's effectiveness on developing critical thinking ability, Pattanapichet and Wichadee (2015) conducted a 14-week quasi-experimental research study on college students' development in critical thinking ability in an *English for Communication Arts* class. They compared students with and without learning experiences involving SNS. Their research findings statistically indicated that learning with SNS brings a higher level of development in critical thinking ability. SNS offers an open and inclusive platform for students to critically evaluate peers' perspectives on a given topic. Similarly, Magogwe et al. (2015) used Facebook in a college level, *Advanced Oral Presentation* class to develop students' online communication ability. The open and free atmosphere on SNS effectively motivated students who rarely contributed in face-to-face discussions during class hours, to engage on Facebook, as much as those who actively participated in the face-to-face setting. Facebook also helped students develop online collaboration abilities while they worked on group projects and used Facebook as a collaboration platform to exchange information and track project progress.

To identify SNS's effectiveness in developing critical thinking creativity, Frydenberg and Andone (2016) conducted a case study which revealed that college students' creativity benefited from the learning experience of creating and sharing micro-videos on Vine (a short-form-video-hosting service) or YouTube. Vine and YouTube provided an open space online for students to appreciate peers' micro-videos and revise their own products accordingly. Participants' critical thinking ability was employed to carefully consider the message they wished to convey on Vine or YouTube.

To test SNS' effectiveness in facilitating problem solving ability, Chao et al. (2018) created a social networking site featuring system-recommended experts and used it as an online discussion forum for 37 graduate students to seek answers to questions regarding English grammar. Their findings indicated that students learning with SNS obtained a statistically higher degree of development in problem solving ability. SNS provided social support in the online setting and promoted interaction between help seekers and potential helpers, which significantly encouraged the students to look for peer support on encountering difficulties in learning English grammar, thus, developing their overall problem solving ability.

As reviewed above, the capacities developed by learning with SNS, as a social-constructivist learning environment, align with the elements of digital literacy (*information and data literacy*, *communication and collaboration*, *problem solving,* and *digital content creation*) defined by the DigComp 2.0 framework (Vuorikari et al., 2016). However, compared to the popularity of SNS integration in higher education, the educational affordances of SNS at the K-12 level requires further empirical evidence (Greenhow & Askari, 2017; Rodríguez-Hoyos, Haya Salmón, & Fernández-Díaz, 2015). In other words, the application of SNS in K-12 digital literacy education has been less investigated. Thus, this study aims to investigate the application of SNS in K-12 education, with a particular emphasis on digital literacy.

Blended Learning Approach as a Bridge: Combining the Use of Social Network Sites and Project-Based Learning Approach

A blended learning environment combines traditional face-to-face and online modes of learning. In this environment, all learners in the learning process are separated by distance some of the time (Horn & Staker, 2014; Siemens et al., 2015). The blended learning approach supports learners with content as well as the knowledge and skills necessary for its application (Margulieux, McCracken, & Catrambone, 2016). For instance, Grover, Pea, and Cooper (2015) used the blended learning approach to combine a massive open online course (MOOC) with in-class quizzes and exercises, which significantly helped middle school students apply and develop text-based programming skills to a higher degree, compared to the traditional face-to-face-only approach.

While the PBL approach has proven its effectiveness and been widely used to support face-to-face digital literacy development, learning with SNS has also been found empirically to promote digital literacy in online spaces. However, digital literacy should encompass a complete skillset weaving face-to-face and online settings (Vuorikari et al., 2016). Thus, Jose (2016) proposed a conceptual framework to articulate the application of the blended teaching approach in digital literacy education at the workplace, integrating learners' face-to-face and online learning experiences. In Jose's framework, learners engaged in authentic tasks across face-to-face and online settings to polish their digital literacy skills in blended learning environments. For instance, a group of learners had face-to-face and online meetings aimed at collaboratively building a website to share knowledge about environment pollution caused by power looms. During their face-to-face and online meetings, they collaboratively employed search engines to look for related information, critically evaluated the information obtained, and selected information for inclusion on their website. Group members simultaneously used cloud-based project management tools to categorize, store, retrieve, and exchange data. This process naturally nourished learners' digital literacy through their work experience in the blended environment.

Thus, the framework of Jose (2016) shared the insights espoused by Reynolds (2016): digital literacy can be effectively cultivated by using task-driven practices. In addition, Jose's framework explicitly describes how the blended learning approach can be used to support task-driven practices in both the face-to-face and online settings. Thus, Jose's framework provides a valuable reference for designing a blended learning environment and implementing this approach to teach digital literacy.

In addition to the workplace setting, the blended learning approach was also conceptually proposed to be beneficial for digital literacy development in the higher education setting (Schwenger, 2017). However, in his ongoing dissertation work, Schwenger (2017) does not explicitly explain how to apply the blended learning approach to digital literacy education in higher education settings in either a theoretical or practical manner. Both the framework of Jose (2016) and ideas of Schwenger (2017) lack empirical support as these are conceptual models. In other words, the question of how to practically teach digital literacy in a blended learning environment still awaits empirical investigation. Moreover, Jose's and Schwenger's ideas were developed specifically for higher education and workplace contexts rather than middle school education. Therefore, this dissertation study aimed to investigate the effectiveness of the blended learning approach on digital literacy development at the middle school level.

The combination of PBL and the blended learning approach has been proven to have positive effects on college students (Bauer-Ramazani, Graney, Marshall, & Sabieh, 2016). For instance, in a case study conducted by Shih and Tsai (2017), a university teacher used an online learning platform to regulate students' self-learning and dedicated the face-to-face class hours to the completion of students' project work in a marketing research class. The investigators found that the combination enhanced college students' learning effectiveness as well as their motivation to learn. The research participants also reported development in the areas of information management, collaboration, communication, and problem solving as a result of this PBL-blended learning experience.

Similarly, using SNS to support a blended learning environment is also popular in higher education (Cheng, Chan, Kong, & Leung, 2016; Naghdipour & Eldridge, 2016). For instance, Naghdipour and Eldridge (2016) conducted a case study to investigate the affordances of Facebook in assisting first-year college students' learning of a foreign language, in terms of vocabulary learning strategies and knowledge, in a blended learning environment. Facebook proved to be a suitable online platform for hosting diverse pre-class learning activities aimed at preparing students for in-class learning activities. The findings indicate that students' overall language, vocabulary knowledge, and vocabulary learning strategies improved as a result of using Facebook. The application of Facebook also engendered a social-constructivist learning environment within which students shared learning experiences and outcomes. Further, it raised students' agency as they accessed various sources of information in order to respond to peers' posts and threads.

Summary of Teaching Approaches to Digital Literacy

The literature reviewed above verifies the effectiveness of PBL and SNS in a blended learning environment in improving students' learning outcomes and motivation. More importantly, the above literature empirically supports that either the combination of PBL and the blended learning approach or the combination of SNS and the blended learning approach is able to develop students' abilities in information search and management, collaboration, communication, and problem solving given a technology-based, social-constructivist learning environment. Such integrative practices featuring a combination of PBL and/or SNS with the blended learning approach are conceptually similar to the idea of social-constructivist digital literacy espoused by Reynolds (2016) and effectively impact digital literacy as defined by the DigComp 2.0 framework (Vuorikari et al., 2016). Such practices, however, have been less often investigated at the K-12 level, as is the impact of these combinations on digital literacy education. Hence, the instructional design framework proposed by this study (BTPII) would help provide empirical evidence regarding the impact of applying a blended learning approach, involving SNS and PBL, on digital literacy education at the middle school level.

Chapter 3: Method

This section provides explicit information regarding this study's overall conceptual framework, research design, trustworthiness, and positionality. In the sub-section on conceptual framework, I not only present this study's epistemology and theoretical perspective, but also discuss conceptual frameworks for digital literacy and the proposed BTPII learning activities. The sub-section of research design primarily presents information regarding the research site, participants, data resources, and data analysis. The sub-section of trustworthiness discusses how this study applied a four-semester, cross-sectional mixed-method case study approach to enhance the trustworthiness of research findings. The last section of positionality discusses my role as a researcher in this study.

CONCEPTUAL FRAMEWORK

The current study, based on the concept of social constructivist digital literacy (Reynolds, 2016), aimed to investigate how middle school students socially construct digital literacy. Thus, this study applied a social constructivist epistemology and interpretivist theoretical perspective (Gray, 2014; Koro-Ljungberg, Yendol-Hoppey, Smith, & Hayes, 2009). The social constructivist epistemology enables this study to describe how students' digital literacy was socially constructed, whereas the interpretivist theoretical perspective provides insight on interpreting students' learning experiences and exploring their perspectives regarding the impact of these experiences on their digital literacy (Gray, 2014). Employing the social constructivist epistemology and interpretivist theoretical perspective, this study attempted to interpret how middle school students changed their digital literacy in a social constructivist learning environment associated with blended, technology-rich, project-based learning activities. The following sections further discuss conceptual frameworks for both digital literacy and the blended, technology-rich, project-based learning activities.

Conceptual Framework for Digital Literacy

This study conceptually referred to the DigComp 2.0 framework created by the EU to define digital literacy as five elements used as instructional goals in the proposed BTPII framework. Bearing in mind that the DigComp 2.0 framework is primarily applicable to individuals aged between 16-65, the five elements were then contextually modified to match the cognitive levels and living experiences of the targeted middle school students aged 12-14 (grades 6-8). For instance, *digital citizenship* in the EU framework involves educating a digitally literate person to use technologies for participation in society. This item was excluded from the proposed BTPII framework's instructional objectives due to middle school students' limited life experience participating in society. Such modification is supported by the International Society for Technology in Education (2016) standards for students in the digital age of learning, which excluded social participation from the item regarding digital citizenship. The modified digital literacy framework was then used to guide the design of the BTPII learning activities in face-to-face and online social constructivist contexts and to assess students' digital literacy changes before and after the program. The definition of the five elements are provided in Table 2.

Table 2: Digital Literacy Defined in Current Study as the Learning Objectives

Element	Components
Information and data literacy	1. To create and update effective search strategies in order to fulfill data, information, and digital content needs. 2. Critically evaluate the credibility and reliability of sources of data, information and digital content. 3. Effectively store, classify, and retrieve data, information, and digital content in a structured environment.
Communication and collaboration	1. To be able to communicate and share data, information, and digital content with others through ICT. 2. To be able to collaborate with others to plan, execute, and monitor groups through ICT. 3. To be able to participate in the community via appropriate digital tools. 4. Be aware of behavioral and ethical norms when interacting with others through ICT. 5. Be able to create and manage multiple identities for reputation protection.

Table 2 (continued)

Element	Components
Digital content creation	1. Create and edit digital content in different formats in order to express one's ideas. 2. Integrate and re-elaborate an existing body of knowledge in different formats to create new and original content. 3. Understand and distinguish between concepts of copyright, copyleft, and licenses and respect them when using others' work. 4. To develop a sequence of order for a computing system to solve a specific problem or perform a particular task.
Safety	1. Be able to protect personal data and privacy.
Problem solving	1. Identify and solve technical problems with available resources. 2. Evaluate personal needs and be able to choose suitable technological responses. 3. Creatively apply digital tools and technologies to generate new content. 4. Be up-to-date with personal knowledge and skills of using digital tools and technologies.

Conceptual Framework for Blended, Technology-Rich, Project-Based Learning Activities

The conceptual frameworks for learning and developing digital literacy guided the design of the BTPII learning activities throughout the pre-class, in-class, and post-class intervention phases. Building on Reynold's (2016) concept of task-driven, social constructivist digital literacy, the proposed BTPII framework aimed to involve students in task-driven learning activities in order to practice digital literacy, thus, weaving face-to-face and online settings in a synergistic manner. In this way, what students contextually learned online would prepare them for in-class, technology-enhanced, PBL activities. Students' digital literacy developed during the in-class PBL experience would in turn empower their subsequent learning activities online. Their improved digital literacy would positively impact students' subsequent learning tasks and further provide opportunities for improving digital literacy through online and face-to-face learning experiences. Thus, the BTPII framework was expected to deliver instructional effectiveness by facilitating a positive feedback circle of digital literacy development across face-to-face and online learning environments. A typical BTPII learning experience was comprised of three parts: (a) pre-class SNS-based learning activities, (b) in-class PBL activities, and (c) post-class SNS-based learning activities. These three parts are further explained in the subsequent sections.

Pre-Class SNS-Based Learning Activities

The pre-class SNS learning activities and corresponding digital literacy elements used as learning objectives are illustrated in Figure 1 and explained in Table 3.

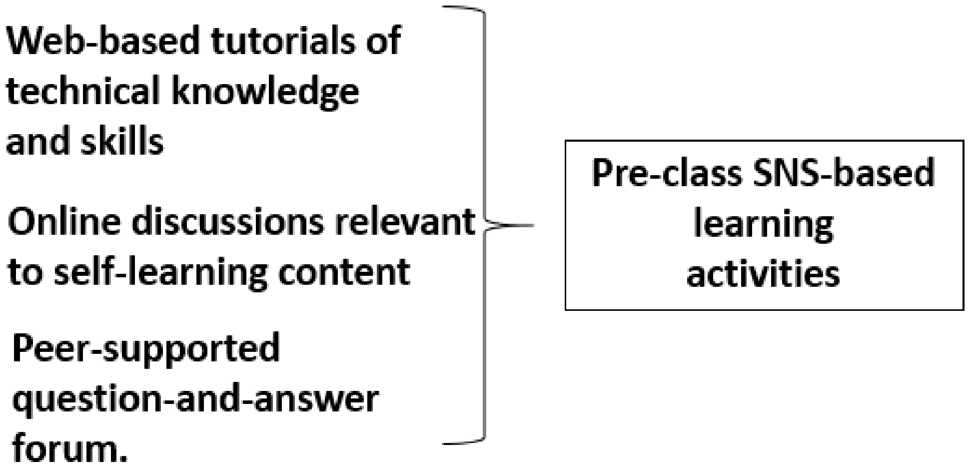

Figure 1: Illustration of Pre-Class Instructional Activities

Table 3: Pre-Class Teaching and Learning Activities and Corresponding Digital Literacy Practices

Teacher	Student	Instructional goals related to digital literacy elements
Upload web-based tutorials on technical knowledge and skills in text or video format.	Self-learn teacher-provided tutorials to acquire technical knowledge and skills required for subsequent in-class project execution.	1. Basic technical knowledge and skills
Oversee students' self-learning by moderating an online discussion activity related to the tutorial content.	Answer teacher-assigned discussion questions and respond to peers' posts to further the discussion activity while safeguarding personal privacy.	1. Communication 2. Safety
Facilitate a peer-to-peer question and answer forum.	Ask questions encountered in the self-learning process, or answer peers' questions using personal learning experience and/or other reliable information resources.	1. Information and data literacy 2. Communication 3. Problem solving

Table 3 (continued)

Teacher	Student	Instructional goals related to digital literacy elements
Evaluate if students behave in an ethical and responsible way in the online environment.	Interact with others with, privacy, ethics, and responsibility in mind. Cite information appropriately to avoid plagiarism.	1. Communication 2. Safety

The pre-class learning activities were implemented on SNS, such as Edmodo, Facebook, or Twitter, and aimed to help students asynchronously share their ideas and seek help. The pre-class learning activities aimed to facilitate students' self-learning as well as such digital literacy practices in cyberspace as communication, collaboration, and problem solving. The teacher would regularly post weekly learning objectives, descriptions of in-class learning tasks, and task rationales, and uploaded self-learning materials on SNS, preparing students for in-class project work. The teacher could also require students to participate in an online discussion related to the self-learning materials. The students were expected to engage with the web-based tutorials to learn basic technical knowledge and skills, which were prerequisites for in-class project engagement.

This design referred to the dual-phase project-based pedagogical approach (Drain, 2010; Good & Jarvinen, 2007), which requires that students be equipped with sufficient knowledge and skills before moving on to the subsequent phase. When students had questions in the pre-class self-learning phase, they were encouraged to post them to SNS and seek peer support via a peer-supported question-and-answer forum. In the meantime, other students were encouraged by the teacher to answer the questions based on their own expertise or by citing credible external resources. The teacher facilitated the question-and-answer phase and monitored potential instances of ethical misconduct (e.g., privacy and plagiarism issues). The pre-class discussion activity allowed the teacher to oversee students' self-learning, thus preparing them for the in-class learning tasks. The pre-class learning activities attempted to create an online social constructivist learning environment for students to learn from others and seek peer support, thus, developing students' digital literacy in the online setting.

In-class Project-Based Learning Activities

The in-class learning activities and corresponding digital literacy elements used as instructional objectives are illustrated in Figure 2 and explained in Table 4.

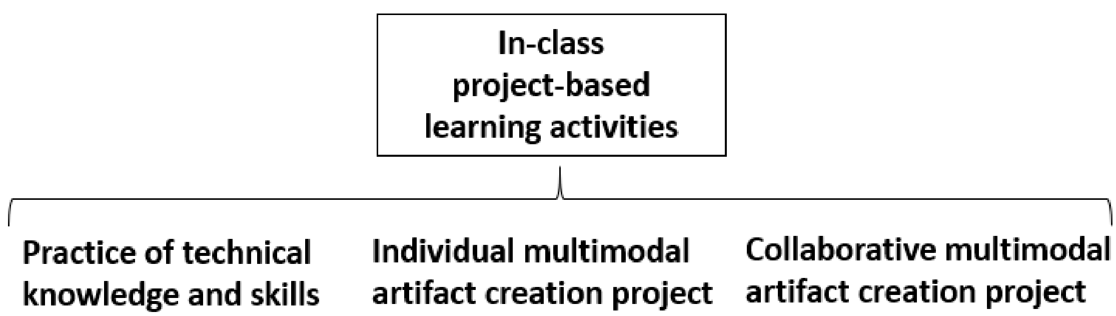

Figure 2: Illustration of In-Class Instructional Activities

Table 4: In-Class Project-Based Teaching and Learning Activities and Corresponding Digital Literacy Practices

Teacher	Student	Instructional goals related to digital literacy elements
Summarize pre-class learning activities and answer students' unsolved questions.	Ask unsolved questions encountered in the pre-class learning phase.	1. Consolidation of basic technical knowledge and skills
Lead students in planning projects involving digital tools.	Set goals, identify needs, and plan a project accordingly.	1. Communication and collaboration 2. Problem solving
Teach application of web-based information management tools.	Use the web-based information management platform to store, classify, and retrieve data.	1. Information, and data literacy
Scaffold students' collaboration and communication abilities, problem solving skills, digital content creation, safety, and problem solving strategies.	Apply digital literacy to navigate authentic tasks in the process of individual and group project execution.	1. Information and data literacy 2. Communication and collaboration 3. Digital content creation and safety 4. Problem solving
Evaluate if students behave in digitally ethical and responsible ways.	Interact ethically and responsibly with others. Provide a reference list and avoid plagiarism.	1. Communication, 2. Digital content creation (particularly within the context of copyrights and licensing)

The in-class PBL activities aimed to facilitate students' task-driven digital literacy practices by authentically using digital tools to search for and evaluate information, communicate and collaborate with others, create digital content, and solve real problems.

The in-class projects also allowed students to apply self-learned knowledge and skills to authentic tasks. The technology-rich project execution experience allowed students to use multimodal information to make an artifact expressing their ideas, such as a digital story or a microfilm. Students were first involved in an individual project followed by a group project. This arrangement allowed them to transfer personal experience to the group project setting, thus, helping them to be sufficiently competent participants in group projects. This design conceptually referred to the dual-phase project-based pedagogical approach (Drain, 2010; Good & Jarvinen, 2007).

