

Mobile Interpretive Apps as Educational Mediating Tools in Science Education: Participant-
Based Digital Design in Natural History and Science Museums

by

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Abstract

The use of mobile and social learning media for K-12 students continues to rapidly increase in both formal and informal learning environments. While many educational apps have been developed for adult visitors to museums and science and technology centres (STCs), very few programs exist that are specifically designed to meet the unique learning and interpretive needs of elementary students in these learning environments. This dissertation explores the inclusion and development of children's ideas and digitally mediated interpretive activities for peers within the exhibits of the natural history gallery at the Royal British Columbia Museum (RBCM) in Victoria, British Columbia. In this triangulated case study, thirteen Grade 4 and 5 students, five museum interpreters, and six elementary teachers worked in teams to design educational apps for their peers using experimental software specifically designed for this project. Five design teams composed of 2-3 students, one teacher, and a museum educator designed a wide variety of science activities for the natural history gallery at the RBCM. The results of analytic triangulation indicate that mobile interpretive apps acted as imperfect but important educational mediating tools for the participants in this study. The analysis revealed that, despite initial preconceptions and frustrations students and educators had about mobile design and technologies, Grade 4 and 5 elementary students were capable and highly interested creating mobile science apps for the natural history galleries at RBCM. Students and educators designed content and activities that extended participant-based learning opportunities beyond the existing science programs and curriculum currently available at the RBCM. The dissertation concludes with an examination of how informal science institutions can move beyond educational interactivity to more participatory frameworks that include the ideas and voices of young people within mobile learning and educational app development at natural history museums and STCs in the future.

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Dr. James Wesley Todd (1932-2014)

John Robert Todd (1966-2014)

Thomas O'Donnell (1933-2017)

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Chapter 1

Introduction to the Study

Chapter Overview: This chapter explores the children's use of mobile technologies and their potential impact on educational systems including natural history and science museums. The rapid adoption of mobile devices and applications within formal and informal educational systems creates a rich socio-cultural matrix for educational research around digitally based and mobile interpretive pedagogies where students explore, design, and share diverse learning activities and experiences with peers and other community members both on site and through social media. This dissertation explores how elementary students and educators can work together in the design of mobile app prototypes for the Royal BC Museum's (RBCM) Natural History Gallery. After presenting a brief overview of the primary goals, questions, and limitations of this study, this chapter concludes by laying out a framework for the research methods, analysis, results and discussion presented in subsequent chapters.

Hello friends! Welcome to the station about the deep deep ocean. There are many strange and wonderful creatures that we never get to see. Let's dive into the deep together! (G4 Student, 2016)

-Grade 4 Participant, 2016

This institution (RBCM) has set itself apart and above from a number of other institutions with its excellence, with close to 500,000 visitors per year, with a particular emphasis on outreach to young British Columbians...(RBCM, 2013, p. 1)

Even a casual observer of children and families today knows big changes are afoot when it comes to children and new media technologies. (Common Sense Media, 2013, p. 7)

Background: Science Museums and the Interpretive Voice

In 1967 a nine-year-old visited the Hayden Planetarium for the first time. In reflecting back on the experience decades later, the noted astrophysicist Neil deGrasse Tyson stated:

Alright it's just another museum until...they turn out the lights and the stars come out. Back then space shows were live and then...there is this voice, 'We are now in the universe and these are the stars.' You're looking up and you don't see anybody...just this voice. So...it's like the universe is talking to me. And there was the sky unlike that, which I have ever seen having been born and raised in New York. There you are bathed in the cosmos. That can be quite influential as it was on me.
(Tyson & Aguirre, 2010)

Shortly thereafter, the young astronomer would receive his first telescope, which further enabled his interest in the cosmos and the field of astrophysics. Neil deGrasse Tyson would go on to become the director of the Hayden Planetarium and the voice of one of its most popular programs today, *Dark Universe*. Tyson was reminded of the importance of his early experiences in the museum's planetarium and the cosmic voice he heard as a young person: "That weekend..." Tyson states, "...called me" (Tyson & Aguirre, 2010).

Neil deGrasse Tyson is not the only scientist to be inspired by a childhood visit to a natural history or science museum. What is remarkable in his testimony is that behind the curtain of that cosmic voice and starry facade of the Hayden Planetarium, like Frank Baum's great and powerful OZ (Denslow & Baum, 1900), exists the voice of a person that inspired visitors on a

scientific adventure to study the cosmos that was normally obscured by the lights of New York City. When the soft velvet curtains were pulled back, whether symbolically in Baum's novel or the Hayden Planetarium, they revealed the ingenious machinations and artificial construction that sought to represent either the narrative or scientific realities of the time where both masterpieces were created. While the significance of the great and powerful Oz will be left for readers and literary scholars to debate, the idea and exploration around the design and use of interpretive voice within natural history museums and science technology centres (STCs) is the central focus of this dissertation.

The rapid use and adoption of mobile technologies by educators and students in the past two decades explored in this chapter complements the emergence of more participatory-based educational design within natural history museums and STCs. The rapid adoption of mobile technologies and learning by young people creates new educational possibilities for students and educators to co-create mobile content and learning activities, including interactive science applications for elementary students. Previous research, presented in the next section, shows that the growing influence and use of mobile technologies by young people will likely inspire natural history museums and STCs to begin developing a wider range of mobile applications and activities for the public, including elementary students and other young visitors. This dissertation explores the utilization of participant-based models of curriculum and mobile app design within informal science settings. However, before exploring the role students can fulfill within the interpretive voice of informal science education, it is important to examine the increasing use of mobile devices such as smart phones, tablets, and portable gaming consoles by young people.

A Rapidly Emerging Mobile Landscape

In the past decade, the use of mobile devices such as smart phones, tablets, readers, and portable electronic gaming consoles with multimedia features such as video/camera and Internet capabilities by young children in North America has continued to accelerate at a remarkable rate. Kabali, Irigoyen, Nunez-Davis, Budaki, Mohanty, Leister & Bonner found that, “almost all children (96.6%) used mobile devices, and most started using before age one” (2016, p. 1044). While their study was limited to communities around Philadelphia in the United States, its findings both update and support national trends reported by earlier and much larger national studies by the research group Common Sense Media (CSM). In 2011, approximately 52% of children in the United States between the newly born and age eight either owned or had access to a mobile device (2011). By 2013, they noted that the ownership of mobile devices like iPads and other tablets jumped from 8% to almost 40% of all children (Common Sense Media, 2013). This mirrors trends in Canada as well. In Canada, a national survey of 5,436 students in the range of Grades 4 to 11 reported that approximately 25% of the population sampled had their own cell phone or mobile device (Steeves, 2014). An international study on the differences in the use of mobile devices by children in India, Egypt, Chile, Paraguay, and Japan reported that 65% of children between the ages of 8 and 18 have access to mobile devices (Global Sense Mobile Analysis, 2013). In this same study, the range of smartphone ownership by children ranged from 44% in Chile to 27% in Japan (Global Sense Mobile Analysis). The use of mobile devices is gradually replacing other more passive activities by children such as watching TV (Common Sense Media, 2013). Most of the activities by young children revolved around accessing games, media, audio files, and electronic books (Common Sense Media). Researchers also noted that the digital divide (Dawson, 2014; Livingstone & Helsper, 2007; Norris, 2001; Warschauer, 2003) between those who have access to these technologies/information and those who do not is

narrowing as well with 65% of all lower income children in the United States having access to some kind of smart phone or mobile device (Common Sense Media, 2013). According to the report, “Parents gave children devices when doing house chores (70%), to keep them calm (65%), and at bedtime (29%)” (2013, Sec. 3). In each of these studies, researchers noted the need for further investigations in other communities, particularly within socio-economic contexts, and on how different families utilized mobile devices and digital information.