At the start of every in-class instruction session, the teacher briefly summarized the pre-class instructional activity and asked students if there were any unsolved questions from the pre-class self-learning phase. Subsequently, students could take advantage of the in-class learning activities to develop their information and data literacy, communication and collaboration, digital content creation, safety, and problem solving skills in the process of executing projects. For example, to develop information and data literacy, students could plan a project using a digital tool, such as Xmind to create a mind map that guided their project execution. In this technology-rich PBL environment, students were encouraged to learn how to store, classify, and retrieve multimodal information by using a web-based information management platform, such as Google Drive or Dropbox. The students were provided with opportunities to also learn how to use a web-based information management platform to manage and share group data while protecting data privacy. For the element of communication and collaboration, when a group of students planned to use HP Reveal (an AR content creation tool) to make an AR-based storytelling artifact on their local community's cultural heritage, they could list all the tasks and distribute them among different members. Students were observed by the teacher to detect whether their work processes involved any ethical and/or responsibility issues. To learn the concept of safety, students were guided by the teacher in learning how to evaluate critically the credibility and reliability of sources of data, information, and digital content produced by third parties. The in-class learning activities attempted to create a face-to-face social constructivist learning environment for students to practice digital literacy and learn from peer interactions contextually, thus, developing students' digital literacy in the face-to-face setting.

Post-Class SNS-Based Learning Activities

The conceptual post-class learning activities and objectives related to digital literacy elements are illustrated in Figure 3 and explained in Table 5.

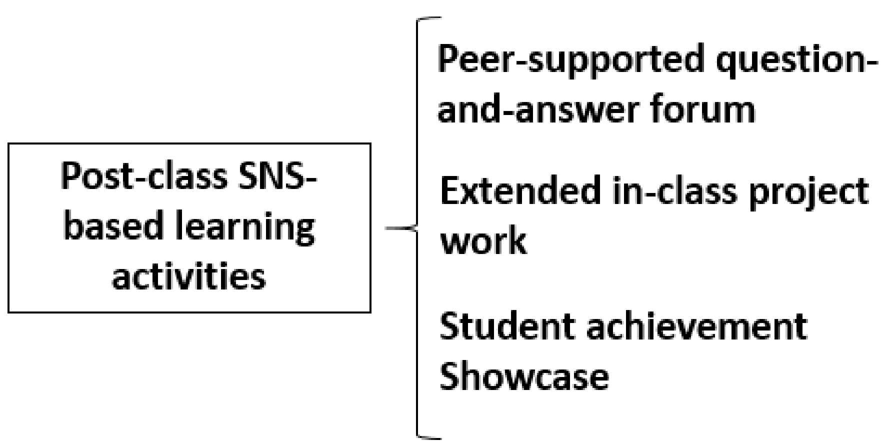

Figure 3: Illustration of Post-Class Instructional Activities

Table 5: Post-Class Project-Based Teaching and Learning Activities and Corresponding Digital Literacy Practices

Teacher	Student	Instructional goals related to digital literacy elements
Moderate post-class, peer-supported question-and-answer forum.	Ask unsolved questions via SNS and answer peers' questions using personal learning experience and/or other reliable information resources. Share personal challenges on SNS in order to seek peer support.	1. Information and data literacy 2. Communication and collaboration 3. Problem solving
Moderate student groups' information management, communication and collaboration, digital content creation, and problem solving attempts using SNS and other digital tools. Observe and address privacy, ethics, and plagiarism related issues, if any.	Discuss group work and communicate and share data with group members to facilitate group work. Propose creative ideas related to group work, using individual creativity or external resources Propose a problem-solving strategy and seek group members' support.	1. Information and data literacy 2. Communication and collaboration 3. Safety 4. Digital content creation 5. Problem solving
Facilitate students' project demonstration or showcasing.	Present project results.	1. Communication 2. Digital content creation (creativity stimulation)

After in-class meetings, SNS served as an instructional platform to extend the in-class learning activities to online spaces and maintain students' project workflow. Right after the in-class learning activities, students were encouraged to post any unsolved questions or answer peer's questions on SNS. Students were also encouraged to share difficulties they encountered during independent work at home. For instance, when a student worked independently on an individual project and faced a technical issue, he/she was encouraged to seek peer-support by posting the question on SNS. Other students who had the same question also benefitted when the question was answered appropriately. Moreover, during these question-and-answer interactions, the teacher could observe if students used reliable information resources to answer peers' questions and appropriately cited their data resources. If inappropriate behaviors emerged, the teacher provided immediate intervention, which promoted information and data literacy as well as problem solving skills.

The integrated application of SNS and various digital tools helped maintain student groups' out-of-class workflow and facilitated students' information and data literacy, communication and collaboration, and digital content creation in cyberspace. For instance, the integration of Edmodo and Google Drive provided an information management and data exchange platform that enabled students to communicate with group members and share their incremental progress as they worked independently and asynchronously. In addition, the students not only exchanged and sparked creative ideas, but also collaboratively solved project-related problems to ensure project progress. During this phase, the teacher kept a watch for potential privacy and plagiarism issues, or inappropriate behaviors when students used digital content from third parties. After each individual or group project, students were prompted to demonstrate publicly their projects on SNS and invited to assess peers' products and provide constructive suggestions, enabling students to learn from each other and reflect on the strengths and weaknesses of their own artifacts and come up with possible ways of improvement. The post-class learning activities again attempted to create an online social constructivist learning environment for students to learn from online peer support, thus, enabling the development of students' digital literacy practices in the online setting.

A Complete Cycle of BTPII Learning Activities

Figure 4 illustrates the comprehensive learning activities included in a typical BTPII learning section: in-class hours were dedicated to PBL whereas out-of-class hours were allocated to deploying self-learning activities on SNS. Beginning with the pre-class learning activities on SNS, students acquired knowledge and skills required for in-class project engagements. Later, the students contextually applied pre-class learning outcomes to in-class project execution and shared their expertise with one another. The post-class learning activities extended the in-class project workflow as well as facilitated the showcase of students' projects, providing opportunities for learning from peers. The combination of PBL and SNS-based learning activities formed a complete cycle for middle school students to contextually and iteratively practice and develop digital literacy in a blended, technology-rich, PBL environment.

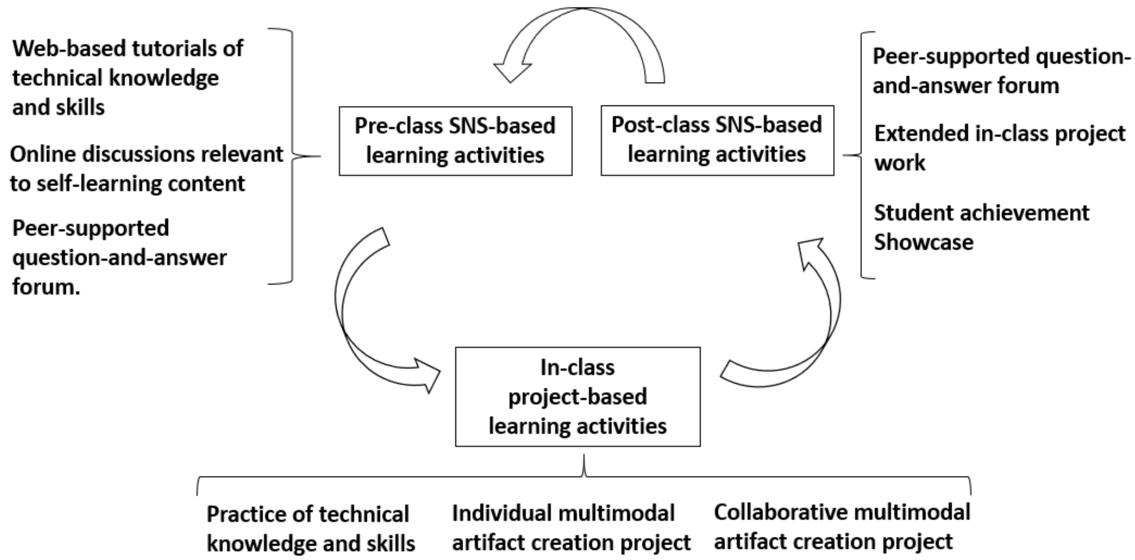

Figure 4: BTPII Framework

Pilot Test of the BTPII

In fall 2016, David, the program instructor, and I pilot-tested the after-school program involving 32 7th graders using Aurasma[1] to create AR content regarding famous sites on campus. Edmodo was used as an online instructional platform for David to distribute instructional materials (e.g., PowerPoint lecture slides and the Aurasma tutorial), and allowed students to ask questions and upload assignments. In addition to teaching technical knowledge and skills for using Aurasma, this 18-week program also taught students how to produce and edit multimodal content, including video recordings, photography, and multimedia editing, in order to help students independently create an Aura. An Aura is a product made using Aurasma's editing platform that functions as a

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[1] Aurasma is an augmented reality software rebranded as HP Reveal (https://www.hpreveal.com/).

digital overlay integrating texts, images, videos, and animations that appear when users point their devices at a specific object. The final project of this pilot program was to build an AR-based campus tour guide system that included 18 AR image-based triggers to introduce famous sites on campus.

This pilot after-school program received positive feedback via an end-of-semester evaluation and questionnaire asking students to self-report their development in critical thinking skills, communication and collaboration, problem solving, and creativity. The students particularly benefited from the collaborative learning experience of using AR to introduce their campus by integrating multimodal information, such as, texts, photos, and self-made music and microfilms. However, there was room for improvement. For example, Aurasma is an English-based software and most of the students spent a lot of time getting used to it, which lowered their motivation to work on Aurasma. Moreover, the official one-hour class session in the after-school program was insufficient for the students to complete all in-class tasks. Therefore, if more out-of-school learning could be introduced to prepare students better for in-class tasks, students would be able to self-learn Aurasma at home and become familiar with its English-based interface. The limited class time could then be used for learning tasks that demanded higher forms of cognitive functions, such as problem solving ability and creativity. Based on the positive results and reflections of the pilot program, David recruited students to enrol in the BTPII after-school program in the spring and fall semesters of 2017 and 2018. These latter four semesters of BTPII application provided the context for this research study.

Research Design

This section provides explicit information regarding research design in terms of four aspects: research site, participants, data sources, and data analysis. The first aspect provides background information regarding the middle school where I conducted this research. The second aspect reports participant details, such as, numbers, demographic information, and ICT ownership. The aspect of data sources describes multiple types of data collected for this study whereas the aspect of data analysis describes how this study analyzed data from multiple sources in order to answer the research questions.

Research Site

The research site was a middle school located in the northern part of Taiwan with approximately 1,200 students from middle-class families. In 2016, this school initiated a pilot AR and virtual reality (VR) learning program funded by the local government. This school was assigned as a county-wide seed school to promote AR and VR for learning. The school administrators formed a teacher learning community and invited a computer science teacher (David) to be the community leader cum instructor to teach AR/VR technical knowledge and skills in order to promote further AR/VR integration in the classrooms. David, at the time of the study, possessed eight years of teaching experience. He was particularly interested in applying AR and VR technologies to support the PBL approach in order to facilitate students' deep learning by employing the power of cutting-edge technologies.

This school encountered a lack of appropriate AR teaching materials soon after the AR/VR program was launched. Given David's passion for AR and PBL, David and I worked together to establish an after-school pilot program featuring PBL and AR content creation beginning in 2016. Our primary goal was to explore the possibility of involving students in an AR content creation process in a PBL environment. The second goal was to develop students' critical thinking skills, communication and collaboration ability, problem solving ability, and creativity through the PBL experience. David and I created an after-school learning intervention featuring blended, technology-rich, project-based instruction innovation, which will be described more fully in later section, and was implemented at the middle school across four semesters.

Participants

The study enrolled a total of 116 student participants across four semesters (see Table 6). Some students repeated enrolment across subsequent semesters.

Table 6: Numbers of Student Participants Who Initially Enrolled in the BTPII After-School Program and Repeat Participation in Each Semester

	Spring 2017	Fall 2017	Spring 2018	Fall 2018
Male	25	26	25	17
Female	7	5	7	4
Total Number of Enrolled Students	32	31	32	21
Number of One-Time, Two-Time, and Three-Time Repeat Enrolments	32, 0, 0	21, 10, 0	14, 13, 5	16, 0, 5

Taiwanese household Internet access rate is 80.9%, and 99.9% of households use broadband Internet service. Average households pay around $28 per month for Internet (Taiwan Netwrok Information Center, 2018). The student participants' highest parental education level was: high school (8.3%), bachelor/college degree (58.6%), graduate degree (22.8%), and I don't know (10.3%). The student participants had: no mobile phones (8%), WiFi-only smartphones (19%), smartphones with limited data plans (48%), and smartphones with unlimited plans (25%). Thirty-three percent of participants used iPhones, 17% of participants used premium Android smartphones, 42% of participants used regular Android smartphones, and 8% of participants had no mobile phones. Three percent of participants had no laptop/computer at home, 55% had one or more computers connected to the Internet at home, but not in their own bedrooms, and 42% had one or more computers connected to the Internet at home with the Internet accessing laptop/computer(s) in their bedrooms.

Data Sources

The current study aimed to investigate the student participants' learning experiences and learning outcomes after participating in the BTPII intervention. My Research Matrix summarizes my data sources and analysis, as aligned to the research questions (see Appendix A).

Pre- and Post-program Questionnaire on Digital Literacy

This questionnaire was designed based on the EU's digital competency 2.0 framework (Vuorikari et al., 2016) and measured students' digital literacy based on the following digital literacy elements: information and data literacy, communication and collaboration, digital content creation, safety, and problem solving. Each element was measured using pre- and post-test questionnaires with identical items. Items were extracted from the surveys used in the Ikanos project of the Basque Government (Spain) (2017), Jeng and Tang (2004) study, and Lin and Wang (1994) study. The survey was constructed using a five-point Likert scale. To secure internal consistency, a pilot test was issued to 32 K-5 and K-6 students (Hsu et al., 2018), and the Cronbach's α value of each element is reported in Appendix B.

Student Interviews

To capture students' learning experience in the BTPII after-school program, which could not be measured by the questionnaires, half of the students registered in the targeted after-school program, throughout the four-semester research period, were randomly invited to participate in post-program interviews in order to understand how they perceived the relationship between their digital literacy changes and the BTPII-based learning experiences. The student interview protocol is provided in Appendix C.

Teacher Interview

At the beginning of each semester of the four-semester timeframe, David and I regularly discussed instructional objectives (mainly regarding digital literacy development), technology integration strategies (primarily regarding AR and VR and SNS), instructional content (mainly regarding technical knowledge and skills for creating AR and VR content and producing multimedia content), pedagogic strategies (primarily from the social constructionist approach), expected student learning experiences, and outcomes.

Lesson Plans

David's lesson plans provided each semester's learning activities within the context of instructional objectives, instructional content, and technology application strategies, which are all necessary to realize students' changes in digital literacy.

Classroom and Social Network Site Observations

The students' learning activities and experience in the classroom (face-to-face setting) and on Edmodo (online setting) were observed to evaluate the relationships between their learning experience and digital literacy changes. The observation protocol focused on capturing the students' behaviors that were manifested in the co-construction and transfer of knowledge in different contexts with increasing sophistication. The observation protocol was theoretically developed using the EU's digital competency framework (Reynolds, 2016) and concurrently referring to a validated Cooperative Learning Observation Protocol (CLOP) (Kern, Moore, & Akillioglu, 2007). CLOP articulated its applicability in observing group learning activities (Raphael, Bachen, & Hernández-Ramos, 2012; Salehizadeh & Behin-Aein, 2014) and was applied to observe middle school students' digital literacy practices in a group project setting (Luo, 2015). The observation protocol was reviewed by David to ensure its appropriateness.

Classroom observations were conducted during the program whereas the Edmodo observations were performed on a weekly basis by the investigator. To conduct the classroom observations, I physically attended the classroom in the last four weeks in each semester.

Student Repeat Participation Numbers in the BTPII After-School Program

These data were provided by the program teacher (David). Student participation numbers ranged from one to three times. These data were later used as an independent variable to compare students' changes in digital literacy and final performance with respect to their repeat participation numbers in the BTPII after-school program.

Final Performance Assessment

A student's final performance score was determined by his/her score in an individual project and a group project in the spring/fall 2017 and spring 2018 semesters. Students' final performance in the fall 2018 semester was only determined by their individual project scores because they did not have the opportunity for a group project due to delayed course progression. Student projects could obtain a maximum of 100 marks and were graded by David based on the following aspects (each aspect contributed 25 points):

1. Information management: Multimodal information was organized meaningfully and coherently to support main themes of an artifact.
2. Creation: Retrieve and design conventions (e.g., text, voice, and video etc.) were used to construct an artifact creatively.

3. Technical fluency: Student appropriately applied learned technical knowledge and skills to support representation of main themes of an artifact. The artifact had no bugs.
4. Ethics and Responsibility: Credit was given to an artifact's information resource(s) in an informative and appropriate way. No plagiarism was evinced.

Internet Use and Self-Learning Questionnaire

An Internet Use and Self-learning Questionnaire was issued to students to investigate students' daily Internet access time and Internet usage purposes. The survey items were extracted from the 2015 National K-12 Student Digital Behaviors Survey administered by the Taiwan Ministry of Education (Ko, 2015). This questionnaire also asked students about their out-of-school self-learning experience with Edmodo. The questionnaire is provided in Appendix D. This questionnaire's items related to Internet usage purposes did not include any items regarding the *safety* element present in the EU digital literacy framework, because the original *safety* element mainly emphasized the cognitive aspects of using digital tools, such as being aware of physical and psychological well-being or knowing how to adjust settings to prevent social media networks from sharing personal data. However, students' perceptions of *safety* were investigated using the student self-reported Digital Literacy Questionnaire described above. In the end, I collected 58 valid responses: Four questionnaire responses from the spring 2017 semester, 13 questionnaire responses from the fall 2017 semester, 24 questionnaire responses from the spring 2018 semester, and 17 questionnaire responses from the fall 2018 semester.

Data Analysis

In this section, the presentation of data analysis aligns to the research questions in order to describe precisely how all the data sources were analyzed to answer the research questions.

Research Question One: What Were the Students' Learning Activities Across the Four Semesters of the BTPII After-School Program?

I summarized the four semesters' BTPII learning activities based on David's lesson plans as the basis to represent the students' BTPII learning activities across the four semesters. The data of teacher interview and classroom and Edmodo observations provided additional information regarding the students' learning activities across the face-to-face and online settings.

Research Question Two: How Did Students' Digital Literacy Change After Engagement in the BTPII After-School Program? Did the Students' Pre- and Post-Digital Literacy Changes Differ With Respect to the Students' Repeat Participation Numbers in the After-School Program, or Levels of the Students' Daily Internet Access Time, or the Students' Daily Internet Usage Purposes?

To measure students' digital literacy changes, the self-reported Digital Literacy Questionnaire (see Appendix B) was issued to the student participants in the first and last weeks of each semester. In each semester, students' pre- and post- questionnaire data were analyzed using the Wilcoxon Signed Ranks Test to understand if students' changes in the five elements of digital literacy were statistically significant. Effect sizes for each element of digital literacy were calculated by the formula proposed by Rosenthal (1994) rather than Cohen's D. The number of valid self-reported pairwise pre- and post- digital literacy questionnaires is provided in Table 7.

Table 7: Number of Valid Self-Reported Pairwise Pre- and Post- Digital Literacy Questionnaire.

	2017 Spring	2017 Fall	2018 Spring	2018 Fall
Male	13	17	23	16
Female	2	2	6	1
Total	15	19	29	17

Student interviews as well as classroom and Edmodo observation data analysis aimed to verify and triangulate the data interpretation of the students' self-reported Digital Literacy Questionnaires through applying theory-driven codes (DeCuir-Gunby, Marshall, & McCulloch, 2011). The data were coded using a priori codes theoretically generated from a review of previous studies (Bruner, 1960; Ferrari, 2012; Lave & Wenger, 1991; Reynolds, 2016). The coding results were checked with David to ensure reliability. To understand students' BTPII learning activities systematically, at the end of each semester, David and I worked together to interpret students' feedback and learning outcomes, as well as how their learning experience explained such outcomes. I also asked David for his viewpoints regarding the BTPII learning activities and experience's impact on the students' changes in digital literacy.

To answer the three sub-questions, changes in the students' mean digital literacy were compared by using non-paramedic test(s) among groups with different repeat participation numbers in the BTPII program, different levels of daily Internet access time, and different levels of Internet usage purposes related to the application of each element of digital literacy.

For the influence of repeat participation on students' digital literacy changes, within a semester, students were categorized as novice (first time participation in BTPII) and veteran (2nd or more participations in BTPII) groups. The two groups' changes in digital literacy were then analyzed by the Mann-Whitney U test.

The participants' Internet access time was categorized into three levels: low-use group (neither weekday Internet access time under two hours nor weekend Internet access time of less than 5 hours), medium-use group (either weekday Internet access time over two hours or weekend Internet access time over 5 hours) and high-use group (both weekday Internet access time over two hours and weekend Internet access time over 5 hours). The threshold of two hours and five hours was justified by the results of the National K-12 Student Digital Behaviors Survey administered by the Taiwan Ministry of Education in 2015 (Ko, 2015). The survey results indicated that the average weekday Internet access time of middle school students in Taiwan was 2 hours, whereas the average weekend Internet access time was 5 hours.

The participants' daily Internet usage purposes were categorized in line with elements of the EU digital literacy framework: (a) information search and management (corresponding to the element of information and data literacy), (b) communication and collaboration (communication and collaboration), (c) creation (corresponding to the element of digital content creation), and (d) problem solving (problem solving). For each element, students were categorized into two to three levels depending on the number of sub-purposes they reported in the Internet Use and Self-learning Questionnaire (Appendix D). For instance, in the purpose category of information search and management, students were asked to report if they used the Internet for the following sub-purposes at least one time a week: (a) search for Information related to my interests, (b) search for Information related to my school work, (c) use cloud service (e.g, Google Drive) to back up my computer's data. Students were categorized in the high-level group when they spontaneously reported engaging in the above three sub-purposes at least one time a week. If students chose any two of the three sub-purposes, they were categorized in the medium-level group. Students who only chose one of the three sub-purposes were categorized in the low-level group. The same categorization method also applied to the purpose categories of communication and collaboration as well as problem solving. By contrast, the purpose category of creation only included two levels because very few students had related experience in creating digital content on a regular basis according to the results of the National K-12 Student Digital Behaviors Survey administered by the Taiwan Ministry of Education in 2015 (Ko, 2015).

However, running a categorical mean comparison with limited samples from a single semester was problematic. For instance, the 13 samples from the fall 2017 semester were categorized by their levels of daily Internet access time, into the low-use group (N=1), a medium-use group (N=1) and a high-use group (N=11). As two groups only had one sample each, an inaccurate *p* value was received when these three groups were compared with a nonparametric test for any possibility of significance at the $\alpha = 0.05$ level for a 2-tailed test. A similar issue was found when applying a categorical mean comparison with only four samples from the spring 2017 semester. Thus, I combined the 58 valid responses and standardized respondents' digital literacy changes in each semester. The first step of standardization involved converting each student's original digital literacy changes to *z* scores using the following formula:

$$z = \frac{x - \mu}{\sigma}$$

x = observed value (digital literacy changes)

μ = mean of all respondents' values in the same semester

σ = standard deviation of all respondents' values in the same semester

T scores were later calculated based on the *z* scores, as it would be awkward to explain why a student had a negative *z* score in his/her digital literacy change. The formula used to calculate a *T* score was:

$$T = 10z + 50$$

Digital literacy changes in different semesters became comparable after converting all respondents' digital literacy changes into *T* scores. The standardized *T* scores were then used to conduct a cross-sectional comparison for the respondents' digital literacy changes with respect to their repeat participation numbers in the after-school program, levels of daily Internet access time and daily Internet usage purposes. On the other hand, to find what Internet usage purposes have highest correlation with the student participants' changes in digital literacy, a Pearson Correlation Analysis was applied accordingly.

Research Question Three: How Do Students' Final Performance in the BTPII After-School Program Differ? Do Student Performance Differ With Respect to the Students' Repeat Participation Numbers in the After-School Program, or Levels of the Students' Daily Internet Access Time or The Students' Daily Internet Usage Purposes?

The variation in students' final performance in the BTPII after-program across the four semesters were represented by performing a descriptive statistics to show minimum, maximum, mean, and standard deviation in students' final performance in each semester.

To answer the three sub-questions, the students' final performance scores were compared by using non-paramedic test(s) among groups with different repeat participation numbers in the BTPII program, different levels of daily Internet access time, and different levels of Internet usage purposes related to the application of each element of digital literacy.

For the influence of repeat participation on students' final performance, within a semester, students were categorized as novice (first time participation in BTPII) and veteran (2nd or more participations in BTPII) groups. The two groups' final performance were then analyzed using a Mann-Whitney U test.

By contrast, the participants' Internet access time was categorized into three levels: low-use group, medium-use group and high-use group, applying the same principle as described above. The method to categorized participants' daily Internet usage purposes applied the same principle mentioned above.

For the same concern of running a categorical mean comparison with limited samples from a single semester, I again combined the 58 valid responses and standardized respondents' final performance scores in each semester. The first step of standardization involved converting each student's original final performance scores to *z* scores using the following formula:

$$z = \frac{x - \mu}{\sigma}$$

x = an observed final performance score

μ = mean of all respondents' scores in the same semester

σ = standard deviation of all respondents' scores in the same semester

T scores were later calculated based on the *z* scores, as it would be awkward to explain why a student had a negative *z* score in his/her final performance. The formula used to calculate a *T* score was:

$$T = 10z + 50$$

The respondent's final performance scores in different semesters became comparable after converting all respondents' final performance scores into *T* scores. The standardized *T* scores were then used to conduct a cross-sectional comparison for the respondents' final performance scores with respect to their repeat participation in the after-school program, levels of daily Internet access time and daily Internet usage purposes. On the other hand, to find what Internet usage purposes have highest correlation with the student final performance, a Pearson Correlation Analysis was applied accordingly.

TRUSTWORTHINESS

The current study applied cross-sectional and mixed-method case study approach, including questionnaires, teacher/student interviews, lesson plan analysis, students' final performance results, and online and face-to-face classroom observations, to triangulate emerging findings and ensure the validity and credibility of data interpretation. In addition to theoretically driven data analysis work, to minimize judgmental bias, I concurrently referred to qualitative and quantitative data to enhance the trustworthiness of the findings.

POSITIONALITY

This study was inspired by my previous research experience that involved pupils in creating augmented reality (AR) content, as a group project, in a blended learning setting (Hsu, Zou, & Hughes, 2018) and verified that AR content creation benefitted the pupils' digital literacy. Thus, the original research goal of this dissertation focused on the impact of creating AR and VR content on middle school students' digital literacy development. Hence, David and I worked together to initiate an after-school program featuring AR and VR content creation at a technology-rich middle school. David was responsible for instructional design, development, implementation, and revision, while my role was primarily that of an instructional design consultant and evaluator in the spring and fall 2017 semesters. In the spring and fall 2018 semesters, David had become familiar with design, implementation and revision of the blended learning approach, so I changed my consultant role to an observer, while I was still responsible for quantitatively and qualitatively evaluating students' digital literacy changes. In the spring and fall 2018 semesters, I also noticed that David tried to introduce AR and VR software with higher technical complexity in order to upgrade technical levels of student-created AR and VR products. David also tried to relate this after-school program's curriculum to STEM education by involving students in creating a location-based AR game-based STEM learning application in the spring 2018 semester. On the other hand, David tried to introduce computational thinking into this after-school program in the fall 2018 semester as a response to the popularity and requirement of teaching computational thinking in Taiwan.

As a four-semester observer in this after-school program, I witnessed how David updated this after-school program's curriculum to fulfill expectations from school administrators, as this after-school program was supported by the local government. Consequently, David felt pressure to demonstrate this program's progression to secure government funding. In David's case, I saw how a passionate teacher dedicated himself to digital literacy education under stresses from school administrators and the local government. I also saw a busy teacher, in addition to his regular job duties, had to weekly complete the following tasks: (a) self-learn new technical knowledge and skills of the AR and VR software, (b) create and upload self-learning materials to Edmodo at least three days before the class date, (c) design and implement pre-, in- and post- class learning activities, and (d) monitor students' online activities on Edmodo.

As I continued to work on this after-school program, I gradually developed the hypothesis that the blended learning experience might have a greater impact on students' digital literacy changes because AR and VR content creation is only a method to implement the blended learning approach. In other words, we could replace the AR and VR content with another multimedia artifact creation activity after ensuring its effectiveness in developing digital literacy. In short, I realized, the essential factor influencing students' digital literacy might be their blended learning experience. We did not have to focus on learning-by-designing AR and VR and observe its influence on digital literacy education. To test my hypothesis, this study specifically explored the relationship between the blended learning approach and middle school students' digital literacy changes. I expected this study to contribute to the researchers and practitioners' understanding of the blended learning approach's effect on middle school digital literacy education.

Chapter 4: Results

This study investigated how middle school students' digital literacy changed after engagement in the BTPII learning activities. This study also examined how the students' repeat participation in BTPII, daily Internet access time, and daily Internet usage purposes impacted their digital literacy changes and final performance. This chapter reports findings that answer the following research questions:

1. What are the students' learning activities across the four semesters of the BTPII after-school program?
2. How do students' digital literacy change after engagement in the BTPII after-school program?
   i. Do the students' pre- and post- digital literacy changes differ with respect to students' repeat participation in the after-school program?
   ii. Do changes, if any, differ with respect to levels of students' daily Internet access time?
   iii. Do changes, if any, differ with respect to the students' daily Internet usage purposes?
3. How do students' final performance in the BTPII after-school program differ?
   i. Does student performance differ with respect to students' repeat participation in the after-school program?

ii. Does performance differ with respect to levels of the students' daily Internet access time?

iii. Does the performance differ with respect to the students' daily Internet usage purposes?

INTENDED LEARNING ACTIVITIES ACROSS THE FOUR SEMESTERS

This section describes how the BTPII instructional design framework was applied to learning activities in the spring and fall semesters of 2017 and 2018. Although each semester's instruction was based on the BTPII instructional design framework, there were some variations in activities across the four semesters' 18-week-long learning activities (see Table 8).

Table 8: Learning Activities of the BTPII After-School Program for Each Semester

Semester	Learning Activities
Spring and Fall 2017	• Introduction to Edmodo and Google drive for information management and communication (1 week) • Photography (1 week) • Photo editing (1 week) • Video recording (1 week) • Video editing (1 week) • Basic operation of Aurasma (1 week) • Advanced operation of Aurasma (1 week)

Table 8 (continued)

Semester	Learning Activities
Spring and Fall 2017	• Advanced operation of Aurasma (1 week) • Mind mapping and project management (1 week) • Mid-term project: AR student ID (individual project) (2 weeks) • Technical knowledge and skills of Roundme (1 week) • Panoramic Photography of famous sites on campus (1 week) • Panoramic Photography of famous sites at a city park (1 week) • Final group project: VR City Park Tour Guide System (4 weeks) • Project presentation (1 week)
Spring 2018	• Introduction to Edmodo and Google drive for information management and communication (1 week) • Photography, photo editing, and mind map application (1week) • Video recording and editing (1 week) • Basic operation of Aurasma (1 week) • Advanced operation of Aurasma (1 week) • Mid-term individual project: AR student ID (1 week) • Basic operation of ARIS: objectives, trigger, and scenes (1 week) • Basic operation of ARIS: locks, trigger types, and locations (1 week) • Advanced operation of ARIS: media and icons, plaques, and times (1 week)

Table 8 (continued)

Semester	Learning Activities
Spring 2018	• Advanced operation of ARIS: items, conversations, and quests (1 week) • Advanced operation of ARIS: factories and QR code login (1 week) • Introduction of location-based and AR game-based STEM learning application (1 week) • How to develop an interesting game storyline and formulate a meaningful question using STEM knowledge (1 week) • Final group project: location-based, AR game-based, STEM learning application (4 weeks) • Project presentation (1week)
Fall 2018	• Introduction to Edmodo and Google drive for information management and communication (1 week) • Introduction to the CoSpaces Interface (1 week) • Basics of CoSpaces: scene and space (1 week) • Basics of CoSpaces: upload and edit 360° images (1 week) • Basics of CoSpaces: operation of an object: size, position, rotation, lock, and delete (1 week) • Basics of CoSpaces: modification of an object’s features: name, speech, opacity, color, state, and posture (1 week)

Table 8 (continued)

Semester	Learning Activities
Fall 2018	• Advance operation of CoSpaces: duplicate objects, permanently group objects, multi-selection, attach one object to another, attach and animate objects, and animate objects with a turn item (1 week) • Advance operation of CoSpaces: application of fantasy objects, adding images to a CoSpaces creation, and application of the physics mode (1 week) • Advance operation of CoSpaces: masking simple objects, using markers and panels in CoSpaces, and application of flexicuboid (1 week) • Advance operation of CoSpaces: application of a camera object, inserting a camera object, changing a camera perspective, and camera collision (1 week) • Screen recording, video editing, and mind map application (1 week) • Final individual project: VR maze (5 weeks) • Individual project demonstration video (1 week) • Project presentation (1 week)

Each semester, participants were assigned a main project topic. Students participating in the spring and fall 2017 semesters shared the same topics of creating an AR student ID with Aurasma and VR City Park Tour Guide System using Roundme. Aurasma is an online platform that allow users to create AR content using texts, images, videos, or animations. Aurasma has been rebranded as HP Reveal (https://www.hpreveal.com/). Roundme is an online VR content creation platform that allows users to upload panoramic pictures to produce 360 degree virtual tours (https://roundme.com/).

The main project for the spring 2018 semester involved creating a location-based and AR game-based science, technology, engineering, and mathematics (STEM) learning application using ARIS. ARIS is an AR-based game design platform created by the Wisconsin Center for Educational Research at the University of Wisconsin (https://fielddaylab.org/make/aris/). The project topic in the fall 2018 semester was to create a VR game, using CoSpaces, to facilitate students' computational thinking. CoSpaces is an online VR content creation platform that uses Scratch-style visual programming language (https://cospaces.io/edu/). The changes in learning activities were determined by the program teacher's (David's) motivation to explore various ways to facilitate students' digital literacy as well as interdisciplinary knowledge and skills.

Spring and Fall 2017 Semesters

These two semesters shared the same learning activities including one individual and one group project. Through various collaborative learning activities, students gained knowledge and skills, such as photography, photo editing, video recording, and editing, for multimedia production. The students were also grouped to learned how to use Xmind, a digital mind mapping tool, to plan a project. The individual project--creating an AR student ID--allowed participants to synthesize learned multimedia knowledge and skills by using Aurasma to create an AR student ID to introduce themselves via AR technology. One example of AR student ID is provided in Figure 5. The final project required students to create a VR City Park Tour Guide System (Figure 6) using Roundme, a platform that enables users to upload 360-degree panoramic photos and add multimedia content to create VR content. This project enabled students to synthesize previous learning outcomes and share knowledge and skills to collectively create VR content for a city park located next to their school.

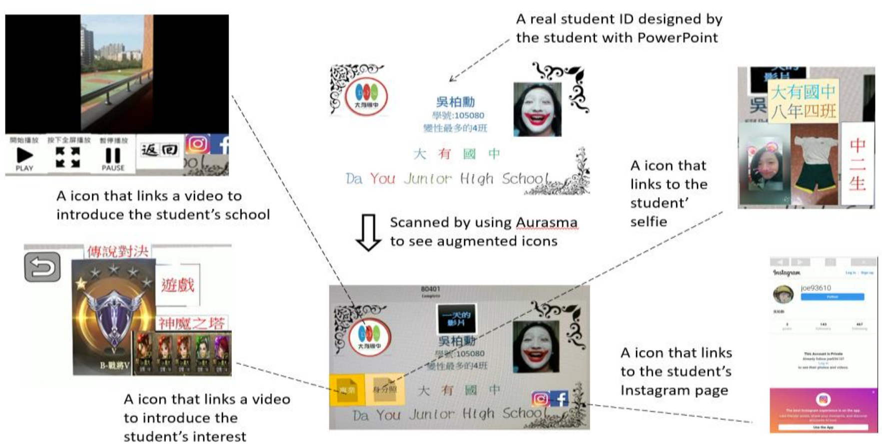

Figure 5: Example of AR Student ID

Figure 6: Screenshot of Student-Created VR City Park Tour Guide System

Spring 2018 Semester

Similar to the previous two semesters, the spring 2018 semester also included one individual project (AR student ID) and one final group project. However, the program teacher decided to introduce location-based AR technology to deepen students' knowledge about AR. Thus, this semester's final group project was altered and involved the development of an AR game-based mobile learning application powered by ARIS, an AR-based game design platform developed by the University of Wisconsin. ARIS served as an AR-based instructional resource used for both *learning by consumption* and *learning by creation* approaches. As a typical approach of *learning by consumption* with ARIS, Atwood-Blaine (2015), in her dissertation, once studied how learning with a location-based game built on the ARIS platform impacted on 5^{th}-9^{th} graders' learning in science and engineering subject matters. A student could use the game to participate in science and engineering practices with exhibits in different spots at a hands-on science center, enabling a learning by doing experience. For the approach of *learning by creation*, Bates et al. (2015) conducted an international study in UK, Greece, Italy and Cyprus to investigate the effects of involving adolescents and young adults (aged from 14+ to 16+) in location-based AR game-design projects with ARIS on their concepts of AR design as well as proto type new design ideas in a vocational education setting.

The AR technology applied in this semester was location-based, which is more complex than the image-based AR used in the previous two semesters. To seek more time to allow students to learn the complex location-based AR technology, the program teacher compressed the timeframe that was originally allocated to teach multimedia production and planning knowledge and skills, such as photography, photo editing, video recording and editing, and mind map application. The teacher believed the reduced time might not be a problem because the students could self-learn multimedia production and planning knowledge and skills with teacher-uploaded materials at home within the blended learning structure of the BTPII.

The final project involved developing a location-based AR game-based STEM learning application, so the students also learned how to develop an interesting game storyline and design a meaningful question addressing STEM factual knowledge. Therefore, the overall complexity and difficulty of the final project was higher than the final projects in the previous two semesters. The students also spent five more weeks learning basic and advanced technical knowledge and skills related to ARIS, compared to their cohorts who learned Aurasma in spring and fall 2017 semesters. One example of the location-based, AR game-based, STEM learning application is provided in Figure 7.

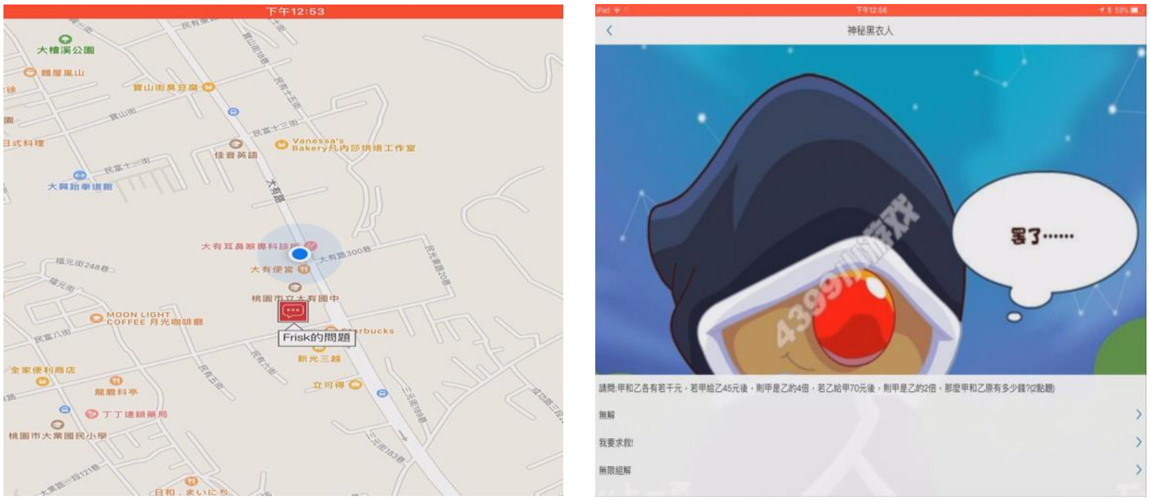

Figure 7: Example of Location-Based, AR Game-Based, STEM Learning Application

When playing with the application, a user's position is marked as a blue circle on the map while the red square represents an event point (see left portion of Figure 7). When a user gets geographically close enough to the event point, the application presents a multiple-choice question related to STEM knowledge (see right portion of Figure 7). The user is awarded a point if he/she answers the question correctly. Subsequently, the user receives a clue to the next event point. A user has to go through as many event points as possible and collect the most points to win the game.