Given the trends of mobile use in the United States and Canada, many educational sectors in both countries began adopting mobile technologies into schools and curricular processes. In 2013, the second largest school district in the United States, Los Angeles, rolled out a \$145 million-dollar program to equip every one of their approximately 667,000 students with an iPad by the end of 2014 (Blume, 2013). Similar programs have been rolled out in other school districts in United States and Canada, though at a much smaller scale. For example, a West Vancouver secondary school required all its students to purchase or have access to an iPad (Bains, 2014). The Ottawa school district released a plan to dramatically increase students’ access to and use of mobile devices (Ottawa-Carlton District School Board, 2012). On Vancouver Island, the superintendent of a school district within the Greater Victoria region reported a similar process of adopting mobile technologies in the district’s schools (Huber, 2013). Interestingly, nearly every one of these efforts stalled, was dramatically cut back, or became mired in controversy and debates around the substantial cost and efficacy of equipping every student with an iPad for learning (Isavoli, 2013; Maharaj, 2014). In 2015, the FBI and the US Department of Education launched investigations into corruption charges against the iPad initiative within the Los Angeles Unified School District noted above (Blume, 2015). The Principal at the West Vancouver Secondary School noted that the administration had reversed its policy as well, citing costs, a

focus on options rather than requirements, and the emergence of inexpensive laptops such as Google's Chromebook (S. Rauh - personal communication, Feb. 9, 2017). Other districts in BC including the smaller school district on Vancouver Island mentioned above purchased iPads at much lower rates than initially planned (2016, p. 159).

Although Rubino (2011) discusses the value of incorporating iPads into museums, research on their use within science education is still emerging. Examples of research in science education include Falloon's (2017) study on the possibilities and challenges of utilizing iPads and science apps to scaffold learning in elementary classroom settings. Lee & Tu (2016) examine the value of using iPads to support English Language Learners (ELLs) in science education. The efficacy of Prediction-Observation-Explanation models using interactive e-books was studied by Hong, Ming, Ming, Huei & Yi (2014). Other research on informal science learning in nature (Boyce, Chandrani, Halverson & Thomas, 2014) and museums (Knight & Davies, 2013) suggest an iPad's value as a reference tool or recording device. There is also a significant body of evidence supporting the use of mobile learning within science education (Burden, Hopkins, Male, Martin & Trala, 2012; Heinrich, 2012; Ward, Finley, Keil & Clay, 2013). According to a systematic review of mobile learning research since 2000, Crompton, Burke, Gregory and Gräbe present emergent trends in science education (2016). Key research findings included:

- (1) The most common research purpose for the studies on mobile learning in science was designing a mobile system for learning, followed by a combination of evaluating the effects of mobile learning and investigating the affective domain during mobile learning;
- (2) case studies, mixed methods, and quasi-experimental design were the most adopted research methods by researchers of mobile learning in science;
- (3) all studies of mobile learning in science reported positive outcomes;
- (4) the majority of

studies of mobile learning were conducted in the area of life science; (5) most of the studies on the use of mobile devices for science learning took place in elementary school settings; (6) the majority of the studies occurred in an informal educational context; (7) the variety of the devices used indicated that the device type was not important; and (8) while research was conducted in thirteen countries, the majority of the studies on mobile learning in science were conducted in Taiwan (2016, p. 159).

The research described in this dissertation fits within the pattern Crompton identifies above as this dissertation examines mobile learning in the life sciences with elementary students in informal settings. The assertion that every research article that Crompton and her co-authors examined in their study was positive may illuminate research and/or publishing biases towards studies only demonstrating positive results. The authors are aware of this trend and note the importance of identifying negative findings and reporting those research findings as well. Other studies in mobile learning suggest negative issues with student distraction and accessing inappropriate websites (Crescente & Lee, 2011), technological infrastructure (Chou, Block & Jesness, 2014), Cognitive Load (Chou, 2017), and the lack of teacher support around the use of new technologies (Baran, 2014).

Common Core and standards based educational movements in the United States such as the Next Generation Science Standards (NGSS) and National Education Technology Standards (NETS), proposed by the National Research Council (NRC) and the International Society of Technology in Education (ISTE) respectively, encouraged the rapid expansion of 21st Century Learning to include digital and personalized mobile learning (International Society of Technology in Education, 2008; National Research Council, 2012). Many of the same trends are occurring in Canada as well. For example, in the Canadian province of British Columbia, the

development of new educational standards by the British Columbia Ministry of Education (2013) emphasize more personalized learning including the use of 21st Century Skills associated with mobile platforms. The confluence of both socio-demographic and curricular trends in the use of mobile devices for learning by students in British Columbia helped set the stage for this research project that focused on the design and use of mobile apps in museum and informal science settings.

Despite the ongoing educational debate in formal education, the one certainty for informal science educators at museums and science technology centres (STCs) is the rapidly increasing number of mobile devices students have access to at home and school. This socio-demographic phenomenon illuminates an important question: What challenges and opportunities exist for natural history museums and STCs with the respect to the rapid infusion and use of mobile devices by young people? Informal learning environments, like natural history and science museums, are also in the process of incorporating the use of mobile devices and platforms into their educational programming (Bressler, 2013; Proctor, 2011; Tallon, 2012). Many large natural history and science museums like the Smithsonian, the California Science Center, the Royal BC Museum, the Royal Ontario Museum, and the Pacific Science Center all have mobile applications¹ that visitors and members of the public can download and use on their personal devices. Numerous informal apps such as *Foursquare*, *ArtMob*, and *Google Maps* allow the user to share their ideas, thoughts, photos and recommendations on museums and science exhibits with each other as well (Bressler, 2013).

With the exception of the Smithsonian Institution, the vast majority of museum and informal place-based apps are primarily designed for adult users and largely inaccessible to a

¹ Mobile applications or “apps” as they are less formally called are software programs for tablets, smartphones and other mobile devices. This dissertation uses the more common term.

significant number of children, given the high level of technical complexity and reading level required by these apps. Educational research has shown how the linguistic and technical complexity of scientific language may act as a barrier for many students (Lemke, 1990 & 2002; Wellington & Osbourne, 2001). Digital experience and literacy by younger students, museum interpreters and other informal science educators also impact the design and use of educational technologies in different science settings (Cahill, Kuhn, Schmoll, Wan-Tso, McNally & Quintana, 2011). Other researchers have noted the challenges of using mobile technologies to facilitate lifelong learning due to app complexity and constantly evolving software updates and functionality upgrades that may require additional training and experience for both students and educators to use effectively (Mehdipour & Zerehkafi, 2013; Moore, 2009; Sharples, 2000).

While many children's museums and other informal learning centers are specifically designed for the developmental and learning requirements of children (Rochelle, 2002; Rogers, Price, Fitzpatrick, Fleck, Harris & Smith, 2004 & 2008), the majority of natural history and science galleries is designed around an adult-centered and largely transmissive model, symbolized predominantly by the display of various artefacts/replicas and the accompanying signage describing them. This can make the process of interacting with and understanding the content of science and museum exhibits more challenging for elementary students and other young visitors. Many informal museum programs for young people lean on the heavy use of the traditional tour and talk or paper-based search and completion activities for students who might otherwise struggle to interact with many displays (including some digital signage) without the assistance of interpreters or other adults accompanying them.

The rapid adoption of mobile devices like iPads and smart phones by families and school districts described above presents museums and STCs with new opportunities and challenges in

designing interpretive programs that blend authentic museum engagement and exploration with digital and facilitated mobile learning (M-learning). Prior to the research presented in this dissertation, this researcher observed that many young people were motivated to bring and use their mobile devices to document their experiences primarily through the use of photography and video within the natural history and science exhibits at the Royal British Columbia Museum (RBCM). Research on informal and student generated meaning making through digital design and learning within informal science settings is still emerging. Most of the existing work in mobile science education revolves around the use of digital games, virtual models, and reference guides (Barab & Dede, 2007; Clark, Tanner-Smith, Killingsworth & Bellemy, 2013; Santos-Gree, Hetcher, Tysinger & Chassereau, 2014; Trindade, Fiohais & Alameida, 2002). This dissertation explores the possibility of integrating the ideas of elementary students within the process of designing mobile apps for educational and peer learning by other young visitors in natural history and science galleries. More specifically, the [research questions](#) on page 18 and discussed in the following sections examine whether the incorporation of elementary students and their ideas for learning within mobile app design creates new curricular possibilities in science education within natural history museum and STCs. An exploration of the research context including the central research questions examining the rich academic interplay existing within educational, scientific and technological frameworks for this research is presented in the following sections.

Research Context: Interpretive Apps in Informal Science Education

The current Museum 2.0 and 3.0 movements harken back to similar New Museum movements, conflicts, and tensions described more than a century ago by Radar and Cain (2014) in their book *Life on Display: Revolutionizing U.S. Museums of Science and Natural History in*

the Twentieth Century. Radar and Cain trace the successive development of museums from their earliest history in North America to their emergence as significant scientific and cultural repositories that include governmental mandates related to public access, engagement and learning for the twenty-first century (2014). In the United States, the transition from Charles Wilson Peale's "cabinet of curiosities" in Philadelphia would begin with the collected legacy in Washington D.C. by the noted British scientist James Smithsonian. Despite never having lived or worked in North America, after his death, Smithsonian's estate and entire collection was bequeathed to the United States and the formation of a charitable trust and museum (the Smithsonian Institute) dedicated to collecting scientific knowledge and research that was constructed in Washington DC in 1846 (Smithsonian, 2016). Over the course of the next century, the Smithsonian Institute would go on to curate some of the largest scientific collections in the world, fund scientific and other academic research, and provide educational programming to more than 17.3 million visitors in its four-main natural history and science museums (Smithsonian, 2017).

In Canada, the New Brunswick Museum is the nation's oldest. The first national museum was authorized in Montreal in 1856 by the colonial United Province of Canada (New Brunswick Museum, 2017). The Canadian Museum of Nature (2017) also traces its origin to the United Province of Canada and its authorization that directed the creation and administration of a National Museum by Sir William Logan in 1856. Originally proposed as geological museum and administered by the Geological Survey of Canada, the National Museum would later expand into six national museums including the Canadian Museum of Nature (renamed in 1986 from the earlier Natural Science Museum) and the Canada Science and Technology Museum founded in 1967 (Baird, 2015). As presented in the literature review in the next chapter, the emergence of

informal science education programs and exhibits specifically designed for elementary students and other young people are inherently linked to evolving views on the nature of childhood and education. The New Museum and Progressive Reform Movements in Canada and the United States spawned public interest and a call for greater public access to scientific collections and educational programming within the national museums of both countries. The move from taxonomic cabinet exhibits to more lifelike and idealized natural dioramas mirrored changing views on informal science education and the romantic notions of paradise as increasingly urban and industrialized societies faced great losses in two world wars, massive dust storms, and vast tracks of cleared forests (Radar & Cain, 2014). In 1957, *Sputnik*, an artificial satellite built by the Soviet Union, was launched spawning fear within the United States that it and its allies were losing their scientific and technological advantage over the Soviet Union. As a result, massive investments in scientific research initiated an era of *Big Science* that significantly influenced the shape of science education as well (Blades, 1997; DeBoer, 1991 & 2000; Murray, 2014; Yager, 2007). The massive infusion of funds for technological and scientific research also affected the science curriculum in the United States. Prior to the era of Big Science, the focus of science education primarily revolved around practical application and the study of natural phenomena in local contexts. The era of Big Science re-oriented science education and inquiry as analogous and supportive of larger national scientific initiatives and federal policies of the time including the space race and other advanced technologies that would maintain the United States dominance in the design and use of military hardware and other defense applications (DeBoer, 2000).

A second golden era of museum construction dedicated to big science, industry and technology emerged in Canada starting in the sixties and continuing through the end of the 20th century. Influential educational theories such as Dewey's discussions on society and experience

in learning (1915, 1938), Vygotsky's Zone of Proximal Development (1978), Schwab's emphasis on inquiry-based model of science education (1978), and Brunner's work on Discovery Learning (1961 & 1974) greatly influenced the development of more interactive exhibits during the seventies. As expanded upon in the next chapter, concerns about the state of science education in both Canada and the United States, combined with new educational frameworks linking science education to society, influenced the nature of natural history museums and STCs as well. The commercialization of informal science education inspired by the emergence of summer blockbusters such as the *Star Wars* (Kurtz & Lucas, 1977; Kershner & Lucas, 1980; Kazanjian & Lucas, 1983), *Indiana Jones* (Marshall & Spielberg, 1981; Kurtz & Spielberg, 1984; Marshall & Spielberg, 1989), and *Jurassic Park* (Spielberg, Molen & Kennedy, 1993; Molen, Wilson & Spielberg, 1997; Kennedy, Franco & Spielberg, 2001) trilogies led to the parallel development of blockbuster science exhibits and the emergence of edutainment in natural history museums and STCs that continues to the present (Radar & Cain, 2014). The educational opportunities and challenges associated with blockbuster exhibits in science education are explored in the next chapter.

The end of the twentieth century re-ignited the partnerships between formal and informal science education initially proposed by Progressives during the New Museum Movement a hundred years prior as evidenced by curricular frameworks in Canada (1997) and the United States (1996) that connected formal and informal science education. Rapid advances in digital and mobile learning platforms during this same period helped drive the Museum 2.0 (Simon, 2010) movement in both countries. However, that is where the similarities between Canada and the United States end and science education in both countries begin to diverge. In the United States, the No Child Left Behind era and the increased politicization of scientific knowledge and

education marked the apparent apex of the standards and high-stake testing movements. The election of President Trump and the Republican Congress's plans to deconstruct/defund many educational programs and agencies including the Department of Education (Marcos, 2017) and the Common Core Curriculum (Camera, 2017) suggest a significant reversal and/or disruption of the national standards movement in the United States. At the time of this writing, it is too early to predict the future of science education as a federal policy in the United States.