Fall 2018 Semester

The after-school teacher initially decided to have participants build a VR STEM game-based learning environment to increase the level of VR technology learned in this after-school program. However, upon consulting with experts in the field of VR in education, he found that constructing a functioning virtual learning environment could take more than a semester's time. Thus, this semester's primary goal was modified to teaching students the technical knowledge and skills required to build a functioning VR environment. The teacher chose CoSpaces, an online VR content creation platform using Scratch-style visual programming language, because most of students had no background knowledge about Unity, a common programming language widely used to develop VR environment. Most participants had learned Scratch in their formal computer science class.

As planned by the teacher, this semester aimed to include one individual (VR maze) and one group project (mini VR animation). The individual project, VR maze, required students to create a virtual maze environment using basic levels of VR technical knowledge and skills. The group project, mini VR animation, aimed to involve a group of students in developing a storyline and collaboratively building a mini VR animation using advanced levels of VR technical knowledge and skills. Therefore, the students also acquired screen recording and video editing skills required to create an animation. However, the students spent ten weeks learning CoSpaces, which was far more time than the teacher had estimated. In the teacher's original estimation, six weeks were supposed to be sufficient for students to gain familiarity with CoSpaces given their background knowledge of Scratch. The teacher found that almost every student was unable to build a bug-free, functioning VR product, so he spent an additional four weeks reteaching CoSpaces, which students were supposed to have self-learned at home. After the teacher retaught CoSpaces, there was not enough time for students to complete the group project.

Hence, the final group project was replaced by individual projects creating a VR maze followed by a demonstration video introducing the maze (see Figure 8).

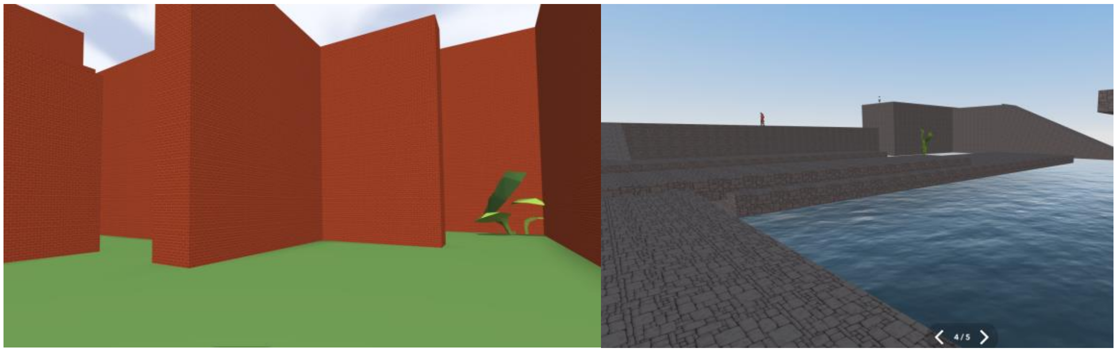

Figure 8: Examples of a Student-Created VR Maze

The intended design of the BTPII framework aimed to facilitate learning activities throughout the pre-class, in-class, and post-class intervention phases, involving middle school students in task-driven learning activities to contextually practice digital literacy. Such design was built on Reynold's (2016) concept of task-driven, social constructivist digital literacy. The proposed BTPII framework also aimed to improve students' digital literacy, weaving face-to-face and online settings in a synergistic manner–what they learned online would prepare them for in-class, technology-rich, PBL activities. Students' digital literacy developed via the in-class PBL experience would, in turn, consolidate their subsequent learning activities online. Their improved digital literacy would positively impact students' subsequent learning tasks and further provide opportunities for improving digital literacy through online and face-to-face learning experiences. Thus, the BTPII framework was expected to facilitate a positive feedback circle of digital literacy development across face-to-face and online learning environments.

ENACTED STUDENTS' LEARNING ACTIVITIES AND EXPERIENCE

This section illustrates the enacted learning activities and experience by participants in both the online and face-to-face settings. The main themes include learning with Edmodo, limited self-learning at home and students with low learning motivation in the classroom.

Learning with Edmodo

This sub-section first describes students' Edmodo use frequency and accessibility. Students' limited online interaction on Edmodo and possible reasons were also discussed.

Access to Edmodo

Fifty percent of students installed Edmodo on their smartphones. Only 5.5% of students checked the Edmodo page daily. Over a quarter of the participants (27.7%) reported that they checked Edmodo if they received a notification from the app. Two-thirds of the students (66.6%) checked the page only on the days of the after-school program. In terms of access, 80.5% of students accessed the Edmodo page via a laptop/computer. Of the remaining participants, 18.8% reported using their smartphones while 0.7% of students accessed the page using both types of devices.

Limited Interaction on Edmodo

The students, on average, neither agreed nor disagreed about their active participation in online interaction on Edmodo (3.00 on a 5-point Likert scale), as reported in the Internet Use and Self-Learning Questionnaire. The students also neither agreed nor disagreed about their active participation in sharing information related to this semester's learning content on Edmodo in online peer interaction on Edmodo (3.40 on a 5-point Likert scale). Thus, the students did not display a preference for Edmodo as their primary online communication platform. Also, the students, on average, neither agreed nor disagreed about actively posting their questions to Edmodo (3.15 on a 5-point Likert scale). The students also, on average, neither agreed nor disagreed about actively answering peer's questions on Edmodo (2.69 on a 5-point Likert scale). Students' limited motivation for using Edmodo to seek help was also supported by the extremely limited number of students' posts on Edmodo: nine posts made among 32 students during the 18-week after-school program in spring 2017 semester, two posts made among 32 students during 18 weeks in fall 2017 semester, zero posts found in spring 2018 semester, and one post made among 21 students in fall 2018 semester during 18 weeks. Therefore, applying Edmodo as a peer-to-peer question and answer forum did not work as expected by the proposed BTPII framework. Moreover, students neither agreed nor disagreed about using Edmodo to discuss group work actively with peers on Edmodo (2.95 on a 5-point Likert scale). Edmodo was not considered as a welcome platform for group work.

This lack of online communication and collaboration as well as problem solving practices could be attributed to three reasons. First, Edmodo does not allow students to send and receive private messages. Therefore, based on David's opinion, participants preferred using other messaging applications, such as Facebook Messenger or Line app, as their primary interaction and collaboration tool, to support more private direct communication. This phenomenon is similar to my previous research findings in a case study of elementary students' blended learning experience (Hsu et al., 2018). The elementary students often used Line app to replace Edmodo for privacy concern when they wanted to communicate with peers. The pupils used less Facebook Messenger because Facebook requires everyone to be at least 13 years old before they can create an account. Second, the asynchronous interaction failed to satisfy students' immediate technical needs. When students encountered a project-related technical problem at home, their survey results indicated they preferred to search for solutions on the Internet (82.7%) or ask family members (34.4%) or peers for help (33.3%). Only 10.3% of students chose to post their questions on Edmodo's question-and-answer forum and waiting for a few days for an answer. Third, students regularly met each other during the school day and had face-to-face interactions. It may have seemed unreasonable to the students to use online communication (Edmodo) to replace face-to-face interactions.

Limited Self-Learning at Home

Although Edmodo played the role of instructional information distribution center by the teacher to the students, the students, on average, neither agreed nor disagreed about actively reading their teacher's post on Edmodo to know in-class learning activities in the forthcoming week (3.47 on a 5-point Likert scale), based on the results of the Internet Use and Self-Learning Questionnaire issued to the students. Compared to the relatively higher level of actively reading their teacher's post, the students spent less time completing preview work with teacher-uploaded learning materials prior to the classroom sessions. The student participants, on average, neither agreed nor disagreed about actively completing their preview work with the learning materials uploaded by the teacher before the after-school program date (2.76 on a 5-point Likert scale). The deviation between reading the teacher's posts and completing preview work is provided in figure 9.

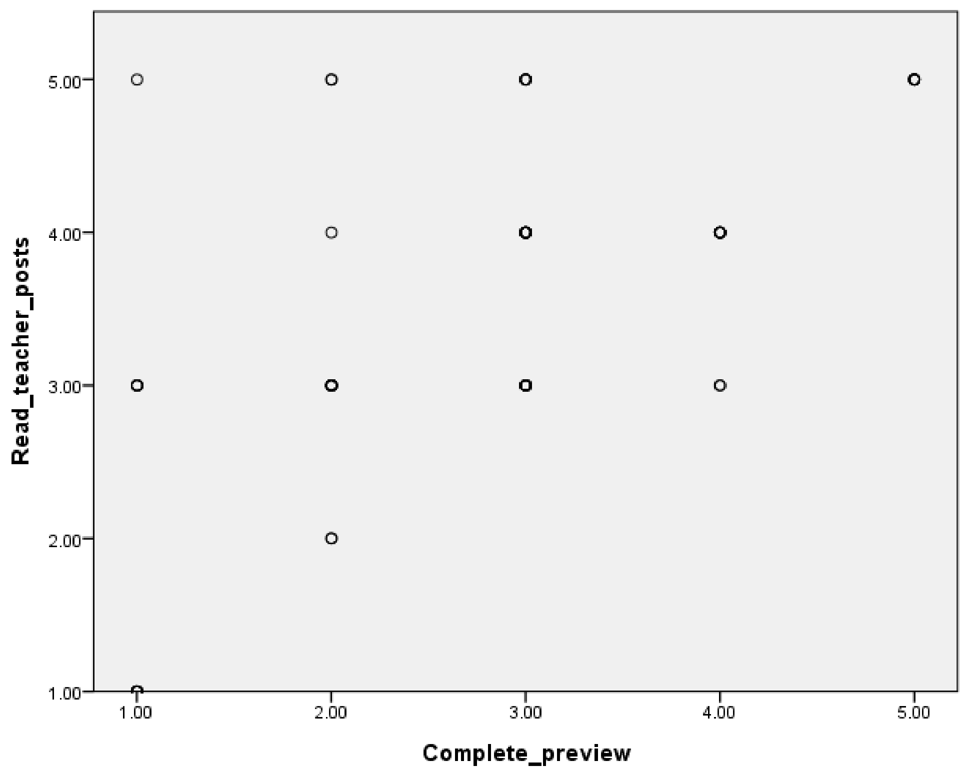

Figure 9: The Deviation of Students' Reading the Teacher's Posts and Completing Preview Work Before Coming to the Classroom

As shown by figure 9, there is a gap between students' reading of teacher's posts and completion of preview work. In other words, some students might only read the teacher's posts to know the forthcoming in-class learning activities but skip their preview work.

The lack of previewing became particularly apparent in the fall 2018 semester because the learning content involved a lot of technical knowledge and skills that students needed to self-learn at home as the limited class hours were used for student creation of VR content. The teacher was often forced to reteach the content meant to be self-learned by the students at home when they did not self-learn. When content was not retaught, the teacher found that half of the students failed to complete basic-level, in-class tasks. This issue finally slowed down the progress of the course in the fall 2018 semester, forcing the teacher to cancel the final group project.

Students With Low Learning Motivation in the Classroom

There were two types of students who displayed lower learning motivation than their peers. The first type of students primarily joined the BTPII after-school program to gain Internet access. In other words, being able to access the Internet legally at an Internet-banned school attracted this type of student to the after-school program. This group of students included those who lacked Internet access at home and those who were addicted to online games. They usually immersed themselves in browsing the Internet or playing online games, instead of participating in in-class learning activities regardless of the teacher's warnings. The second type of less motivated students were those left behind due to the course's difficulty. This type of students became particularly apparent in the fall 2018 semester.

Less motivated students belonged to both types of groups identified above because the first type of students could fall behind as a result of surfing the Internet and missing the teacher's lecture or the opportunity to learn from peers. The second type of students might do nothing but surf the Internet because they gave up following the course's progression. Both types of students either failed to turn in their individual projects or completed them with fair to poor quality.

STUDENTS' DIGITAL LITERACY CHANGES AFTER COMPLETING THE BTPII PROGRAM

This section illustrates the BTPII participants' changes in each element of digital literacy across the spring and fall 2017 and 2018 semesters.

Spring 2017 Semester

Fifteen (two girls and 13 boys) of 32 participants completed the entire BTPII after-school program and completed valid, self-reported, pairwise pre- and post- digital literacy questionnaires. The descriptive statistics result is provided in Table 9.

Table 9: Descriptive Statistics for Elements of Pre- and Post-Digital Literacy in the Spring 2017 Semester

Descriptive Statistics

	N	Mean[a]	Std. Deviation	Minimum	Maximum
Pre_IDL	15	4.13	0.23	3.76	4.56
Post_IDL	15	4.43	0.31	3.70	4.83
Pre_com_colla	15	3.94	0.32	3.33	4.42
Post_com_colla	15	4.33	0.43	3.36	4.81
Pre_creation	15	2.86	0.26	2.30	3.13
Post_creation	15	3.22	0.51	2.17	4.08
Pre_safety	15	4.35	0.22	3.97	4.72
Post_safety	15	4.63	0.29	3.98	4.95
Pre_PBL	15	3.82	0.32	3.23	4.28
Post_PBL	15	4.26	0.42	3.23	4.81
Pre_DL	15	3.82	0.22	3.38	4.11
Post_DL	15	4.18	0.35	3.38	4.66

Note. [a] 5-point Likert scale from 1 (*strongly disagree*) to 5 (*strongly agree*)

A Wilcoxon Signed Ranks Test was applied to analyze if students' changes in each element of digital literacy were statistically significant. The test results are shown in Table 10.

Table 10: Results of Wilcoxon Signed Ranks Test for Each Element of Pre- and Post-Digital Literacy for the Spring 2017 Semester

Test Statistics[b]

	Post - Pre_ IDL	Post - Pre_ Com_Colla	Post - Pre_ Creation	Post - Pre_ Safety	Post - Pre_ PBL	Post - Pre_ Overall DL
Z	-3.211[a]	-3.238[a]	-2.231[a]	-3.296[a]	-3.238[a]	-3.297[a]
Asymp. Sig. (2-tailed)	.001	.001	.026	.001	.001	.001
Effect size	0.83	0.84	0.58	0.85	0.84	0.85

a. Based on negative ranks.
b. Wilcoxon Signed Ranks Test

For the element of *information and data literacy*, the increase from the pre-test mean of 4.13 to the post-test mean of 4.43 is statistically significant (Z = -3.211, $p = .001$) with an effect size of 0.83. For the element of *communication and collaboration*, the increase from the pre-test mean of 3.94 to the post-test mean of 4.33 is statistically significant (Z = -3.238, $p = .001$) with an effect size of 0.84. For the element of *creation*, the increase from the pre-test mean of 2.86 to the post-test mean of 3.22 is statistically significant (Z = -2.231, $p = .026$) with an effect size of 0.58. For the element of *safety*, the increase from the pre-test mean of 4.35 to the post-test mean of 4.63 is statistically significant (Z = -3.296, $p = .001$) with an effect size of 0.85. For the element of *problem* *solving*, the increase from the pre-test mean of 3.82 to the post-test mean of 4.26 is statistically significant (Z = -3.238, p = .001) with an effect size of 0.84. The students' overall digital literacy development is statistically significant (Z = -3.297, p = .001) with an effect size of 0.85 and its mean increased from 3.82 in the pre-test mean to 4.18 in the post-test.

Fall 2017 Semester

Nineteen (two girls and 17 boys) of 31 participants completed the semester-long BTPII after-school program and filled out valid, self-reported, pairwise pre- and post-digital literacy questionnaires. The descriptive statistics result is provided in Table 11.

Table 11: Descriptive Statistics for Each Element of Pre- and Post-Digital Literacy in the Fall 2017 Semester

Descriptive Statistics

	N	Mean[a]	Std. Deviation	Minimum	Maximum
Pre_IDL	19	4.29	0.22	3.91	4.65
Post_IDL	19	4.41	0.25	4.06	4.84
Pre_com_colla	19	4.12	0.36	3.27	4.62
Post_com_colla	19	4.31	0.36	3.48	4.83
Pre_creation	19	3.14	0.28	2.66	3.59
Post_creation	19	3.28	0.39	2.76	4.05
Pre_safety	19	4.49	0.22	4.10	4.82
Post_safety	19	4.60	0.24	4.12	5.01
Pre_PBL	19	4.10	0.34	3.56	4.71
Post_PBL	19	4.27	0.32	3.81	4.84
Pre_DL	19	4.03	0.25	3.62	4.48
Post_DL	19	4.17	0.27	3.71	4.71

Note. [a] 5-point Likert scale from 1 (*strongly disagree*) to 5 (*strongly agree*)

A Wilcoxon Signed Ranks Test was applied to analyze if students' changes in each element of digital literacy were statistically significant. The test results are shown in Table 12.

Table 12: Results of Wilcoxon Signed Ranks Test for Each Element of Pre- and Post-Digital Literacy in the Fall 2017 Semester

Test Statistics[b]

	Post - Pre_ IDL	Post - Pre_ Com_Colla	Post - Pre_ Creation	Post - Pre_ Safety	Post - Pre_ PBL	Post - Pre_ Overall DL
Z	-1.691[a]	-1.952[a]	-1.449[a]	-1.610[a]	-1.852[a]	-1.993[a]
Asymp. Sig. (2-tailed)	.091	.051	.147	.107	.064	.046
Effect size	0.39	0.45	0.33	0.37	0.42	0.46

a. Based on negative ranks.
b. Wilcoxon Signed Ranks Test

For the element of *information and data literacy*, the increase from the pre-test mean of 4.29 to the post-test mean of 4.41 is non-significant (Z = -1.691, p = .091) with an effect size of 0.39. For the element of *communication and collaboration*, the increase from the pre-test mean of 4.12 to the post-test mean of 4.31 is non-significant (Z = -1.952, p = .051) with an effect size of 0.45. For the element of *creation*, the increase from the pre-test mean of 3.14 to the post-test mean of 3.28 is non-significant (Z = -1.449, p = .147) with an effect size of 0.33. For the element of *safety*, the increase from the pre-test mean of 4.49 to the post-test mean of 4.60 is non-significant (Z = -1.610, p = .107) with an effect size of 0.37. For the element of *problem solving*, the increase from the pre-test mean of 4.10 to the post-test mean of 4.27 is non-significant (Z = -1.852, p = .064) with an effect size of 0.42. The students' overall digital literacy development is statistically significant (Z = -1.993, p = .046) with an effect size of 0.46 and it increased from the pre-test mean of 4.03 to the post-test mean of 4.17.

Spring 2018 Semester

Twenty-nine (six girls and 23 boys) of 32 participants completed the semester-long BTPII after-school program and filled out valid, self-reported, pairwise pre- and post- digital literacy questionnaires. The descriptive statistics result is shown in Table 13.

Table 13: Descriptive Statistics for Each Element of Pre- and Post- Digital Literacy in the Spring 2018 Semester

Descriptive Statistics

	N	Mean[a]	Std. Deviation	Minimum	Maximum
Pre_IDL	29	4.30	0.30	3.56	4.86
Post_IDL	29	4.36	0.30	3.64	4.86
Pre_com_colla	29	4.14	0.39	3.24	4.78
Post_com_colla	29	4.19	0.43	3.27	4.86
Pre_creation	29	3.18	0.42	2.23	3.98
Post_creation	29	3.26	0.45	2.23	4.05
Pre_safety	29	4.50	0.26	3.86	4.95
Post_safety	29	4.54	0.28	3.92	5.01
Pre_PBL	29	4.08	0.42	3.15	4.84
Post_PBL	29	4.20	0.43	3.22	4.89
Pre_DL	29	4.04	0.29	3.33	4.55
Post_DL	29	4.11	0.32	3.39	4.65

Note. [a] 5-point Likert scale from 1 (strongly disagree) to 5 (strongly agree)

A Wilcoxon Signed Ranks Test was applied to analyze if students' changes in each element of digital literacy were statistically significant. The test result is shown in Table 14.