The debate and recent history of science education in Canada since the publication of the *Common Framework of Science Learning Outcomes, K-12: Pan-Canadian Protocol for Collaboration on School Curriculum for use by Curriculum Developers* (Council of Ministers of Education, Canada, 1997) are much less polarized compared to the United States. Since publication, many provinces and territories in Canada either updated or re-wrote their science curriculum. Among the most notable curricular revision efforts in science education in Canada occurred in British Columbia where this research takes place. The new BC curriculum was developed over a four-year period and gradually released starting at the primary grades in 2015 and at the secondary grades in 2016. The publication of the province's new science curriculum marked an important shift in science education as described in the BC Ministry of Education's curricular design documents:

The science group explored several potential changes to the science curriculum. The group identified the importance of science education in developing scientific literacy and the need to emphasize creativity and collaboration in science education. With a focus on K-10 Science, they explored possible ways to structure science curricula to encourage more creative and critical thinking. The group discussed the importance of integrating key concepts into future curriculum. Giving attention to key concepts would guide the

development of big ideas and higher level learning standards, leading to more inquiry-based approaches. The science group also grappled with ways to balance the content and processes of science. (2013, p. 6)

Other curricular development programs in science education across the different provinces and territories will likely influence the development and support of science frameworks in Canada as well. According to a study of leading science educators across Canada, Murray (2014, 2015) noted that many participating science education professors and curriculum designers in different post-secondary and other science education institutes and organizations in Canada felt that it was time to update the *Common Framework of Science Learning Outcomes, K-12: Pan-Canadian Protocol for Collaboration on School Curriculum for use by Curriculum Developers*. This includes the Museum 2.0 movement by which natural history museums and STCs would partner with Canada's different Ministries of Education to include the use digital and mobile content to extend learning, point out additional resources, and facilitate social interactions between students as examined in this research.

The increasing presence and use of digitally-mediated social forums and discussions moderated for the public by museums and STCs elucidates important questions related to the design and use of socially-mediated forums by students as well. The complex technological intersections and social interactions among young people utilizing the numerous mobile devices they possess and utilize while engaged in learning suggests complex sociocultural, pedagogic, and technological factors are essential to understand when exploring the design and use of M-learning in STCs and natural history museums. In addition to utilizing student-created interpretive apps to augment learning within science galleries, the ability of other visiting students as app users to use, evaluate and share their thoughts on peer-created content and

activities through social media and class forums is another important area of research within science education and curriculum design. This educational research is also in line with the BC Ministry's *Digital Learning Framework* emphasizing the development of students capable of utilizing digital technology (including mobile devices/software) for research, critical thinking, problem solving, digital communication/collaboration and digital citizenship connected to 21st century and personalized learning (2013). Within the specific educational framework for Grades 3-5, students are required to:

- Produce a media-rich digital story about a significant local event based on first-person interviews.
- Use digital-imaging technology to modify or create works of art for use in a digital presentation.
- Recognize bias in digital resources while researching an environmental issue with guidance from the teacher.
- Select and apply digital tools to collect, organize, and analyze data to evaluate theories or test hypotheses.
- Identify and investigate a global issue and generate possible solutions using digital tools and resources.
- Conduct science experiments using digital instruments and measurement devices.
- Conceptualize, guide, and manage individual or group learning projects using digital planning tools with teacher support.
- Practice injury prevention by applying a variety of ergonomic strategies when using technology.

- Debate the effect of existing and emerging technologies on individuals, society, and the global community.
- Apply previous knowledge of digital technology operations to analyze and solve current hardware and software problems. (BC Ministry of Education, 2013, sec. 8)

In addition to touching on many of the above curricular requirements such as constructing media rich software, using digital tools to investigate science environments, and guiding group learning projects, this study also examined whether the process of co-authoring digital and mobile content with and for young people allowed science educators to monitor and assess students' interests and scientific knowledge related to natural history and science exhibits at the RBCM. The potential design and use of participant-based mobile science apps is discussed as an emerging area of future research in Chapter 6.

Although this research acknowledges the importance of knowing how to construct and frame digital inquiry within online social contexts for students by educators around a wide variety of topics related to science in order to foster digital citizenship (International Society of Technology in Education, 2016; Smith & Mader, 2014), this area was not included within this research even though it was technically possible with the experimental software utilized for this study. Instead, as presented in Chapters 3 through 6, this dissertation focuses on the design process itself as a way to explore the technological and curricular feasibility of informant-based design to authentically involve young people within the process of creating exhibit inspired mobile content and activities that their peers might be able to engage with, share, and discuss in other social and educational settings. Other settings include formal classrooms, online forums, and other social-media sites administered by schools, museums, and STCs. As a pilot project, this research stopped at the point of peer editing and review of each team's digital prototype for

scientific accuracy. The process of peer-review and issues around student generated content having scientific errors/misconceptions by young designers is discussed and proposed as a future area of research in the final chapter. Challenges related to scientific accuracy and addressing student misconceptions are particularly important topics for museums interested in converting student and participant designed prototypes into fully developed educational apps for public use. The next three sections of this chapter present the research focus of this triangulated case study, the essential questions related to the design and use of mobile apps as important mediating tools, and a discussion describing important implications connected to this research at the RBCM.

Research Questions

This research explored fundamental questions related to the inclusion of elementary students' ideas and activities within mobile interpretive apps around research context and frameworks described above. Each of the following questions connected to the socio-cultural, curricular and technological contexts is sharply influenced by the unique cultural spaces, learning experiences, interpretive design contributions, and mobile sharing participants engaged in during this study.

Research Question 1: *What effects do mobile technologies and app designs have on the educational roles of students and educators working together to create informal science education content and activities at natural history museums and STCs like the RBCM?*

For the purpose of this dissertation, the researcher was interested in exploring how a participant's status as an elementary student affected their ability to participate in mobile design initiatives. While many educators, including the participants in this study, acknowledge the ideas and interests of the students they are working with, this research sought to identify to what degree young people's ideas and mobile design would influence and/or transform both formal

and informal educators' views on the participation of students within natural history museums and STCs mobile design initiatives. Finally, for this first question, this research examined whether mobile design initiatives influenced how museums and STCs think about the inclusion of young people within future interpretive design projects and the broader public and socially mediated discourses connected to the collections and overall educational mission of informal science institutions.

Research Question 2: *How might the interpretive pedagogies and the participation of young people and educators in mobile design initiatives contribute toward a co-authored interpretive design process that fosters more socially-engaged and self-directed learning within natural history museums and STCs?*

In addition to the inclusion of ideas and activities of elementary students within the interpretive design process, this research explored whether participant-based learning and learner-centered design were effective curricular development pedagogies when designing mobile experiences with and for young people. This research question also examined how museums and STCs might evaluate and/or assess the effectiveness of the mobile interpretive software and activities elementary students created for this study. Findings from this research will help illuminate how participatory-based curricular design as an inclusive process informs the co-creation of learning activities, digital meaning making, and assessment on the educational value of augmented M-learning apps inspired by exhibit interactivity and curiosity of elementary students designing mobile learning activities for peers to use within the natural history galleries at the RBCM.

Research Question 3: *What opportunities and challenges exist in the development and use of mobile interpretive apps for facilitating social and self-regulated learning among young people in the natural history galleries at the RBCM?*

The third research question examined important ways in which the underlying and emerging technologies connected with mobile design initiatives and interpretive apps function as both significant and dynamic mediating tools that can be utilized by educators and learners in natural history museums and STCs. If the design and use of mobile apps as an important mediating tool is validated by the results of this study, it will be critical for science educators (both formal and informal) to have a greater understanding of the role mobile apps function within learning and how these rapidly evolving technologies might be integrated within the existing interpretive infrastructure operating in the science galleries and exhibits. The results of this study and analysis, including additional opportunities and challenges associated with M-learning and the design in informal science settings, are reported and discussed in Chapters 5 and 6.

Research Focus: Mobile Learning and Interpretive Apps as Educational Mediating Tools

From the earliest clay tablets to the use of slates and lined notebooks, educational tools represent an important cultural interplay between students and educators both in historic and modern contexts. As explored below and in more detail in the next chapter, the infusion of computers, laptops, tablets, and smartphones into formal and informal science education over the past few decades have significantly added to that complexity. While researchers have many different definitions for informal science education as learning that occurs outside the classroom at a wide range of settings such as parks, nature centres, zoos, aquaria, science museums, and STCs (Crane, Nicholson, Chen & Bitgood, 1994; Dierkling, Falk, Rennie, Anderson &

Ellenbogen, 2003; Hoffstein & Rosenfeld, 1996 & Reinne, 2007), this research focuses on informal science education as described by Pedretti (2002) that relates to educational processes and learning within the, “science museum world’ (p. 1).

Davidson writes that there is a “rich flora of sociocultural or cultural-historical frameworks” (2012, p. 3) that might form the foundation upon which to explore and analyze the interactions of young people in STC and museums. Most of the early work within sociocultural learning revolves around Vygotsky’s (1978, 2004) theories on cognitive social development and learning communities. His examination of development and learning within the context of cultural means (artefacts and tools) forms a fundamental basis for research linked to how and why young users of mobile technologies engage with the interpretive and informal environments existing in natural history museums and STCs. This research examined how the design and use of mobile science apps by students and educators working together can act as mediating tools within social constructivist, participatory and technological-based frameworks existing within informal science education. The use of mobile technologies, including mobile science apps as potential mediating tools in science education, is occurring as a result of the rapid advancement of smart mobile technologies within the past decade. More specifically, mobile devices include ever increasingly sophisticated M-technologies capable of simultaneously running complex educational software that includes social media and peer sharing thus illuminating the potential of mobile devices and software as mediating tools. The analysis and use of participant-based mobile science apps utilized in this study, including a discussion on their use as mediating tools within informal science education, is presented in Chapters 5 and 6.

Key research areas and topics illuminated within the mobile research design project presented include an analysis and exploration of new forms of digital meaning making,

participation, and inclusive digital citizenship by young people participating within public discourses associated with natural history museums and STCs. As cultural institutions, the educational roles students occupy within informal science settings may significantly differ when compared to students' roles and forms of learning occurring in formal classroom settings and activities. Wellington partially addressed this in 1990 when discussing the features differentiating formal and informal learning as exemplified in [Table 1.1](#).

Since then, many scholars have commented on Wellington's description of the differences between formal and informal learning as overly simplistic (Hofstein & Rosenfeld, 1996), incomplete (Nicolson & Chen, 1994) and ignoring increasing levels of cooperation between formal and informal science educators and museums developing at the time in both Canada and the United States (see Chapter 2 for a more detailed discussion). However, as a historical reference, the educational features Wellington listed in Table 1.1 are not only useful in illuminating how students and educators operated within formal and informal science settings at the time it was written, but also creates opportunities to examine how formal and informal cultural institutions change and evolve within contemporary contexts. More specifically, Wellington's features of formal and informal education predate widespread infusion of mobile technologies and apps within educational systems providing an important reference point for discussing how these educational technologies might influence the nature of formal and informal science education as it exists at present. The question related to how mobile technologies and information influence educational processes and partnerships existing within formal and informal science systems represent a central focus for this research project at the RBCM.

Understanding how mobile technologies and apps influence science education within informal settings is particularly important within the context of Driver and Oldham's (1986)

view of science education as a social constructivist process of scientific enculturation whereby learning revolves around a complex process of social interaction and interpretation of scientific

Table 1.1

Wellington's Features of Formal and Informal Learning

Informal Learning - Fieldtrips	Formal Learning - School
Voluntary	Compulsory
Haphazard, unstructured, unsequenced	Structured
Non-assessed, non-certified	Assessed, certificated
Open-ended	More closed
Learner-led	Teacher-led
Learner-centred	Teacher-centred
Outside of formal settings	Classroom & institution based
Unplanned	Planned (curriculum-based)
Many unintended outcomes (difficult to measure)	Fewer unintended outcomes
Social aspect central, e.g. social interactions between visitors	Social aspects less central
Low 'currency'	High 'currency'
Undirected not legislated for	Legislated and directed (controlled)

Source: Wellington (1990, p. 248)

models and observed phenomenon. This is particularly relevant in science museum settings where the interpretation of artefacts and exhibits is often socially mediated. Livingstone, Pedretti, and Soren (2001) discuss the important role science museums and exhibits play in allowing the process of visitor "meaning making" (p. 357). The use of participatory and

digitally-based meaning making by students as both digital designers and users provides additional insight for participatory museums when invited as a full partner in the co-creation of educational content and exhibits. Despite curricular opportunities with the rapidly advancing capabilities of mobile technologies, the complex technical language (Wellington & Osborne, 2001) and contested history of science (see Mohr, 2008) often complicates the production of educational content and initiatives for young people in informal science settings. Within informal science and museum education; scientific participation and social constructivism occurs through the process of social interaction and the interpretation of the exhibits, artefacts, and museum models presented in natural history and other science galleries by visitors. Hein's (1995) further divides sociocultural models of informal education into inquiry-based models of self and social discovery that are based upon constructivist theories. Other diverse sociocultural research frameworks include: Dewey's (1938) pragmatic perspective; Schwab's (1978) use of science demonstrations, linguistic and semiotic models (Halliday, 1975; Lemke 1990 & 2001), multimodal learning (Linell, 2001, Kress & van Lee, 2001), institutional perspectives developed by Wenger (1998), and activity theory (Engeström, 1987; Plakitsi, 2013), which are discussed within the literature review presented in Chapter 2.