Table 14: Results of Wilcoxon Signed Ranks Test for Each Element of Pre- and Post-Digital Literacy in the Spring 2018 Semester

Test Statistics[b]

	Post - Pre_ IDL	Post - Pre_ Com_Colla	Post - Pre_ Creation	Post - Pre_ Safety	Post - Pre_ PBL	Post - Pre_ Overall DL
Z	-1.242[a]	-.797[a]	-1.093[a]	-1.158[a]	-1.449[a]	-1.720[a]
Asymp. Sig. (2-tailed)	.214	.425	.274	.247	.147	.085
Effect size	0.23	0.15	0.20	0.22	0.27	0.32

a. Based on negative ranks.

b. Wilcoxon Signed Ranks Test

For the element of *information and data literacy*, the increase from the pre-test mean of 4.30 to the post-test mean of 4.36 is non-significant (Z = -1.242, p = .214) with an effect size of 0.23. For the element of *communication and collaboration*, the increase from the pre-test mean of 4.14 to the post-test mean of 4.19 is non-significant (Z = -0.797, p = .425) with an effect size of 0.15. For the element of *creation*, the increase from the pre-test mean of 3.18 to the post-test mean of 3.26 is non-significant (Z = -1.093, p = .274) with an effect size of 0.20. For the element of *safety*, the increase from the pre-test mean of 4.50 to the post-test mean of 4.54 is non-significant (Z = -1.158, p = .247) with an effect size of 0.22. For the element of *problem solving*, the increase from the pre-test mean of 4.08 to the post-test mean of 4.20 is non-significant (Z = -1.449, p = .147) with an effect size of 0.27. The students' overall digital literacy development is non-significant (Z = -1.720, p = .085) with an effect size of 0.32 although it increases from the pre-test mean of 4.04 to the post-test mean of 4.11.

Fall 2018 Semester

Seventeen (one girl and 16 boys) of 21 participants completed the semester-long BTPII after-school program and filled out valid, self-reported, pairwise pre- and post-digital literacy questionnaires. The descriptive statistics result is provided in Table 15.

Table 15: Descriptive Statistics for Each Element of Pre- and Post-Digital Literacy in the Fall 2018 Semester

Descriptive Statistics

	N	Mean[a]	Std. Deviation	Minimum	Maximum
Pre_IDL	17	4.22	0.31	3.65	4.80
Post_IDL	17	4.20	0.47	3.27	4.90
Pre_com_colla	17	3.95	0.54	2.57	4.76
Post_com_colla	17	4.00	0.69	2.70	4.91
Pre_creation	17	3.08	0.40	2.49	3.84
Post_creation	17	3.07	0.69	1.69	4.08
Pre_safety	17	4.37	0.39	3.25	4.92
Post_safety	17	4.34	0.52	3.20	5.05
Pre_PBL	17	3.95	0.47	3.05	4.80
Post_PBL	17	4.00	0.62	2.83	4.94
Pre_DL	17	3.91	0.40	3.17	4.63
Post_DL	17	3.92	0.57	2.86	4.78

Note. [a] 5-point Likert scale from 1 (*strongly disagree*) to 5 (*strongly agree*)

A Wilcoxon Signed Ranks Test was applied to analyze if students' changes in each element of digital literacy were statistically significant. The test results are shown in Table 16.

Table 16: Results of Wilcoxon Signed Ranks Test for Each Element of Pre- and Post-Digital Literacy in the Fall 2018 Semester

Test Statistics[b]

	Post - Pre_ IDL	Post - Pre_ Com_Colla	Post - Pre_ Creation	Post - Pre_ Safety	Post - Pre_ PBL	Post - Pre_ Overall DL
Z	-0.237[a]	-0.734[a]	-0.426[a]	-0.640[b]	-0.947[a]	-0.639[a]
Asymp. Sig. (2-tailed)	.813	.463	.670	.522	.344	.523
Effect size	0.06	0.18	0.01	0.16	0.23	0.15

a. Based on negative ranks.
b. Wilcoxon Signed Ranks Test

For the element of *information and data literacy*, the decrease from the pre-test mean of 4.22 to the post-test mean of 4.20 is non-significant (Z = -0.237, *p* = .813) with an effect size of 0.06. For the element of *communication and collaboration*, the increase from the pre-test mean of 3.95 to the post-test mean of 4.00 is non-significant (Z = -0.734, *p* = .463) with an effect size of 0.18. For the element of *creation*, the decrease from the pre-test mean of 3.08 to the post-test mean of 3.07 is non-significant (Z = -0.426, *p* = .670) with an effect size of 0.01. For the element of *safety*, the decrease from the pre-test mean of 4.37 to the post-test mean of 4.34 is non-significant (Z = -0.640, *p* = .522) with an effect size of 0.16. For the element of *problem solving*, the increase from the pre-test mean of 3.95 to the post-test mean of 4.00 is non-significant (Z = -0.94,7, *p* = .344) with an effect size of 0.23. The students' overall digital literacy development is non-significant (Z = -0.639, *p* = .523) with an effect size of 0.15, although it increases from the pre-test mean of 3.91 to the post-test mean of 3.92.

Comparison of Students' Difference in Digital Literacy Changes in Different Semesters

To compare the BTPII program participants' digital literacy changes in each semester, *p* values for all four semesters were obtained from Wilcoxon Signed Ranks test results (see Table 17) as well as effect sizes for each element of digital literacy: information and data literacy, communication and collaboration, creation, safety, and problem solving.

Table 17: Comparison of Results of Wilcoxon Signed Ranks Test and Effect Size for Each Element of Pre- and Post-Digital Literacy in the Spring and Fall 2017 and 2018 Semesters

Test Statistics[b]

	Information and data literacy	Communication and collaboration	Creation	Safety	Problem solving	Overall digital literacy
Spring 2017 (N = 15)						
p value	.001	.001	.026	.001	.001	.001
Effect size	0.83	0.84	0.58	0.85	0.84	0.85
Fall 2017 (N = 19)						
p value	.091	.051	.147	.107	.064	.046
Effect size	0.39	0.45	0.33	0.37	0.42	0.46
Spring 2018 (N = 29)						
p value	.214	.425	.274	.247	.147	.085
Effect size	0.23	0.15	0.20	0.22	0.27	0.32
Fall 2018 (N = 17)						
p value	.813	.463	.670	.522	.344	.523
Effect size	0.06	0.18	0.10	0.16	0.23	0.15

As Table 17 indicates, the participants of each semester had different *p* values and effect sizes in terms of changes in overall digital literacy and each element of digital literacy. The participants of the spring 2017 semester had statistically significant changes and large effect sizes in almost every element of digital literacy (excluding the *creation* element with a medium effect size of 0.58), whereas those in the fall 2017 semester only exhibited a statistically significant change and a medium effect size in overall digital literacy. Both groups of participants in the spring and fall 2018 semesters had no statistically significant changes and small effect sizes in every element of digital literacy.

The difference in digital literacy changes among the four semesters might be preliminarily explained by the difference in curriculum structure in various semesters. The curriculum in the spring and fall 2017 semesters provided more opportunities for students to develop digital literacy by contextually applying every element of digital literacy to diverse learning tasks, compared to the spring and fall 2018 semesters.

The diversity of learning activities in 2017 semesters allowed students to apply different elements of digital literacy to multiple types of tasks. For instance, although the four semesters' learning activities all covered how to apply Google Drive to manage multimodal data, the element of information and data literacy was additionally enhanced in the spring 2017 and fall semesters. Both semesters specifically included a stand-alone lesson to teach students how to use a mind map to plan the structure of their digital artifacts, which improved the students' information and data literacy. As student B, a participant in the fall 2017 semester, said: "a mind map is super helpful for planning a project because it is like a checklist to help me keep track of my work." This student continued to use a mind map to manage his group project, which familiarized himself with the application of mind map application as well as consolidated his information and data literacy. The diversity of learning activities was also helpful in developing students' creativity. As the program teacher stated:

> Creating a VR tour guide system is a brand-new task for students. I believe it has opened a new window for students' creativity. To create a VR scene, students had to know how to organize different modes of information, like panoramic pictures, sounds, and videos to express their creativity.

By contrast, the curriculum in spring and fall 2018 laid more emphasis on learning technical knowledge and skills relevant to particular software (e.g., ARIS in spring 2018 and CoSpaces in fall 2018).

For the element of problem solving, the diversity of learning activities in a technology-rich environment increased the opportunities for students to find challenges in various settings, which developed their ability and confidence in using various technologies to deal with different types of challenging tasks in an innovative way. The ability of creatively mixing different technologies for solving various problems is specifically stressed by the element of problem solving of the EU's digital literacy framework.

The element of safety was also likely to develop when students were presented various tasks and encountered increased opportunities to contextually become aware of the importance of safety in a digital environment. For instance, when students created different new accounts in order to utilize various online tools, the teacher could take advantage of these moments to remind students to check carefully how these websites collected and exploited users' information.

In addition to the effects of diverse learning activities, a curriculum offering collaborative learning experiences also matters for digital literacy development. Working on group projects was particularly beneficial for students' development in terms of communication and collaboration. The students might have developed other elements of digital literacy, such as information and data management capacity, problem solving skills, and innovative thinking, through the exchange of knowledge and experience. However, it is interesting to find a non-significant result for students' digital literacy changes after the BTPII engagement, particularly in the element of collaboration and communication in the spring 2018 semester. Although no significant change was found by the statistical result, several students in this semester indicated that their group work experience improved their communication and collaboration. For instance, student Y, a participant of the spring 2018 semester indicated, "working with my group members make me realize the power of collaboration. Everyone has special expertise and can make unique contribution to group tasks." Student W of the same semester also indicated: "creating an AR game-based learning application involved many different types of works, such as storyline development, multiple questions design, and game interface design and so on. You cannot complete all of them along." Moreover, student C particularly indicated how the group project experience promoted his AR technical skills as well as a positive attitude toward collaboration: "Without the help of student D, I could not complete the works assigned to me. He spent much time teaching me how to use ARIS's special effects." Student D also indicated: "the experience of teaching my group members advanced operations of ARIS helped me learn how to use different ways to effectively communicate my ideas."

The conflict between the quantitative and the qualitative data analysis results might be attributed to different time frames allocated for collaborative learning experiences when comparing the curriculum of the spring/fall semesters in 2017 and spring/fall 2018 semester. Students in the spring and fall 2017 semesters allowed 12 weeks of collaborative learning activities: photography and photo editing (two weeks), video recording and editing (two weeks), mind mapping and project management (one week), panoramic photography of famous sites on campus and at a city park (two weeks) and the final group project and presentation (five weeks). By contrast, the spring 2018 curriculum offered 7 weeks of collaborative learning activities: photography and photo editing (one week), video recording and editing (one weeks) and final group project and presentation (five weeks). After excluding the time period for the final group project and presentation, there was five weeks difference for students to have collaborative learning experiences between the spring/fall 2017 and the spring/fall 2018 semester.

On the other hand, participants in the fall 2018 semester showed no significant changes in every element of digital literacy. This outcome might be explained by the lack of a group project experience.

Students' Digital Literacy Changes with Respect to Repeat Participation in the BTPII Program

This section illustrates the difference in BTPII participants' digital literacy changes. Comparisons were drawn between veteran (2nd or more participations in BTPII) and novice (first time participation in BTPII) participants across the spring and fall 2017 and 2018 semesters.

Spring 2017 Semester

As this semester was the first semester in which the BTPII after-school program was offered, comparative analysis could not be conducted to investigate changes in students' digital literacy changes based on their repeat program participation. Thus, there is no statistical result to be reported.

Fall 2017 Semester

Table 18 shows the descriptive analysis results of the veteran and novice groups' pre- and post- digital literacy. The novice student group concurrently had higher mean scores of pre-digital literacy (M = 4.08) as well as higher post-digital literacy (M = 4.19) compared to the veteran group's pre- (M = 3.89) and post-digital literacy (M = 4.14). Table 19 demonstrates each group's digital literacy changes respectively. The novice group had a lower mean for digital literacy changes (M = 0.12) compared to the veteran group (M = 0.25).

Table 18: Descriptive Statistics Result on Pre- and Post-Digital Literacy for Each Group in the Fall 2017 Semester

Descriptive Statistics

Independent Variable		N	Mean	Std. Deviation	Minimum	Maximum
Novice Group	Pre_DL	14	4.08	0.19	3.74	4.29
	Post_DL	14	4.19	0.24	3.83	4.52
Veteran Group	Pre_DL	5	3.89	0.35	3.62	4.48
	Post_DL	5	4.14	0.38	3.71	4.71

Table 19: Descriptive Statistics Result on Digital Literacy Changes in Each Group in the Fall 2017 Semester

Descriptive Statistics

Independent Variable		N	Minimum	Maximum	Mean	Std. Deviation
Novice Group	DL_Change	14	-0.43	0.59	0.12	0.30
Veteran Group	DL_Change	5	0.09	0.43	0.25	0.12

A Mann-Whitney U test was further used to investigate if the novice and veteran groups of students had differences in digital literacy changes. As shown in Table 20, there was no statistically significant difference ($U = 27$, $p = .459$) between the novice and the veteran group's digital literacy changes in the fall 2017 semester.

Table 20: Results of Mann-Whitney U Test for Digital Literacy Changes Between the Novice and Veteran Groups in the Fall 2017 semester

Test Statistics[b]

	DL_Change
Mann-Whitney U	27.000
Wilcoxon W	132.000
Z	-0.741
Asymp. Sig. (2-tailed)	.459
Exact Sig. [2*(1-tailed Sig.)]	

a. Not corrected for ties.

b. Grouping Variable: Veteran

Spring 2018 Semester

Table 21 shows the descriptive analysis results of the veteran and novice groups' pre- and post-digital literacy. The novice student group concurrently had higher mean scores of pre- digital literacy (M = 4.14) as well as higher post-digital literacy (M = 4.24) compared to the veteran group's pre- (M = 3.97) and post-digital literacy (M = 4.02). Table 22 demonstrates each group's digital literacy changes respectively. The novice group had a higher mean for digital literacy change (M = 0.10), compared to the veteran group (M = 0.05).

Table 21: Descriptive Statistics Result on Pre- and Post-Digital Literacy for Each Group in the Spring 2018 Semester

Descriptive Statistics

Independent Variable		N	Mean	Std. Deviation	Minimum	Maximum
Novice Group	Pre_DL	12	4.14	0.27	3.79	4.55
	Post_DL	12	4.24	0.30	3.74	4.62
Veteran Group	Pre_DL	17	3.97	0.30	3.33	4.49
	Post_DL	17	4.02	0.31	3.39	4.65

Table 22: Descriptive Statistics Result on Digital Literacy Changes in Each Group in the Spring 2017 Semester

Descriptive Statistics

Independent Variable		N	Minimum	Maximum	Mean	Std. Deviation
Novice Group	DL_Change	12	-0.32	0.68	0.10	0.29
Veteran Group	DL_Change	17	-0.58	0.43	0.05	0.22

A Mann-Whitney U test was further used to investigate if the novice and veteran groups of students had differences in digital literacy changes. As shown in Table 23, there was no statistically significant difference (U = 96, p = .790) between the novice group and the veteran group's digital literacy changes in the spring 2018 semester.

Table 23: Results of Mann-Whitney U Test for Digital Literacy Changes Between the Novice and Veteran Groups in the Spring 2018 Semester

Test Statistics[b]

	DL_Change
Mann-Whitney U	96.000
Wilcoxon W	174.000
Z	-0.266
Asymp. Sig. (2-tailed)	.790
Exact Sig. [2*(1-tailed Sig.)]	

a. Not corrected for ties.
b. Grouping Variable: Veteran

Fall 2018 Semester

Table 24 shows the descriptive analysis results of the veteran and novice groups' pre- and post-digital literacy. The novice student group concurrently had higher mean scores of pre-digital literacy (M = 3.93) as well as higher post-digital literacy (M = 4.01) compared to the veteran group's pre- (M = 3.89) and post- digital literacy (M = 3.70).

Table 25 demonstrates the digital literacy changes in each group. The novice group had a lower mean of digital literacy change (M = 0.09) compared to the veteran group (M = -0.19).

Table 24: Descriptive Statistics Result on Pre- and Post-Digital Literacy for Each Group in the Fall 2018 Semester

Descriptive Statistics

Independent Variable		N	Mean	Std. Deviation	Minimum	Maximum
Novice Group	Pre_DL	12	3.93	0.37	3.17	4.48
	Post_DL	12	4.01	0.51	3.30	4.78
Veteran Group	Pre_DL	5	3.89	0.49	3.34	4.63
	Post_DL	5	3.70	0.70	2.86	4.59

Table 25: Descriptive Statistics Result on Digital Literacy Change in Each Group in the Fall 2018 Semester

Descriptive Statistics

Independent Variable		N	Minimum	Maximum	Mean	Std. Deviation
Novice Group	DL_Change	12	-0.71	0.52	0.09	0.32
Veteran Group	DL_Change	5	-0.70	0.08	-0.19	0.31

A Mann-Whitney U test was further used to investigate if the novice and veteran groups of students had differences in digital literacy changes. Table 26 shows, there was no statistically significant difference ($U = 12.5$, $p = .065$) between the novice and veteran group's digital literacy changes in the fall 2018 semester.

Table 26: Results of Mann-Whitney U Test for Digital Literacy Changes Between the Novice and Veteran Groups in the Fall 2018 Semester

Test Statistics[b]

	DL_Change
Mann-Whitney U	12.50
Wilcoxon W	27.50
Z	-1.847
Asymp. Sig. (2-tailed)	.065
Exact Sig. [2*(1-tailed Sig.)]	

a. Not corrected for ties.

b. Grouping Variable: Veteran

Overall Analysis of Repeat Participation Impact on Students' Digital Literacy Changes

This section illustrates the differences in participants' digital literacy changes with respect to their repeat participation in the BTPII program. Table 27 shows the descriptive analysis results of *T* scores of digital literacy changes of three groups whose repeat participation numbers spanned one, two, and three times.

Table 27: Descriptive Statistics for the Participants' *T* Scores of Digital Literacy Changes With One, Two, and Three Participations in the BTPII After-School Program

Descriptive Statistics

Number of Program Participations		N	Minimum	Maximum	Mean	Std. Deviation
One	DL_change_T	36	28.28	75.02	52.14	10.69
Two	DL_change_T	13	26.44	62.13	50.48	9.14
Three	DL_change_T	9	28.83	56.36	48.31	8.31

The one-time-participation group had the highest mean of *T* scores of 52.14 while the two-time- participation group had a mean of 50.48, and the three-time-participation group had a mean of 48.31. A Kruskal-Wallis Test was further used to investigate whether participants' repeat participation in the program significantly impacted their digital literacy changes. As shown in Table 28, no significant differences (Chi square = .493, p = .782, df =2) were found among the three groups. In sum, students' repeat participation in the BTPII after-school program did not significantly impact their digital literacy changes.

Table 28: Results of Kruskal-Wallis Test for Digital Literacy Changes Among Students With One, Two, and Three Participations in the BTPII After-School Program

Test Statistics[a,b]

	DL_change_T
Chi-square	.493
df	2
Asymp. Sig.	.782

a. Kruskal Wallis Test
b. Grouping Variable: Internet_time

The Role of Daily Internet Access Time on Students' Digital Literacy Change

This section illustrates the participants' differences in digital literacy changes with respect to three levels of daily Internet access time. Table 29 shows the descriptive analysis results of *T* scores of digital literacy changes for all three groups with low-use group (neither weekday Internet access time under two hours nor weekend Internet access time of less than 5 hours), medium-use group (either weekday Internet access time over two hours or weekend Internet access time over 5 hours) and high-use group (both weekday Internet access time over two hours and weekend Internet access time over 5 hours).