While there is a significant body of academic publications within each of these sociocultural frameworks, much less research exists on how emerging mobile and socially-mediated technologies affect the abilities of children to explore new educational identities and roles within the educational culture of informal science education. The research presented in this dissertation examined how the design and use of experimental museum apps might function as important mediating tools for students to explore different educational roles as educational designers and curriculum developers. More specifically this researcher was interested in learning

how elementary students' roles and perspectives changed through their involvement within informal science education and the development of mobile interpretive apps designed for peers to use in the natural history galleries at the RBCM. Through the analysis of participant experiences and responses in mobile design and learning, this research also sought a deeper understanding related to the process of co-creation and shared educational authority by students and educators working together as co-designers of mobile content and activities. In examining how iPads and the use of experimental prototyping software operate as transformative educational mediating tools, it was also important to examine how digital tools including mobile science apps influence the complex pedagogical and curricular processes students and educators engage in when creating learning activities for other students and young visitors in informal science settings. In addition to the rapid evolution of mobile technologies, provincial requirements such as the *Digital Literacy Framework* for personalized learning/digital citizenship (BC Ministry of Education, 2013), and the rapid use and adoption of these technologies by elementary students in Canada and the United States, the inclusion of elementary students' mobile activities and ideas represents an important source of social inclusion within informal science discourses existing at natural history museums and STCs. All of these elements are examined more fully in the research analysis and discussions presented in Chapters 5 and 6.

In addition to the sociocultural discussion around the potentially transformative influence mobile apps may have on the traditional roles of educators and students, participant-based curriculum theory of design existed as a crucial secondary framework for this dissertation. More specifically, this research explores the complex relationships existing between students and educators as co-designers of mobile interpretive apps for other students to use in the museum's gallery. Participant-based curricular theory and design frameworks are examined in more detail

in Chapter 2 for use in this project including: participatory design (Barab & Dede, 2007; Lemke, 1990), problem/object-based learning (Gallagher, Sher, Stepien & Workman, 1995; Savery & Duffy, 1995), learner-centered design (Sandholtz et al., 1997), and activity-based approaches (Stamoulis & Plakitsi, 2013). Because this research was primarily interested in how students and formal/informal educators designed mobile interpretive content together, a participant-based curricular framework was ultimately selected. Of particular interest in this study were inquiries into the ideas, values and perceptions students and educators reported when creating new activities and content together within informal science settings. The research in this secondary framework also sought to examine the value of socially constructed curricular design as it related to the use of mobile interpretive apps by young people within informal science settings such as the natural history galleries at the RBCM.

The design and use of informational technologies (IT) within sociocultural and curricular contexts represents a tertiary framework for this research as well. Within the complex fields of IT, this project focuses on User Design Theory (UDT). Just as in the case of the sociocultural and curricular discussions above, there are many possible routes to go in the case of UDT explored in the next chapter including: User-Centered Design (Head, 1999; Scaife & Rogers, 1999), contextual design (Beyer & Holzblatt, 1999), participatory design (Carmel, Whitaker & George, 1993), cooperative inquiry (Druin, 1999), informant design (Scaife, Rogers, Aldrich & Davies, 1997), and learner-centered design (Soloway, Guzdial & Hay, 1994). Druin (1999) notes that childhood as a culturally unique and dynamic state, favours a cooperative and experientially based approach to software design. This research combined cooperative inquiry (CI) with informant design (ID). In the case of software development with young people operating as both designers and users, Scaife notes that children and teachers act as native informants that

consciously and unconsciously inform the process of design by software through, "...aspects of learning/teaching that we are not aware and need to be told of..." (1997, p. 344). ID uses a combination of active and technologically infused methods for capturing the users' ideas and experiences within the design process including low-tech strategies such as flow charts and paper-based modeling combined with more high-tech stages of building digital prototypes. This blended process can be advantageous within STC and museum settings as it allowed students and educators to experiment with prototyping software designers used to focus on mobile content and activities based upon student interest and interactivity within the museum's diverse natural history galleries and exhibits. Given the limited time and resources available for this project, the process of ID also allowed the participants to complete their designs within a relatively short period.

Each of these areas: educational roles as student or educator, participant-based curriculum design, and the use of mobile technology for interactive learning were explored via the process of triangulated analysis (described in Chapters 3 through 5) during a four-week mobile design initiative at the RBCM conducted in the spring of 2016. The mobile interpretive app design project involved elementary students, teachers, museum educators and learning team volunteers participating with the permission of a large urban school district and the RBCM. Having presented the primary research context above, it is time to address the central research questions that emerged around each framework analyzed in this study.

Limitations of the Study

While there is a significant body of research published on the design and use of educational software for young people, a topic explored in Chapter 2, as discussed so far in this chapter, research on the educational value of utilizing iPads within natural history museums and STCs is

still emerging. The limited published work represented an opportunity to both experiment with and develop participatory models for the inclusion of elementary students' ideas and activities within mobile and digital interpretive design. Because this was a pilot study using experimental app prototyping software (see Chapter 3), no completed apps could be published and evaluated by users outside of the participants of this study. However, this limitation also spawned the idea and development of future interpretive stations and kiosk prototyping libraries that encourage users and visitors to select M-learning activity content and titles based upon their history, experience and interest in combining hands on exploration with M-learning as discussed in Chapter 6.

In addition to the experimental software, the design format of the mobile design program at the RBCM was experimental in nature and represents another significant limitation of this study as the format and number of iPads available for research restricted the number of participants who could participate in this study. Also, as described in Chapter 3, all the participants were selected from one school and museum thus limiting the generalizability of the results of this study to other schools, museums, and STCs. Since all the participants voluntarily chose to participate in the mobile design project, this is a representative rather than randomly selected study. However, the results of this pilot process (mobile design initiative) and software do provide important insights into how elementary students and formal/informal educators might work together in creating and testing interpretive science apps for natural history museums and STCs in other parts of Canada and the United States.

Organization of the Dissertation

This dissertation is composed of six chapters. Chapter 1 explores how the infusion of digital and multimedia technologies create new possibilities around the inclusion of young

people within the interpretive voice and discourse existing within natural history museums and STCs. After presenting a rationale for more research on the inclusion of young people into the design of place based interpretive apps, the case for undertaking this research is presented within social constructivism, participant-based curricular pedagogies and informant design. Next the central research questions around the three most significant frameworks in this study: socio-cultural, curriculum design, and the use of educational technologies were identified. Chapter 1 concluded with a brief discussion on the limitations for this study within the field of informal science education.

Chapter 2 explores the literature and key elements related to the use of participatory mobile design initiatives in museums and STCs. Essential research fields reviewed here includes a discussion on social constructivism and the impact different socio-cultural elements have within the field of science and museum education. Another area within mobile design revolved around User Design (UD) theories directly connected to participant models of interpretive curriculum design. Chapter 2 concluded with a review of the use of educational and mobile technologies by young people in museums and STCs.

The research methodology is presented in Chapter 3. The chapter starts with an overview of the various research methodologies that might be utilized for a dissertation of this nature including: participatory (Chevalier & Buckles, 2013), action based (Noffke & Somekh, 2009 & 2011), and communities of practice (Lave & Wenger, 1991; Kindon et. al., 2013; Wenger, 1998 & 2007, 2011). For this research, the case study (Chadderton & Torrance, 2011) was selected due to its value in providing critical insights into the complex relationships, educational orientations, socio-cultural and institutional identities of the participants involved in this research project. This case study utilized three analytical tools selected for the process-triangulated

analysis (Tindall, 1994) including thematic networks, recursive analysis and the use of research narratives.

Chapter 4 provides an overview and description of the participants and research data collected through from the experimental mobile design initiative conducted at the RBCM. Participants included elementary students (Grade 4 & 5), elementary teachers from a large urban school district, and museum interpreters/learning team volunteers from the RBCM. In addition to a description of the participants and experimental setting, the process for recruitment, ethical guidelines, process for securing participant permissions, and data is described. The development and use of experimental software for this project is presented as well.

The process of triangulated analysis is presented in Chapter 5 including summaries and analysis of the three analytical tools utilized in this study: thematic networks, recursive analysis, and the use of research narratives. For this research project, participant survey data included survey responses related their educational roles, participation and views on mobile technologies including the software utilized in this research. For this project, all participant surveys were transcribed, coded and analyzed in the construction of thematic networks (Attride-Stirling, 2001) that illuminated educational elements, patterns, and themes associated with the design and use of mobile science apps within informal science settings like the natural history galleries at the RBCM. The process of recursive analysis also served as an important analytical tool for dynamic and reflective modification of the experimental process in order focus in on areas of particular interest and significance within the research process.

In addition to thematic network and recursive analysis, three research narratives were developed (see [Appendix H](#)). The analysis of related data including transcribed interviews, video recordings of mobile interpretive prototypes, learning artefacts (team concept maps and paper

prototypes), photos, informal team video reflections, and research field notes within the process of recursion and constructing research narratives is also described. The first research narrative explored how mobile interpretive design influences the traditional educational roles of students and educators within cultural institutions such as natural history museums and STCs. The second research narrative examined participant views and experiences within an informant-based model of user design. The third and final research narrative analyzed the area of mobile learning and the technology utilized in this case study. Each of these research narratives was examined in detail with the goal of illuminating how the design and use of mobile science apps might influence educational roles, participant-based curriculum design and M-learning in informal science settings.

The final chapter of this research discusses key findings of this research project with a focus on the inclusion of elementary students in mobile interpretive design and the use of these mobile technologies as educational mediating tools. The challenges and opportunities around the complex social and technological infrastructure required for more participatory-based design, evaluation, sharing and use in museums and STCs for young people are also discussed. Future research and development, based on the results of this case study including a model for future research related to the creation of mobile co-authoring stations and interpretive kiosks for elementary students and other young people are also described and presented. This dissertation concludes with an argument for the inclusion of young people into the process of mobile interpretive design and co-authoring as a moral imperative that empowers young people to enact their participation within scientific and interpretive discourses occurring at natural history museums and STCs.

Chapter 2

Literature Review

Chapter Overview: This chapter explores all the relevant research and theoretical literature educational research associated with the history of informal science education and the use of digitally based education programs for young people. Starting with an examination of the various socio-cultural theories related to M-learning in museums and STCs, a brief exploration of the history and nature of science as it is modeled and displayed in exhibits and other museum settings including their impact on informal science education today, is presented. Pedagogical research related to participatory-based design within museum and science education is also presented. Research related to mobile learning and software design forms the final area within the literature review. The chapter concludes with a discussion on key contributions of this research within sociocultural, participant-based pedagogies, and user theory as it relates to mobile interpretive design in natural history museums and STCs.

It offers something new to do for people who have been to the museum lots and it encourages people to spend more time here. (Grade 5 Participant, 2016)

Children can be marked out as a social group, distinguished by the visibility of their low chronological age. Their points of view, opinions and desires have often been ignored because their age has been taken as a sign that they are not worth listening to. (Lee, 2001, p. 1)

However, readers must remember, the iChildren I am describing primarily live in industrialized countries where access to mobile technologies is common place. I call them iChildren because they are interactive, independent, and international. These young people use many forms of technology, where they expect to interact with others through such social computing experiences as Webkinz or Facebook, or through simple email, texting, or mobile phone communication (Druin, 2009, p. xix).

Historical Overview - Childhood, Science & Early Museums

In the previous chapter, we examined how the use of mobile apps might expand the educational opportunities and participation of young people within the interpretive design and discourse at museums and STCs. Indeed, as the research context and questions of this dissertation are explored both in this literature review below and the research project itself in subsequent chapters, it appears that mobile interpretive apps and devices might soon function as essential mediating tools in shifting long standing and well-trodden transmissive models of museum and science education (Bennett, 1997; DeBoer, 1991 & MacDonald, 1998) to more active participatory and inquiry-based ones (Bressler, 2013; Pedretti, 2002; Simon, 2010; Zimmerman, 2011). This chapter provides the academic, historic, and research foundations related to mobile design initiatives and the inclusion of children within the institutional and public discourses around science and the informal institutions supporting them. First we start with theories associated with the nature of childhood as it relates to informal science education and mobile learning.

The rapid adoption and use of mobile technologies by young people described in Chapter 1 may be altering the nature of childhood in culturally significant ways as many digital technologies and virtual environments allow young people to experiment, play and imagining themselves differently than previous generations of children. According to Druin (2009), the nature of childhood itself may be transforming in the digital age. She writes that, “There is no one “correct” answer, just a spectrum of possibilities” (p. xviii). The interests, abilities and agency of children as applied to their choice and use of mobile technology, she notes in an earlier article, varies quite differently from adults (Druin, 2002). Druin’s spectrum of possibilities is an

intriguing idea in the field of informal education and mobile learning where access and technical boundaries between children and adult are increasingly blurred. However, many of the promises made around mobile learning and the Museum 2.0 and 3.0 movements discussed today as it relates to informal science education and children are not without precedents in the history of museums and STCs. Characterized by the widespread infusion of digital and informal technologies as a means of fostering increased public awareness and participation, the Museum 2.0 and 3.0 movements echo earlier efforts to foster public education and awareness about science and nature.

More than a century ago a similar New Museum Movement emerged with the ambitious goal of reacquainting children and the public with the wonders of nature and the new industries emerging at the time (Radar & Cain, 2014). Frederick Jackson Turner's essay *The Significance of the Frontier in American History* in 1894 argued that the loss of wilderness and unmapped regions of the United States (despite being occupied and known by indigenous cultures for thousands of years) signified a significant loss to the vibrant culture and history of the young republic (Turner & Faragher, 1994). The idea of a lost wilderness or frontier was not an issue in Canada at the time due to the much lower population density over a larger geographic area of land. Canada's National Museum and the Smithsonian in Washington DC, like other newly emerging natural history and science museums at the time, were primarily oriented towards the collection of objects of particular economic, scientific, or cultural significance from predominantly colonizing and/or the manifest destiny orientations by Canada and the United States respectively in their early histories. This would change with the increased urbanization, industrialization, and emergence of progressive public education movements from the turn of the century till the Second World War in both nations. The extinction of unique species in the United

States such as the Passenger Pigeon and decimation of the American Bison also symbolized the notion of a vanishing wilderness and sense of urgency among many museum curators during this historical period.

Prior to the Progressive Movement in education at the beginning of the twentieth century, many of the first national museums in Canada and the United States tended to focus on the eclectic interests of each museum's earliest curators (MacDonald, 1998; Radar & Cain, 2014). Educational programs for children, if they existed, were predominantly transmissive in nature as Locke's notion of the child as *tabular rasa* or a blank mental state emphasized pedagogies in which knowledge and scientific concepts were explicitly transmitted from knowledgeable guides through the use of a tour and talk (Bennett, 1997). The use of a tour and talk dominated the interpretive pedagogy of natural history museums well into the twentieth century prior to the influence of the Progressive Movement in education (1997). From 1900 to the Second World War, efforts were made by many museums to organize the natural curios in the cabinets into more scientific and taxonomic collections. Interpretive programs and the professionalization of museum educators began evolving in parallel with other public reform efforts related to education occurring in both Canada and the United States during this period. The influence the Progressive Era had on natural history and early proto-science museums as it relates to increasing interactivity and learning is described in the next section.