Table 29: Descriptive Statistics for Participants' *T* Scores of Digital Literacy Changes at Three Levels of Daily Internet Access Time

Descriptive Statistics

Internet_time		N	Minimum	Maximum	Mean	Std. Deviation
low use	DL_change_T	8	28.75	62.66	51.29	10.05
medium use	DL_change_T	13	26.44	70.65	50.71	11.37
high use	DL_change_T	37	28.28	75.02	51.31	9.73

The high Internet access group had the highest mean of *T* scores (51.31). The low Internet access group had a mean of 51.29, and the medium Internet access group had a mean of 50.71. A Kruskal-Wallis Test was further used to investigate whether participants' levels of daily Internet access time impacted their digital literacy changes. As shown in Table 30, no significant differences (Chi square = .548, p = .760, df =2) were found among the three groups. In sum, students' amount of daily Internet access time did not impact changes in their digital literacy.

Table 30: Results of Kruskal-Wallis Test for Digital Literacy Changes Among Students With Three Levels of Daily Internet Access Time

Test Statistics[a,b]

	DL_change_T
Chi-square	.548
df	2
Asymp. Sig.	.760

a. Kruskal Wallis Test
b. Grouping Variable: Internet_time

THE ROLE OF DAILY INTERNET USAGE PURPOSES ON STUDENTS' CHANGES IN DIGITAL LITERACY

This section explored the participants' difference in digital literacy changes with respect to their daily Internet usage purposes related the following four categories of Internet Usage Purposes:

- information search and management,
- communication and collaboration,
- creation and,
- problem solving.

For each category, students were categorized into two to three levels depending on the number of sub-purposes they reported in the Internet Use and Self-learning Questionnaire (Appendix D). For instance, in the purpose category of information search and management, students were asked to report if they used the Internet for the following sub-purposes at least one time a week: (a) search for Information related to my interests, (b) search for Information related to my school work, (c) use cloud service (e.g, Google Drive) to back up my computer's data. Students were categorized in the high-level group when they spontaneously reported engaging in the above three sub-purposes at least one time a week. If students choose any two of the three sub-purposes, they were categorized in the medium-level group. Students who only chose one of the three sub-purposes were categorized in the low-level group. The same categorization method also applied to the purpose categories of communication and collaboration as well as problem solving. By contrast, the purpose category of creation only included two levels because very few students had related experience in creating digital content on a regular basis according to the results of the National K-12 Student Digital Behaviors Survey administered by the Taiwan Ministry of Education in 2015 (Ko, 2015).

Information Search and Management

Table 31 shows the descriptive analysis results of *T* scores for the digital literacy changes among three groups of students with low, medium, and high levels of daily Internet use for information search and management.

Table 31: Descriptive Statistics of the Participants' *T* Scores for Digital Literacy Changes at Three Levels of Daily Internet Use for Information Search and Management Purposes

Descriptive Statistics

Independent Variable		N	Minimum	Maximum	Mean	Std. Deviation
Low-level	DL_change_T	18	28.83	70.65	51.67	10.19
Medium-level	DL_change_T	9	43.35	75.02	54.54	9.17
High-level	DL_change_T	31	26.44	70.65	49.91	10.12

The medium-level group had the highest mean of *T* scores (54.54). The low-level group had a mean of 51.67, and the high-level group had a mean of 49.91. A Kruskal-Wallis Test was further used to investigate whether the participants' levels of daily Internet use for the purpose of information search and management impacted their digital literacy changes. As shown in Table 32, no significant differences (Chi square = 0.820, p = .664, df =2) were found among the three groups for information search and management.

Table 32: Kruskal-Wallis Test for *T* Scores of Digital Literacy Changes Among Students at Three Levels of Daily Internet Use Related to Information Search and Management

Test Statistics[a,b]

	DL_change_T
Chi-square	.820
df	2
Asymp. Sig.	.664

a. Kruskal Wallis Test
b. Grouping Variable: Information search and management

Communication and Collaboration

Table 33 shows the descriptive analysis results of *T* scores for digital literacy changes among three groups of students with low, medium, and high levels of daily Internet use for the purpose of communication and collaboration.

Table 33: Descriptive Statistics of the Participants' *T* Scores for Digital Literacy Changes at Three Levels of Daily Internet Use for Communication and Collaboration Purposes

Descriptive Statistics

Independent Variable		N	Minimum	Maximum	Mean	Std. Deviation
Low-level	DL_change_T	18	26.44	70.65	51.16	11.29
Medium-level	DL_change_T	23	28.28	70.65	53.01	9.51
High-level	DL_change_T	17	28.83	75.02	48.71	9.11

The medium-level group had the highest mean of *T* scores (53.01). The low-level group had a mean of 51.16, and the high-level group had a mean of 48.71. A Kruskal-Wallis Test was further used to investigate whether the participants' levels of daily Internet use for the purpose of communication and collaboration impacted their digital literacy changes. As shown in Table 34, no significant differences (Chi square = 3.328, p = .189, df =2) were found among the three groups for communication and collaboration.

Table 34: Kruskal-Wallis Test for *T* Scores of Digital Literacy Changes Among Students With Three Different Levels of Daily Internet Use Related to Communication and Collaboration

Test Statistics[a,b]

	DL_change_T
Chi-square	3.328
df	2
Asymp. Sig.	.189

a. Kruskal Wallis Test
b. Grouping Variable: Communication and collaboration

Creation

Table 35 shows the descriptive analysis results of *T* scores for digital literacy changes of two groups of students with low and high levels of daily Internet use for the purpose of creation.

Table 35: Descriptive Statistics of the Participants' *T* Scores for Digital Literacy Changes at Two Different Levels of Daily Internet Use for Creation Purposes

Descriptive Statistics

Independent Variable		N	Minimum	Maximum	Mean	Std. Deviation
Low-level	DL_change_T	39	28.28	70.65	51.83	8.59
High-level	DL_change_T	19	26.44	75.02	49.84	12.49

The low-level group had the higher mean of *T* scores of 51.83 while the high-level group had a mean of 49.84. A Kruskal-Wallis Test was further used to investigate whether the participants' levels of daily Internet use for the purpose of creation impacted their digital literacy changes. As shown in Table 36, no significant differences (Chi square = 1.232, p = .267, df =1) were found between the two groups for creation.

Table 36: Kruskal-Wallis Test for T Scores of Digital Literacy Changes Between Students With Two Different Levels of Daily Internet Use Related to Creation

Test Statistics[a,b]

	DL_change_T
Chi-square	1.232
Df	1
Asymp. Sig.	.267

a. Kruskal Wallis Test
b. Grouping Variable: Creation

Problem Solving

Table 37 shows the descriptive analysis results of *T* scores for digital literacy changes of three groups of students with low, medium, and high levels of daily Internet use for the purpose of problem solving.

Table 37: Descriptive Statistics of the Participants' *T* Scores for Digital Literacy Changes at Three Levels of Daily Internet Use for Communication and Collaboration

Descriptive Statistics

Independent Variable		N	Minimum	Maximum	Mean	Std. Deviation
Low-level	DL_change_T	9	46.23	62.66	54.21	6.32
Medium-level	DL_change_T	33	26.44	70.65	49.84	10.09
High-level	DL_change_T	16	28.28	75.02	52.22	11.35

The low-level group had the highest mean of *T* scores (54.21). The high- level group had a mean of 52.22, and the medium-level group had a mean of 49.84. A Kruskal-Wallis Test was further used to investigate whether the participants' levels of daily Internet use for problem solving impacted their digital literacy changes. As shown in Table 38, no significant differences (Chi square = 1.538, p = .463, df =2) were found among the three groups for the purpose of problem solving.

Table 38: Kruskal-Wallis Test for *T* Scores of Digital Literacy Changes Among Students With Three Different Levels of Daily Internet Use Related to Communication and Collaboration

Test Statistics[a,b]

	DL_change_T
Chi-square	1.538
df	2
Asymp. Sig.	.463

a. Kruskal Wallis Test
b. Grouping Variable: Problem solving

Correlation Analysis of Students' Differences in Digital Literacy Changes With Respect to Daily Internet Usage Purposes

To confirm the non-significance between students' digital literacy changes and their daily Internet usage purposes, a Pearson Correlation Analysis was applied to investigate coefficients between students' *T* scores for digital literacy changes and the four different daily Internet usage purposes. The results are shown in Table 39.

Table 39: Results of Pearson Correlation Analysis Between Students' Digital Literacy Changes and Different Internet Usage Purposes

		Internet_ info_srch_mng	Internet_ com_col	Internet_ creation	Internet_PBL
DL_change_T	Pearson Correlation	-.094	-.094	-.094	-.029
	Sig. (2-tailed)	.482	.484	.481	.831
	N	58	58	58	58

According to the results, the students' digital literacy changes were not significantly impacted by their daily Internet usage purposes related to information search and management ($r(58) = -.094$, $p = .482$), communication and collaboration ($r(58) = -.094$, $p = .484$), creation ($r(58) = -.094$, $p = .481$), and problem solving ($r(58) = -.029$, $p = .831$). In sum, students' daily Internet usage purposes did not have an impact on changes in their digital literacy.

STUDENTS' FINAL PERFORMANCE IN THE BTPII AFTER-SCHOOL PROGRAM

This section examines the BTPII participants' final performance assessed according to a hundred-mark system across the spring and fall 2017 and 2018 semesters. Students' final performance scores are provided in Table 40.

Table 40: Descriptive Statistics for Participants' Final Performance Scores in the Spring and Fall Semesters 2017 and 2018

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Spring 2017	15	58.00	87.00	74.67	7.42
Fall 2017	19	58.00	97.00	81.05	11.50
Spring 2018	29	76.00	95.00	86.69	6.26
Fall 2018	17	43.00	97.00	68.24	17.07

The fall 2018 semester had the largest standard deviation (17.07) in students' final performance, which indicates a large achievement difference. This result could be explained by three reasons. First, learning activities for this semester were considerably different from those of previous semesters. Specifically, learning activities focused on the application of scratch-style coding blocks to create VR content. Thus, even veteran students were unable to apply learning outcomes from prior semesters to this semester's learning tasks. The first reason was corroborated by Student Y: "when I had a question, I could only ask my neighbors, but they usually did not know the answer either. We only had one teacher, and he could not answer every student's question at the same time." Second, the issue of less motivated students also increased the final performance variance. This semester's learning activities were far more complex than those in the previous three semesters. The students might have been more likely to give up and become less motivated, which resulted in the large differences in final performance. Finally, this semester's final performance score was only determined by students' individual project works. The performance of individual project work directly reflected students' individual differences in levels of digital literacy and learning motivation. By contrast, the previous three semester's final performance concurrently involved individual and group projects, which might have reduced the influence of differences in individual digital literacy and motivation on students' final performance scores. As the learning activities were identical in the spring and fall 2017 semesters, the results indicated a higher mean score of 81.5 in the fall 2017 semester compared to the mean score of 74.67 for the spring 2017 semester. This result could be explained by the fact that some students who participated in both semesters who could apply what they learned in the prior semester to similar tasks in the subsequent semester. These experienced students' higher final performance scores also might have caused a larger standard deviation in this semester; 11.50, compared to the spring 2017 semester's standard deviation of 7.42.

The Relationship of Students' Final Performance to Their Repeat Participation in the BTPII Program

This section illustrates the difference in participants' final performance with respect to the repeat participation of BTPII program. Table 47 shows the descriptive analysis results of *T* scores for final performance of three groups—students who participated in one, two, or three iterations.

Spring 2017 Semester

All the participants were new to the BTPII after-school program in this semester. Thus, comparative analysis was not conducted to investigate if the students' final performance differed based on their multiple program participations.

Fall 2017 Semester

Table 41 shows the descriptive analysis results of the veteran and novice groups' final performance. The veteran group had a higher mean score of 91.60 compared to the novice group's mean of 77.29.

Table 41: Descriptive Statistics Result for Final Performance of Each Group in the Fall 2017 Semester

Descriptive Statistics

Independent variable		N	Minimum	Maximum	Mean	Std. Deviation
Novice Group	Final Performance	14	58.00	91.00	77.29	11.02
Veteran Group	Final Performance	5	88.00	97.00	91.60	3.36

A Mann-Whitney U test was further used to investigate if the novice and veteran groups of students differed in their final performance. As shown in Table 42, the test results indicate a statistically significant difference (U = 5.00, p = .003) in the final performance of the novice and the veteran groups for the fall 2017 semester.

Table 42: Results of Mann-Whitney U Test for Final Performance of the Novice and Veteran Groups in the Fall 2017 Semester

Test Statistics[b]

	Final Performance
Mann-Whitney U	5.00
Wilcoxon W	110.00
Z	-2.781
Asymp. Sig. (2-tailed)	.005
Exact Sig. [2*(1-tailed Sig.)]	0.003[a]

a. Not corrected for ties.

b. Grouping Variable: Veteran

Spring 2018 Semester

Table 43 shows the descriptive analysis results of the veteran and novice groups' final performance. The veteran group had a higher mean score of 88.12 compared to the novice group's mean of 84.67.

Table 43: Descriptive Statistics Result for Final Performance in Each Group in the Spring 2018 Semester

Descriptive Statistics

Independent variable		N	Minimum	Maximum	Mean	Std. Deviation
Novice Group	Final Performance	12	76.00	95.00	84.67	7.39
Veteran Group	Final Performance	17	76.00	95.00	88.12	5.09

A Mann-Whitney U test was further used to investigate if the novice and veteran groups of students displayed a difference in their final performance. As shown in Table 44, no statistically significant difference (U = 71.00, p = .166) was found in the final performance between the novice and the veteran groups for the spring 2018 semester.

Table 44: Results of Mann-Whitney U Test for Final Performance Between the Novice and Veteran Groups in the Spring 2018 Semester

Test Statistics[b]

	Final Performance
Mann-Whitney U	71.00
Wilcoxon W	149.00
Z	-1.386
Asymp. Sig. (2-tailed)	.166
Exact Sig. [2*(1-tailed Sig.)]	.180[a]

a. Not corrected for ties.

b. Grouping Variable: Veteran

Fall 2018 Semester

Table 45 shows the descriptive analysis results of the veteran and novice groups' final performance. The novice group had a higher mean score of 71.50 compared to the veteran group's mean of 60.4.

Table 45: Descriptive Statistics Result on Final Performance in Each Group in the Fall 2018 Semester

Descriptive Statistics

Independent variable		N	Minimum	Maximum	Mean	Std. Deviation
Novice Group	Final Performance	12	48.00	97.00	71.50	14.82
Veteran Group	Final Performance	5	43.00	93.00	60.40	21.28

A Mann-Whitney U test was further used to investigate if the novice and veteran groups of students displayed a difference in their final performance. As shown in Table 46, no statistically significant difference ($U = 17.50$, $p = .187$) was found in the final performance between the novice and the veteran groups for the fall 2018 semester.

Table 46: Results of Mann-Whitney U Test for Final Performance Between the Novice and Veteran Groups in the Spring 2018 Semester

Test Statistics[b]

	Final Performance
Mann-Whitney U	17.50
Wilcoxon W	32.50
Z	-1.318
Asymp. Sig. (2-tailed)	.187
Exact Sig. [2*(1-tailed Sig.)]	.195[a]

a. Not corrected for ties.

b. Grouping Variable: Veteran

Overall Analysis of Students' Difference in Final Performance with Respect to Repeat Participation in the BTPII After-School Program

This section illustrates that the participants' difference in final performance with respect to their repeat participation in the BTPII program. The below Table 47 shows a descriptive analysis result of *T* scores of final performance of three groups with one-time, two-time and three-time participation numbers.

Table 47: Descriptive Statistics for the Participants' T Scores of Final Performance With One, Two, Three Times of the BTPII After-School Program Participation Numbers

Descriptive Statistics

Number of Participation		N	Minimum	Maximum	Mean	Std. Deviation
One	Final_pfm_T	36	31.93	66.85	49.64	10.28
Two	Final_pfm_T	13	32.93	64.19	54.08	9.16
Three	Final_pfm_T	9	35.22	64.51	49.80	10.24

The two-times participation group had the highest mean of *T* scores (54.08). The three-time group had a mean of 49.8, and the one-time group had a mean of 49.64. A

Kruskal-Wallis Test was further used to investigate whether participants' participation numbers impacted their digital literacy changes. As shown in Table 48, no significant differences (Chi square = 2.268, p = .322, df =2) were found among the three groups that participated one, two, and three times in the BTPII after-school program.

Table 48: Results of Kruskal-Wallis Test for *T* Scores of Final Performance Among Students With One, Two, Three Participations in the BTPII After-School Program

Test Statistics[a,b]

	DL_change_T
Chi-square	2.268
df	2
Asymp. Sig.	.322

a. Kruskal Wallis Test
b. Grouping Variable: Internet_time

Thus, students' multiple participations in the BTPII after-school program did not significantly impact their difference in final performance.

THE ROLE OF DAILY INTERNET ACCESS TIME WITH STUDENTS' FINAL PERFORMANCE

This section illustrates the difference in participants' final performance with respect to three levels of daily Internet access time. Table 49 shows the descriptive analysis results of *T* scores of digital literacy changes for the final performance of three groups—students with low Internet access (neither weekday Internet access time under two hours nor weekend Internet access time of less than 5 hours), medium-use group (either weekday Internet access time over two hours or weekend Internet access time over 5 hours) and high-use group (both weekday Internet access time over two hours and weekend Internet access time over 5 hours).

Table 49: Descriptive Statistics for the Student Participants' *T* Scores of Final Performance With Three Different Levels of Daily Internet Access Time

Descriptive Statistics

Internet_time		N	Minimum	Maximum	Mean	Std. Deviation
low use	Final_pfm_T	8	32.93	59.23	46.54	8.89
medium use	Final_pfm_T	13	32.93	64.51	49.14	9.98
high use	Final_pfm_T	37	31.93	66.85	52.08	10.20

The high Internet access group had the highest mean of *T* scores (52.08). The medium Internet access group had a mean of 49.14, and the low Internet access group had a mean of 46.54. A Kruskal-Wallis Test was further used to investigate whether participants' levels of daily Internet access time impacted their final performance. As shown in Table 50, no significant differences (Chi square = 2.980, p = .225, df =2) were found among the three groups in terms of amount of daily Internet access time. In sum, students' amount of daily Internet access time did not have a significant impact on their final performance.

Table 50: Results of Kruskal-Wallis Test for *T* Scores of Final Performance Among Students With Three Different Levels of Daily Internet Access Time

Test Statistics^{a,b}

	Final_pfm_T
Chi-square	2.980
df	2
Asymp. Sig.	.225

a. Kruskal Wallis Test
b. Grouping Variable: Internet_time

THE ROLE OF STUDENTS' DAILY INTERNET USAGE PURPOSES WITH STUDENTS' FINAL PERFORMANCE

This section illustrates the difference in participants' final performance with respect to their daily Internet usage purposes related the following four categories: information search and management, communication and collaboration, creation, and problem solving. Further, categories of information search and management, communication and collaboration, and problem solving were broken down into three levels while the creation category was divided into two levels.

Information Search and Management

Table 51 shows the descriptive analysis results of *T* scores for the final performance of three groups of students with low, medium, and high levels of daily Internet use for the purpose of information search and management.

Table 51: Descriptive Statistics of Participants' *T* Scores for Final Performance at Three Different Levels of Daily Internet Use for Information Search and Management

Descriptive Statistics

Independent Variable		N	Minimum	Maximum	Mean	Std. Deviation
Low-level	Final_pfm_T	18	31.93	59.23	48.21	8.91
Medium-level	Final_pfm_T	9	32.93	63.27	50.03	10.72
High-level	Final_pfm_T	31	32.93	66.85	52.26	10.45

The high-use group had the highest mean of *T* scores (52.26). The medium-use group had a mean of 50.03, and the low-use group had a mean of 48.21. A Kruskal-Wallis Test was further used to investigate whether the participants' levels of daily Internet use for information search and management impacted their final performance. As shown in Table 52, no significant differences (Chi square = 2.261, p = .323, df =2) were found among the three groups for information search and management.

Table 52: Results of Kruskal-Wallis Test for *T* Scores of Final Performance Among Students With Three Different Levels of Daily Internet Use Related to Information Search and Management

Test Statistics[a,b]

	Final_pfm_T
Chi-square	2.261
df	2
Asymp. Sig.	.323

a. Kruskal Wallis Test
b. Grouping Variable: Information search and management

Communication and Collaboration

Table 53 shows the descriptive analysis results of *T* scores for the final performance of three groups of students with low, medium, and high levels of daily Internet use for the purposes of communication and collaboration.

Table 53: Descriptive Statistics of Participants' *T* Scores for Final Performance at Three Different Levels of Daily Internet Use Related to Communication and Collaboration

Descriptive Statistics

Independent Variable		N	Minimum	Maximum	Mean	Std. Deviation
Low-level	Final_pfm_T	18	32.93	64.51	50.34	9.29
Medium-level	Final_pfm_T	23	32.93	66.85	51.88	9.82
High-level	Final_pfm_T	17	31.93	64.19	49.35	11.41

The medium-use group had the highest mean of *T* scores (51.88). The low-use group had a mean of 50.34, and the high-use group had a mean of 49.35. A Kruskal-Wallis Test was further used to investigate whether the participants' levels of daily

Internet use for communication and collaboration impacted their final performance. As shown in Table 54, no significant differences (Chi square = .590, p = .744, df =2) were found among the three groups for the purposes of communication and collaboration.

Table 54: Results of Kruskal-Wallis Test for *T* Scores of Final Performance Among Students With Three Different Levels of Daily Internet Use Related to Communication and Collaboration

Test Statistics[a,b]

	Final_pfm_T
Chi-square	.590
df	2
Asymp. Sig.	.744

a. Kruskal Wallis Test
b. Grouping Variable: Communication and collaboration

Creation

Table 55 shows the descriptive analysis results of *T* scores for the final performance of two groups of students with low and high levels of daily Internet use for the purpose of creation.

Table 55: Descriptive Statistics of Participants' *T* Scores for Final Performance at Two Different Levels of Daily Internet Use Related to Creation

Descriptive Statistics

Independent Variable		N	Minimum	Maximum	Mean	Std. Deviation
Low-level	Final_pfm_T	39	31.93	66.85	49.63	10.33
High-level	Final_pfm_T	19	32.93	64.51	52.78	9.30

The medium-use group had a higher mean of *T* scores of 52.78 while the low-use group had a lower mean of 49.63. A Kruskal-Wallis Test was further used to investigate whether the participants' levels of daily Internet use for creation impacted their final performance. As shown in Table 56, no significant differences (Chi square = 1.367, p = .242, df =1) were found between the groups for creation.

Table 56: Results of Kruskal-Wallis Test for *T* Scores of Final Performance Among Students With Two Different Levels of Daily Internet Use Related to Creation

Test Statistics[a,b]

	Final_pfm_T
Chi-square	1.367
df	1
Asymp. Sig.	.242

a. Kruskal Wallis Test
b. Grouping Variable: Creation

Problem Solving

Table 57 shows the descriptive analysis results of *T* scores for the final performance of three groups of students with low, medium, and high levels of daily Internet use for the purpose of problem solving.

Table 57: Descriptive Statistics of Participants' *T* Scores for Final Performance at Three Different Levels of Daily Internet Use for Problem Solving

Descriptive Statistics

Independent Variable		N	Minimum	Maximum	Mean	Std. Deviation
Low-level	Final_pfm_T	9	45.18	66.51	55.33	6.95
Medium-level	Final_pfm_T	33	31.93	64.51	48.06	10.12
High-level	Final_pfm_T	16	32.93	66.85	53.40	10.11

The low-use group had the highest mean of *T* scores (55.33). The high-use group had a mean of 53.40, and the medium-use group had a mean of 48.06. A Kruskal-Wallis Test was further used to investigate whether the participants' levels of daily Internet use for problem solving impacted their final performance. As shown in Table 58, no significant differences (Chi square = 5.029, p = .081, df =2) were found among the three groups for problem solving.

Table 58: Results of Kruskal-Wallis Test for *T* Scores of Final Performance Among Students With Three Different Levels of Daily Internet for Problem Solving

Test Statistics[a,b]

	Final_pfm_T
Chi-square	5.029
df	2
Asymp. Sig.	.081

a. Kruskal Wallis Test

b. Grouping Variable: Problem solving

Correlation Analysis of Students' Difference in Final Performance With Respect to Daily Internet Usage Purposes

To further confirm the non-significance between students' final performance and their daily Internet usage purposes, a Pearson Correlation Analysis was applied to investigate coefficients between students' *T* scores for their final performance and the four different daily Internet usage purposes. The results are provided in Table 59.

Table 59: Results of Pearson Correlation Analysis Between Students' Final Performance and Different Internet Usage Purposes

		Internet_ info_srch_mng	Internet_ com_col	Internet_ creation	Internet_PBL
Final_pfm_T	Pearson Correlation	.182	-.037	.149	.005
	Sig. (2-tailed)	.085	.391	.133	.485
	N	58	58	58	58

According to the results, the students' final performance was not significantly correlated to daily Internet usage purposes for information search and management ($r(58) = .182$, $p = .085$), communication and collaboration ($r(58) = -.037$, $p = .391$), creation ($r(58) = -.149$, $p = .133$), and problem solving ($r(58) = -.005$, $p = .485$). Thus, students' daily Internet usage purposes did not significantly influence their final performance. This non-significance might explain why students with low-level usage of the Internet for problem solving exhibited the highest level of final performance.

Chapter 5: Discussion

This study aimed to understand how middle school students' digital literacy (DL) changes upon engagement in a blended, PBL environment. This study further investigated how students' multiple participations, daily Internet use time, and daily Internet usage purposes impacted their digital literacy changes and learning performance. Thus, the investigator applied a mixed method design to achieve the above goals. Conducted at a middle school, where an after-school program spanning four semesters was created, this study comprised of 80 students who provided valid survey responses upon completion of the program. The final chapter of this study provides: (a) interpretations of the research findings, (b) recommendations for parents, educators, and researchers, and (c) the limitations of this study.

Interpretation of Findings

This study revealed five main findings: (a) relationships between the BTPII learning activities and dl changes across semesters, (b) students' limited Edmodo application, (c) project-based learning experience in developing digital literacy, (d) no significant impact of students' repeat participations in the BTPII and final performance on digital literacy changes and final performance differed across semesters, (e) no significant impact of students' daily Internet access time and Internet usage purposes on their digital literacy changes and final performance.

Relationships Between the BTPII Learning Activities and DL Changes Across Semesters

This study investigated students' digital literacy changes after participation in an after-school program that featured a blended, technology-rich, PBL environment throughout the fall and spring semesters of 2017 and 2018. Participants of the spring and fall 2017 semesters displayed a significant development in digital literacy. However, participants of the spring and fall 2018 semesters showed no significant difference in their digital literacy. This outcome might be explained by the differences in curricula across semesters and the potential effects of social interaction on students' development of digital literacy.

With regards to the content covered, the curricula of the spring and fall 2017 semesters were identical and provided multiple types of opportunities for students to practice different elements of digital literacy contextually. The students practiced their information and data literacy to collect, evaluate, store, and organize multimodal information meaningfully to create the individual project (AR student ID). Through collaborating on the final group project (VR City Park Tour Guide System), the students further gained opportunities to collaborate and communicate with others to solve authentic problems and create VR content. Their concepts of safety were nourished when being involved in different tasks and had opportunities to think of how to protect personal data and privacy during the project execution process.

The positive effects of contextual learning, offered by the PBL experience, on digital literacy development was also evidenced by Loizzo, Conner, and Cannon (2018).

Their study investigated how undergraduate students applied their digital literacy to complete an agricultural and environmental science communication project featuring video and photography production for the Nebraska Extension. Working with Extension-related topics, the students contextually practiced their digital literacy through the application of digital databases and websites for researching and defining photo essay topics (information and data literacy), working with subject matters experts (collaboration), use of digital cameras for learning photography techniques (problem solving), and creation of a photo essay as well as a new mobile video application to explain extension topics for online audiences (digital content creation). Their results empirically indicated that the PBL approach provided a contextual learning experience for undergraduate students to construct and develop their digital literacy by solving real-world problems and complete authentic tasks. My results further confirmed the PBL's effects of contextual learning on digital literacy development in the middle school setting.

Moreover, the curriculum structure in both the spring and fall 2017 semesters provided an iterative learning process for students to develop digital literacy by applying prior learning outcomes to subsequent tasks. For example, both semesters involved students in an individual project first in order to help them apply individual project experience to a subsequent group project. This design represented a revised version of the two-phase project-based approach (Drain, 2010; Good & Jarvinen, 2007), which espouses that students should be equipped with sufficient knowledge and skills in the first phase before moving on to the subsequent phase. In this dissertation, students were involved in an individual project in order to develop necessary knowledge and skills required for the following group project, which empirically revealed the effect of the two-phase project-based approach on digital literacy education in the middle school level.

By contrast, in the spring 2018 semester, the students' overall digital literacy development was non-significant. This phenomenon might be explained by the fact that this semester's curriculum invested more time in independent learning activities regarding technical knowledge and skills of creating AR content rather than collaborative learning activities, compared to the curriculum in the spring/fall 2017 semesters. The more time spent in independent learning activities inevitably compromised students' opportunities in practicing and developing digital literacy via the experience of collaborating and communicating with others to solve a problem and learn from peers' expertise and creative insights. Moreover, the more time spent in learning technical knowledge and skills might have contributed to students' development in computer skills instead of digital literacy. The impact of collaborative learning experience and instructional content on digital literacy became particularly apparent in the subsequent semester. Students of the fall 2018 semester showed no significant change in digital literacy, and there was a lack of group project experience. The curriculum in this semester also highly focused on students' individual learning in technical knowledge and skills of a specific VR software. Thus, it is possible that social interaction plays a large impact on digital literacy development. In fact, Reynolds (2016) stated that students' digital literacy development is a social constructivist activity. In other words, students' digital literacy development highly relies on social interaction and their digital literacy might be constructed through working with others and sharing others' experience and expertise. The lack of group project experience might fundamentally reduce the students' opportunity to construct their digital literacy due to lack of social interaction.

Students' Limited Edmodo Application

This study empirically evidenced that middle school students' engagement and acceptance of SNS in education was low. Won, Evans, and Huang (2017) conducted a case study with 30 rural students aged 10-12 in an after-school STEM program and displayed the students' intensive engagement through sharing their knowledge and expressing their experiences on Edmodo. The key difference between that study and this dissertation is the support of facilitators to promote students' online interaction. In Won et al.'s study, on average three to four undergraduate facilitators were shared by 15 students. The facilitators played essential roles in initiating online discussions, encouraging students to make comments on peers' posts, and promoting more thought exchange among the students. By contrast, the single instructor in this dissertation study could not pay full attention to facilitating students' online discussion, which might explain students' limited engagement on Edmodo.

The middle school students in this study, on average, neither agreed nor disagreed about their active participation on Edmodo for the purposes of communication and collaboration, and problem solving. This finding might reflect on the middle school students' neutral attitude toward SNS for education. This finding is similar to a survey study conducted by Hershkovzt and Forkosh-Baruch (2017). They indicated that 52% (349 of 667) of Israeli students aged from 12-19 regarded that Facebook could not be used for learning, whereas 48% of them (318 of 667) had the opposite perspective. In the same study, 59% (396 of 667) of the students did not want to be connected with their current teachers on Facebook. In sum, both that survey study and this dissertation represented teenagers' neutral or negative attitude toward social media for education.

This study's finding of students' limited Edmodo use might also be explained by the informal-grading nature of the after-school program. Lantz-Andersson, Vigmo, and Bowen (2012) conducted an ethnographic study with students aged 13-16 in Colombia, Finland, Sweden and Taiwan in terms of adopting SNS as English teaching and learning education platforms. They indicated that students viewed interacting with others on SNS for educational purposes as "doing school work" and would perform intentionally to fulfill institutional requirements in order to get good grades. As this dissertation's context was in an after-school program, student might have been less motivated to interact with others on Edmodo because their after-school performance was not officially graded.

Students' neutral or negative attitude toward SNS in this dissertation study might be also explained by both the nature of SNS and students' SNS use habit established before this after-school program. The nature of SNS is to connect users with friends or someone else they know personally. The after-school program gathered students from different classes and the students did not know each other very well, which might also explain the limited online interaction. For the influence of SNS use habit, some students might have had friended each other on other SNS before coming to the after-school program. Hence, it made less sense for them to use the assigned Edmodo to replace their original SNS, if their Edmodo application was not officially graded.

Project-Based Learning Experience in Developing Digital Literacy

Students' limited interaction on Edmodo and self-learning at home largely hindered the effect of the proposed blended learning approach on developing digital literacy. Instead, their digital literacy development could only be attributed to their face-to-face PBL experience, as evidenced by their significant development in digital literacy as well as student and teacher interview analysis in the 2017 semesters. However, the effect of PBL on digital literacy was not significant in both semesters of 2018. The different effects of PBL on digital literacy between the 2017 semesters and the 2018 semesters might be explained by one of principles of designing effective PBL curriculum, proposed by Barron et al. (1998). Barron et al. proposed four PBL design principles: (a) defining learning-appropriate goals, (b) providing scaffolding and beginning with problem-based learning activities before doing a project, (c) securing several opportunities for enabling formative self-assessment and revision; and (d) developing social structure to facilitate participation and a sense of agency.

The last principle, developing social structure to facilitate participation and a sense of agency, focuses on the construction of a social organization to promote students' active participation and agency development, which might be able to explain the different effects between the two semesters in 2017 and 2018. The learning activities in the 2017 semesters were identical and allowed more collaborative learning activities to promote students' active participation and peer interaction (13 out of 18 weeks), compared to the 2018 semesters (7 out of 18 weeks for the spring semester and 0 out of 18 for the fall semester).

The AR and VR software used in the 2017 semesters were also less technically demanding. Consequently, students' lack of self-learning at home caused less impact on students' active participation in in-class collaborative learning activities because they could apply their previous ICT usage experience in learning tasks. Moreover, the lower technical complexity of software used in class also provided students with more sense of agency because they could decide their own project themes without being restricted by software's technical complexity. By contrast, the learning activities in the 2018 semesters involved students in learning more complex AR and VR software, which underlined the lack-of-preview problem and its negative influence on students' social interaction and sense of agency. For instance, in the fall 2018 semester, the seriously increased technical complexity of the VR software and the students' lack of self-learning largely reduced students' social interaction through peer support. In class, the students either focused on the teacher's lecture or gave up following the course's progression. The students' sense of agency in doing an individual project was also undermined. Students were less able to fully express their creativity because of the VR software's technical complexity. In sum, the curriculum in the 2017 semesters, compared to the 2018 semesters, allowed more social interaction opportunities and demanded less technical knowledge and skills, which facilitated students' active participation and sense of agency in the project execution processes.

Impact of Students' Repeat Participation in the BTPII After-School Program on the Difference in Digital literacy Changes and Final Performance

As learning activities in both spring and fall 2017 semesters were identical, the students who participated in both semesters were able to transfer their experience from the spring semester to the learning tasks in the fall semester. This transferability explains their statistically improved final performance in the fall 2017 semester, compared to the novice cohort in 2017 spring. The effects of learning transferability on a PBL environment were previously empirically evidenced by investigators of studies in the high school (Yasuda, 2017) and pre-service teacher education settings (Howard, 2002). Yasuda (2017) conducted an interpretive case study to investigate how 12 undergraduate students applied what they learned from a high school Senior Capstone Project (SCP) to their school work. The research results empirically indicated the SCP experience benefited students' content knowledge, academic skills, dispositions, and self-efficacy, which were transferred to support their college work. Howard (2002), in a three-semester longitudinal study, indicated pre-service teachers who had technology-enhanced PBL experience during their teacher training programs were more likely to use a computer and have their students use computers during instruction, which evidenced the effect of learning transferability of PBL. This study added to the available literature on PBL and learning transferability through indicating effects of learning transferability on digital literacy development in a PBL environment.

However, the effect of learning transferability on students' project performance was weak in the spring 2018 semester as veteran students encountered partially unfamiliar learning activities (ARIS, an advanced AR software). There was no significant difference in the final performance between the veteran and novice students although the veteran students scored relatively higher on their final performance than novice peers. The effects of learning transferability on final performance disappeared in the fall 2018 semester, because the learning content in this semester greatly differed from that of the previous three semesters. Such a colossal modification of learning content resulted in non-significant differences in the final performance of both veteran and novice groups in this semester. This result could be attributed to the fact that veteran and novice groups had the same level of prior knowledge related to this semester's learning activities, which was knowledge of Scratch because they all had been exposed to Scratch in their in-school curriculum.

Students' multiple participations across semesters did not result in a significant difference between the veteran and novice students in terms of their digital literacy changes before and after engagement in the BTPII after-school program. However, according to the descriptive statistics results, novice students were more likely to report higher degrees of digital literacy changes compared to veteran students. This result might be explained by the application of the self-reported Digital Literacy Questionnaire. When veteran students were repeatedly asked the same set of questions over and over in different semesters, they were more likely to provide similar responses displaying relatively less change between their pre- and post-questionnaire results. Moreover, the novelty of the BTPII learning experience could also have motivated the novice group of students to self-report higher degrees of post-digital literacy, which explains the finding of higher changes of digital literacy in the novice group. Finally, the novice had more space to learn new knowledge and skills, compared to the veteran, and perceived more progression in their own digital literacy. However, the above inferences related to the veteran group's reduced changes and smaller reported in digital literacy lack statistical support.

No Significant Impact of Students' Daily Internet Access Time on the Difference in Digital Literacy Changes and Final Performance

The amount of students' Internet access time was not significantly associated with either their digital literacy changes or final performance. This no-significant association between Internet access time and digital literacy changes found in this study is aligned with results in a study by Li and Ranieri (2010). Li and Ranieri indicated that 9th graders' digital literacy was not significantly influenced by their frequency of Internet use. Thus, this study failed to find a significant relationship between Internet access time and digital literacy changes because of the no-significant association between either the students' pre- or post- digital literacy and Internet access time.This disseration also empricially extended the research findings of Šorgo et al. (2017) from the college to middle school setting. According to Šorgo et al., college students' Internet use experience did not statistically predict their information and data literacy levels. I further verified that middle school students' Internet use experience was also not statistically associated with their possession of information and data literacy through their project performance. In sum, how much Internet a student use might not stand for his/her digital literacy level.

This study identified that students' frequent Internet use for collaboration and communication purposes had no significant influence on their digital literacy changes, particularly for the purpose of information and data literacy. By contrast, Alkan and Meinck (2016) empirically articulated that 8th graders' frequent use of information and communication technology (ICT) for communication contributed to statistically significant development of information and data literacy. Such variation in the research finding might be explained by the difference in measurement tools. In their study, they relied on a test to evaluate students' information and data literacy, while this dissertation relied on students' self-reported questionnaire. However, Porat, Blau, and Barak (2018) statistically indicated that middle school students were likely to over-estimate their actual digital literacy. In other words, this is a deviation between middle school students' objective and subjective digital literacy.

In sum, on comparing the findings of this dissertation study with those of the three previous studies (Alkan & Meinck, 2016; Li & Ranieri, 2010; Šorgo et al., 2017), we can conclude that the debate on students' Internet use pattern's relation to development of digital literacy awaits further research efforts. More studies are needed to investigate how other individual difference factors influence the association between middle student's Internet use patterns and digital literacy levels, such as gender, social economic status, or parenting mediations. For example, Rodríguez-de-Dios, van Oosten, and Igartua (2018), in a study with 1,446 middle school students, statistically evidenced that restrictive parental mediation is negatively associated with the students' digital literacy levels. It might be worth to investigate how parental mediations influence the association between middle school students' Internet use patterns and digital literacy levels. More research is also needed in identifying ways to help students effectively apply their digital literacy to their learning tasks in a blended technology-rich PBL environment.

RECOMMENDATIONS

Recommendations for Parents

Although there is still a debate about the impact of Internet use patterns on possession of digital literacy, it remains vital to oversee children and teenagers' Internet use and provide appropriate guidelines on the amount of Internet use time. Moreover, although no significant association was found between Internet usage purposes and possession of digital literacy, guiding children and teenagers' use of the Internet remains an excellent way to develop every element of digital literacy through tasks such as using cloud storage services to manage and share information with others or critically applying information obtained from the Internet.

Recommendations for Educators

When planning an instructional unit on digital literacy education, involving learners in a series of related tasks might be helpful in increasing the possibility of learning transferability. For instance, involving students in an individual project first is beneficial for students to develop necessary knowledge and skills required for a group project. In such design, students are able to apply knowledge and skills learned in the individual project to subsequent and similar tasks in the group project, allowing the students to consolidate learned knowledge and skills. In addition to the curriculum arrangement, a teacher' guides also play an important role to help students apply prior learning outcomes in a subsequent task. For instance, when a student has learned how to record and edit a video in an earlier learning activity, a teacher can prompt the student to create a video to better communicate his ideas and express his/her creativity in a digital storytelling artifact, instead of downloading a video from the Internet.

Less motivated students can be found in most classrooms. In this dissertation study, eagerness to access the Internet and course difficulty in terms of learning tasks resulted in the issue of less motivated students. Therefore, the first recommendation for future educators is to negotiate with students to formulate an Internet use management rule. For instance, students can freely access to the Internet as long as they complete specific tasks. The second recommendation is to design courses of varying difficulty levels and follow a sequence that takes students' pre-digital literacy and progression into consideration.

Using SNS for education to support blended learning was found to be less effective at encouraging students' online learning. This result was corroborated by Pew Center (2017) research data that indicated a cessation of growth when SNS were used for education in 2017. Therefore, future educators interested in incorporating SNS might need to consider students' possible reactions before introducing SNS into their classrooms. Moreover, students' application of SNS for learning might be also guided by educators, since using SNS for socializing with others and for learning required different skillsets and mindsets (Stewart, 2015). Having a facilitator to promote students' online interaction on SNS might be also essential for a successful implementation of teaching and learning with SNS (Won et al., 2017).

FUTURE RESEARCH

There are two recommendations for future research. First, one line of inquiry of this study was to investigate if students' experience in Internet use contributed to better blended learning performance. This inquiry was based on the hypothesis that students' online experience improved their digital literacy and fostered superior performance in a blended, technology-rich, PBL environment. In other words, students' digital literacy plays the role of a mediator between students' Internet use and learning performance. However, the method applied in this study to measure students' digital literacy was a self-reported questionnaire. The results of the questionnaire could not be used to run mediation analyses of the association between Internet use and a blended learning environment as the correlation analysis I performed showed no significant impact on students' pre-digital literacy and final performance or students' post-digital literacy and final performance. It is possible that the self-reported digital literacy questionnaire failed to represent students' actual digital literacy. In other words, student perceptions of personal digital literacy levels did not represent their actual digital literacy. This finding was also evidenced by Porat et al. (2018). They statistically indicated that middle school students significantly over-estimated their actual digital literacy. This is an obvious gap between the students' self-reported and actual digital literacy. Therefore, future studies should apply an objective method (e.g., a digital literacy test or serious of authentic tasks relevant to practices of digital literacy) to obtain students' comparable digital literacy levels and use the results as a mediator to analyze the correlation between students' Internet use pattern (e.g., amount of access time and usage purposes) and learning performance in the blended learning environment. Second, future study should explore alternative tools to facilitate online peer communication and collaboration, such as instant messaging tools or social media platforms that enable private communication channels to encourage more peer conversation and reduce the risks of privacy issues.

LIMITATIONS

The findings of this study should be interpreted within the context of two limitations. First, the sample size was relatively small, which might have contributed to a non-significant result. For example, comparison analysis of pre- and post-digital literacy for the fall 2017 semester yielded a non-significant result but moderate effect size for each digital literacy element. Moreover, the correlation between Internet usage purposes and possession of digital literacy might have become apparent with a larger sample size. Second, this study relied on students' self-reported digital literacy via a questionnaire. An objective measurement (e.g., a digital literacy test or serious of authentic tasks relevant to practices of digital literacy) might have contributed a more trustworthy result to help understand the effects of the BTPII program on students' digital literacy development.

Appendices

APPENDIX A: RESEARCH MATRIX

Research Question	Data Sources	Specific data to answer this question	Analysis Required	What will this allow me to say?
What are the learning activities across four iterations of the blended, technology-rich, project-based instructional innovation (BTPII)?	*Classroom and Edmodo observation*	*Learning activities observed in the classroom and Edmodo*	*Coding for themes*	*Represent the students' learning activities in face-to-face and online settings across four iterations of the BTPII.*
	Lesson Plans	*Activities related to instructional objectives, instructional content, technology application, and assessment strategies described in the lesson plan*	*Coding for themes*	*Represent the students' learning objectives, learning content, and the assessments they received across four iterations of the BTPII.*
How does students' digital literacy change after engagement in the BTPII after-school program?	*80 students' self-reported digital literacy pre- and post-the BTPII after-school program via a questionnaire*	*Items related to information and data literacy, communication and collaboration, creation, safety, and problem solving*	*Descriptive statistics and Wilcoxon Signed Ranks Test (SPSS)* *Effect size (Microsoft Excel)*	*Students perceived their digital literacy change in every element of digital literacy, which is supported by statistical results, across four iterations of the BTPII.*

Appendix A (continued)

Research Question	Data Sources	Specific data to answer this question	Analysis Required	What will this allow me to say?
How does students' digital literacy change after engagement in the BTPII after-school program?	*Classroom and Edmodo observations across four iterations of the BTPII program*	*Learning activities observed in the classroom and on Edmodo*	*Coding for themes*	*The observational data illustrated students' utilization of digital literacy and allowed me to correspond their self-reported digital literacy change to their engagement in the BTPII.*
	Teacher interview	*Transcribed interviews*	*Coding for themes*	*From the teacher's perspective, how students' BTPII learning experiences justified students' change (or no change) in various elements of digital literacy post-intervention.*
	Student Interviews	*Transcribed interviews*	*Coding for themes*	*From the students' perspectives, how their BTPII learning experiences justified their change (or no change) in elements of digital literacy post-intervention.*

Appendix A (continued)

Research Question	Data Sources	Specific data to answer this question	Analysis Required	What will this allow me to say?
Do the students' pre- and post-digital literacy changes differ with respect to students' repeat participation in the BTPII program?	*58 Students' enrollment data*	Students' participation time in the BTPII after-school program	*Descriptive statistics and Mann-Whitney U test (SPSS)*	*Students with repeat participation in the BTPII did not have statistically significantly digital literacy changes than their peers who did not.*
Do the changes differ with respect to levels of students' daily Internet access time?	*58 students' out-of-school Internet use survey*	Amount of Internet use time	*Descriptive statistics and Kruskal-Wallis Test (SPSS)*	*There was no statistically significant correlation between the students' amount of out-of-school Internet use time and digital literacy changes.*
Do the changes differ with respect to the students' daily Internet usage purposes?	*58 students' out-of-school Internet use survey*	Internet usage purposes related to utilization of digital literacy	*Descriptive statistics and Kruskal-Wallis Test and Pearson's Correlation analysis (SPSS)*	*There was no statistically significant correlation between the students' out-of-school Internet usage purposes and their digital literacy changes.*

Appendix A (continued)

Research Question	Data Sources	Specific data to answer this question	Analysis Required	What will this allow me to say?
How does students' final performance in the BTPII after-school program differ?	*80 Students' assessment results across four iterations of the BTPII program*	*Students' final performance scores*	*Descriptive statistics and Wilcoxon Signed Ranks Test (SPSS)*	*Students' final performance in the learning activities differed in every iteration of the BTPII.*
Does student performance differ with respect to repeat participation?	*58 Students' enrollment data*	*Students' T score of final performance and their participation times in the BTPII after-school program*	*Descriptive statistics and Mann-Whitney U test (SPSS)*	*Students with repeat participation in the BTPII did not have statistically significantly final performance compared to peers who did not.*
Does performance differ with respect to levels of the students' daily Internet access time?	*58 students' final performance scores and out-of-school Internet use survey*	*Students' T scores of final performance and their amount of Internet use time*	*Descriptive statistics and Kruskal-Wallis Test (SPSS)*	*There was no statistically significant correlation between students' final performance scores and their amount of out-of-school Internet use time.*

Appendix A (continued)

Research Question	Data Sources	Specific data to answer this question	Analysis Required	What will this allow me to say?
Does performance differ with respect to levels of the students' daily Internet usage purposes?	*58 students' final performance scores and out-of-school Internet use survey*	*Students' T score of final performance and their Internet usage purposes related to utilization of digital literacy*	*Descriptive statistics and Kruskal-Wallis Test and Pearson's Correlation analysis (SPSS)*	*There was no statistically significant correlation between students' final performance and their out-of-school Internet usage purposes related to utilization of creation, as an element of digital literacy*

APPENDIX B: SELF-REPORTED DIGITAL LITERACY QUESTIONNAIRE

To what extent do you agree with the following statements related to your digital literacy (1 = strongly disagree, 5 = strongly agree)

Information and data literacy — Cronbach's α = 0.84

1. I use the Internet to search for all kinds of information relating to my personal interests and/or my professional needs.
2. When I need to look for specific information, besides the basic functions offered by search engines, I use advanced searches, online databases, and/or searches via linked references.
3. I use filtering mechanisms to be able to make an appropriate selection of information of interest to me on the web (e.g., source discrimination, use of RSS feeds, Microblogging).
4. I am able to use different browsers to surf the Internet (Explorer, Chrome, Firefox, Opera, Netscape, others).
5. I am capable of identifying whether the information I have obtained on the web is valid, reliable, and appropriate, as well as the reliability of its source.
6. I know of and check for several parameters that websites and information available online must comply with in order to consider their contents of reliable quality.
7. I have no problem in recognizing what online content is legal and what is illegal.
8. I store information on a number of different physical supports (internal and/or external hard disk, CD, USB stick, memory card…).
9. Periodically, I make backup copies of the information and/or files I have stored on my devices and/or equipment.
10. I classify the information in an organized manner using files and folders in order to locate these easily at a later date.
11. I locate and recover stored information without difficulty.

Communication and collaboration — Cronbach's α = 0.90

1. I am familiar with e-mail and can use it to communicate with others.
2. I am familiar with instant messaging tools (Line, Facebook Messenger, Wechat, WhatsApp, etc) and use them to contact others.
3. Before sending a message, I usually read it once or several times in order to ensure that it can be understood correctly and that the spelling is right.
4. I use tools available in the cloud to share content, knowledge, and/or resources with other people (documents, photos, videos, etc.): Google Drive, Dropbox, others.
5. I am able to use digital tools for planning a group project in face-to-face settings (e.g., Use Xmind to assist brainstorming activities in a group).
6. I am able to use digital tools to execute group work in face-to-face settings (e.g., Use PhotoScape to edit photos captured by other group members).

Appendix B (continued)

To what extent do you agree with the following statements related to your digital literacy (1 = strongly disagree, 5 = strongly agree)	
Communication and collaboration	Cronbach's α = 0.90
7. I am able to use digital tools for monitoring group work in face-to-face settings (e.g., Use Google Calendar for tracking group progress).	
8. I am able to use digital tools for planning a group project in an online context (e.g., Use Xmind Cloud Service to conduct a brainstorming activity online).	
9. I am able to use digital tools to execute group work in an online context (e.g., Use Google Doc to collaborate with peers on a document online in real time).	
10. I am able to use digital tools to monitor group work in an online context (e.g., use Edmodo to keep track of the work progress of our team).	
11. While collaborating with a team, I am able to complete the work assigned to me on time.	
12. While collaborating with a team, I am able to provide timely support to my teammates.	
13. While assigning work to my teammates, I am able to assign to my teammates proper amounts of work that matches their interest and speciality.	
14. I participate on the web in a polite and respectful manner, and I avoid offensive expressions from the point of view of religion, race, politics, or sexuality.	
15. I am familiar with social network sites (Facebook, Instagram, Google +, etc.) and can manage one or multiple accounts, to be able to protect my reputation.	
Creation	Cronbach's α = 0.88
1. I am capable of using Microsoft Office to generate simple digital content in at least one format (text, Table, image, etc.).	
2. I am capable of generating simple digital content in at least one format (text, Table, image, etc.) using a tool (Word, PowerPoint…).	
3. I can produce digital content in multiple formats, including multimedia, with more than one tool.	
4. I can make appropriate choices on what software to use for generating certain formats of digital content.	
5. I am aware of what software can be used to edit images, sound, and video files.	
6. When conveying an idea, I am capable of expressing myself adequately with the support of different digital means (graphics, mental or conceptual maps, diagrams, etc.) in order to set it out in a creative manner.	
7. I am capable of making basic changes in digital content produced by third parties, which I access or have in my possession (presentations, documents, photographs, videos, etc.).	
8. I can mix multiple tracks and different, pre-existing elements of content of all kinds and generate new content based on these.	
9. I can always find a new way to improve the digital content I created.	

Appendix B (continued)

To what extent do you agree with the following statements related to your digital literacy (1 = strongly disagree, 5 = strongly agree)	
Creation	Cronbach's α = 0.88
10. Generally, I am able to integrate different modes of information to present a topic without difficulty.	
11. I like generating new ideas through brainstorming activities.	
12. I differentiate correctly between content that may be subject to restrictions to their use under copyright or license protection and those that are not.	
13. I am aware of the consequences of illegally downloading digital content (music, software, films, etc.).	
14. I distinguish between concepts such as copyright, copyleft, and/or creative commons.	
15. I apply, in the correct manner, the different kinds of licenses that exist for the information I use and generate on the web, in accordance with my requirements.	
Safety	Cronbach's α = 0.82
1. I act with caution when I receive messages with content and attached files from a sender I am not familiar with (SPAM).	
2. I frequently modify the basic privacy configuration offered by default by the online services I use in order to improve my protection.	
3. When I use my Facebook or Google account to access other websites/online services, I check the terms pertaining to how service providers use my personal profile, as well as their privacy policies.	
4. I use the privacy functions available in applications to approve or reject anyone who might access my profile.	
5. I am familiar with privacy settings on social network sites (Facebook, Instagram, Google +, etc.) and can change settings to protect my privacy.	
Problem solving	Cronbach's α = 0.86
1. I am aware of how digital devices and computer equipment work (computers, networks, communications devices, etc.).	
2. I am capable of resolving, in an adequate manner, any kind of problem that might arise when the technologies or devices I use do not operate correctly.	
3. I am capable of identifying adequate alternatives when I cannot resolve problems with the technologies or devices I choose at first.	
4. I know who to turn to or what to do should I need technical support and assistance when the technologies I use do not work correctly and when I use a new device, program, or application.	
5. I have knowledge of the available technologies, their strengths and weaknesses, and whether or not and how they can enable me to reach my goals.	
6. I am capable of evaluating, in an adequate and critical manner, which tool best adapts to my needs and objectives in each individual case.	

Appendix B (continued)

To what extent do you agree with the following statements related to your digital literacy (1 = strongly disagree, 5 = strongly agree)	
Problem solving	Cronbach's α = 0.86
7. I know how to edit and modify, by using a number of different digital applications or tools, the format of different kinds of files (photographs, videos, and texts) created by me or by others.	
8. I am capable of creating multimedia content (sound, video…) using a wide range of tools.	
9. In general, I am able to mix a variety of digital tools to solve problems.	
10. I am capable of generating my own original and creative digital products using appropriate software and/or tools (e.g.: PhotoScape, Prezi, …).	
11. I like thinking about how to improve existing technology/methods to make life more efficient.	
12. I keep up-to-date with my knowledge and skills of using digital tools and technologies.	

APPENDIX C: STUDENT INTERVIEW QUESTIONS

1. Do you think your program participation experience generally influenced various aspects of your digital literacy[2], such as information and data literacy, communication and collaboration, digital content creation, safety, and problem solving? If yes, why and how?
2. Do you think any of your project-based learning experiences influenced any aspect of your digital literacy? If yes, why and how?
3. Do you think your interaction with peers or group work experiences (either on Edmodo or in classroom settings) helped you change any aspect of digital literacy? If yes, why and how?
4. Do you have any experience of applying learning gains (e.g., knowledge and skills) obtained from teachers, peers, or your own experience from a prior task to the subsequent task or from online to the face-to-face setting and vice versa? If yes, why and how? Do you think such experience influenced any aspect of your digital literacy? If yes, why and how?

[2] I explained every sub competency of digital literacy with a concrete example.

APPENDIX D: INTERNET USE AND SELF-LEARNING QUESTIONNAIRE

Internet Use and Self-Learning Experience Survey

Demographics

1. Name: __________
2. Gender: Female____ Male_____
3. Grade: 7th grade___ 8th grade___
4. Age: _________________
5. After-school participation semester: ________________

Phone and data plan

6. Personal mobile phone brand (choose one from the following options):
   (a.) iPhone
   (b.) Premium Android phone (market price over 363USD)
   (c.) Regular Android phone (market price lower than 363USD)
   (d.) Traditional cellphone
   (e.) I do not have a mobile phone

7. What is your parent's highest education level? (the parent who spends the most time taking care of you)
   (a.) Elementary school
   (b.) Middle school
   (c.) High school or vocational education
   (d.) College
   (e.) Graduate school
   (f.) Others________________
   (g.) I do not know

8. What data plan do you use for your phone?
   (a.) Unlimited plan
   (b.) Limited data plan
   (c.) WiFi-only
   (d.) My phone does not have Internet accessibility/I do not have a phone

Access to Internet

9. Do you have computers that connect to the Internet at home?
   (a.) I don't have any computers that connect to the Internet at home

(b.) I have one or more computers that connect to the Internet at home, but not in my own bedroom
(c.) I have one or more computers that connect to the Internet at home, and one or more of them is/are in my own bedroom

10. The time I spent on the Internet daily this semester:

	Yes	No
I spent over two hours daily using the Internet on week days		
I spent over five hours daily using the Internet on weekends		

Daily Internet usage purposes

Please check the box to indicate whether you have the following Internet usage purposes at least one time a week

Information and data management	
(a.) Search for Information related to my interests	
(b.) Search for Information related to my school work	
(c.) Use cloud services (e.g, Goolge Drive) to backup my computer's data	
Communication and collaboration	
(a.) Chat with friends or family members using instant messaging tools like WhatsApp and WeChat	
(b.) Check social networking sites like Facebook and Twitter	
(c.) Share information with peers for a school group project	
Creation	
(a.) Create digital content, such as a blog article, video, or webpage, on topics of interest	
Problem solving	
(a.) Search for answers to solve everyday problems, e.g., find directions or look up a map	
(b.) Search for information to learn something new	
(c.) Search for an answer to a problem related to my school work	

Out-of-school self-Learning experience

11. Do you install Edmodo app on your smartphone?
(a.) Yes
(b.) No
(c.) I do not have a mobile phone

12. What types of mobile devices do use to access the after-school program's Edmodo page? (Multiple choices)

(a.) Smartphone
(b.) laptop/computer
(c.) Tablet

13. How often do you check your after-school program's Edmodo page?

(a.) Everyday
(b.) Only if I received a notification from the app
(c.) Only on the days of the after-school program
(d.) I never checked the page

14. How do you solve project-related technical problems while you are at home? (Multiple choices)

(a.) Post my problem to Edmodo's question-and-answer forum
(b.) Search for solutions on the Internet
(c.) Ask family members for help
(d.) Ask peers for help
(e.) Check professional books
(f.) Call a computer technician
(g.) Give up

Edmodo Application

Strongly disagree<——> Strongly agree

	1	2	3	4	5
I actively read my teacher's post on Edmodo to know in-class learning activities in the forthcoming week					
I actively complete my preview work before going to the classroom					
I actively seek help by posting my question(s) to Edmodo when doing my project work alone					
I actively answer my peers' questions on Edmodo					
I actively share information related to this semester's learning content on Edmodo					
I actively use Edmodo to discuss group work with group members					
I actively appreciate my peers' project work on Edmodo					
Overall, I actively participate in online interaction on Edmodo					

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