Progressivism and the New Museums

The history of early museums is well documented (Asma, 2001; Bennett, 1997; MacDonald, 1998; Pedretti, 2002; Radar & Cain, 2014). Prior to the progressive reform movements symbolized in the New Museum Movement at the start of the twentieth century early museums in Canada and the United States tended to be exclusive venues where children, when

allowed into museums, were told, “Look but don’t touch” (Bunny, 2010; Radar & Cain, 2014). That would begin to change with the influence of the Progressive Movement and the growing awareness that many children in larger urban cities were unfamiliar with nature. Hein (2016) explores the influence of Progressive Movement educators such as Dewey on museum education as it relates to art and culture. Progressive ideals influenced natural history museums as well. Prior to World War I, curators such as Frank Chapman at the American Museum of Natural History and Jesse Figgins at the Museum of Natural History in Denver initiated programs where school groups began touring the galleries in order to learn about the region’s natural history, which was difficult to see for many children and their families living within densely populated urban centers at the time (Radar & Cain, 2014). The rapid urbanization, exploitation and transformation of vast tracks of forests, prairies and other natural environments for intensive agricultural, commercial and industrial production in both Canada and the United States increased the awareness of some museum curators such as John Champion from the Colorado Museum of Natural History (now Denver Museum of Nature and Science), about the problems of overdevelopment and loss of natural habitats (2014).

As a result, many natural history museums began re-organizing and displaying their collections within natural habitats and ecosystems. For many curators, solutions to the challenge of educating the public and children about the disappearing habitats and wildlife revolved around the creation of dioramas where the diversity of plants and animals could be viewed in more naturalistic though highly idealized settings (Poliquin, 2012). Although the dominant model of informal science education still oriented around the transmissive model through the use of a tour and talk, some natural history museums began experimenting with ideas from the Progressive Movement such as discovery, interactivity and experimentation. As the collections became more

organized within the scientific taxonomies of the time, other cultural views and perspectives in a colonizing process were often omitted within the grand or universal narrative of interpretation presented by early museums (Bennett, 2004; Sauvage, 2010). Concerns about society's impact on nature and the loss of wilderness, in combination with the Progressive Education Movement and theorists like John Dewey (1915, 1916 & 1938) and Jane Addams (1902) began shifting museums from purely scientific orientations towards a blend of science and public education, including the creation of natural dioramas, the use of more tactile biofacts, and simple experiments related to the diverse properties and unique characteristics of plants and animals on display at the museum.

These early models and experiments allowed young visitors to manipulate and explore basic scientific properties and western concepts of the artefacts and replicas on display. Biofacts, illustrations, ecological models and activities were constructed such that children could touch realia, discuss nature in different contexts, and conduct simple experiments around the unique characteristics of the museum's plants and animals (Hein, 2016 & Radar & Cain, 2014). This contrasted with the orientations of early mineral and technology museums (the era of Big Science Museums discussed in the next section was still decades away) that generally presented more pragmatic and utilitarian uses of natural resources and technology emphasizing the economic benefits of the displayed artefacts and resources to the communities where the museum was located (Butler, 1992; Morris, 2010). The Second World War, in combination with other world events and developments in the field of educational research and cognition would begin to shift many local orientations to include global perspectives.

World War II, Sputnik and Big Science in Museums

DeBoer's (1991) description of the profound impact the Soviet Union's launch of the artificial satellite *Sputnik* in 1957 had on science education in the United States and Canada signified a major shift in how science would be taught and prioritized for the rest of the century. Prior to World War II and *Sputnik*, the pedagogy and nature of science education tended to be oriented towards the observation and understanding of every day phenomena and practical knowledge of the mechanics and physics of machines, architectural, and basic engineering design (Aikenhead, 2006; Blades, 1997; DeBoer, 1991; Murray, 2014). After *Sputnik*, science was elevated as a national priority with the passage of the *National Defense Education Act* (NDEA) in the United States in 1958 (DeBoer, 1991). In addition to infusing nearly a billion dollars into science education, NDEA laid the foundation for greatly expanded scientific research and what later came to be known as the era of Big Science, which also included the reformation and increased budget for research and education via the National Research Council (founded in 1916). Eggleston (1978) and Murray (2014) describe a similar process in Canada where the National Research Council in Canada (also founded in 1916) evolved to encompass scientific and technological research, including in its mandate of educational outreach across Canada. Although many natural history museums, including the Smithsonian Institution, predated the rapid evolution of science education in the post-*Sputnik* era, these museums significantly benefitted and transformed from the policy and funding shifts that likewise influenced the development of formal science education as it was being taught in schools and universities during this period. As Schwab's (1978) development of demonstration-based science learning and activities began to take hold within formal education, his curricular approach to science inquiry was also being incorporated into the interpretive programs of natural history and science museums as well (Zimmerman, 2011). Prior to Schwab's influence most visitors, including

students, were passive spectators. The inclusion of activity-based science education that increasingly invited visitors to participate in the museum's show and tell activities (2011) shifted the educational model of informal education as a largely passive and observational experience. In addition to the rebirth and revitalization of natural history museums during this time, the emergence of regional science centers and science museums demonstrated the important role these institutions began to play in terms of educating and engaging the general public on the perceived value and importance of science as it related to society (Pedretti, 2002). We see this in the development of major science centres; for example, the California Science Museum expanded its role from an exposition center in 1951 (California Science Museum, 2014), the Pacific Science Center started in 1962 after the 1962 World's Fair in Seattle (PSC, 2010), in Canada, the Ontario Science Museum laid its foundation in 1967 (Ontario Science Museum, 2014), Science World at the Vancouver *Telus World of Science* started in 1977 (Science World Telus World of Science, 2014)—to name a few.

In separate books both Morris (2010) and Radar & Cain (2014) note that the rapid advancement of scientific research and technologies increased the need for newer and larger museums since many scientific artefacts such as early computers and advanced machinery (e.g., rockets, satellites and early spacecraft) required exhibition space beyond the capabilities and function of science education programs in schools and even most universities. The ability to house and display large and complex artefacts in natural history museums and the new STCs that emerged from the late sixties through the eighties set the stage for increased collaboration between formal and informal science education.

The emergence and popularity of hands-on children's science museums influenced the development of similar programs and exhibits in many of the older natural history museums with

varying degrees of success (Bressler, 2013, Zimmerman, 2011). When founding the Exploratorium in San Francisco, Frank Oppenheimer (1968) noted the importance of interactivity within exhibits where visitors, including students, could “gain some understanding [of science and technology] by controlling and watching the behavior [sic] of laboratory apparatus and machinery” (p. 207). Influenced by many of the progressive and constructivist theorists, informal science programs for younger visitors became an important staple (and source of revenue) for many natural history museums and STCs.

These updated and much larger natural history and science museums also adopted the use of mobile and other educational technologies early such as audio tours and other electronic mobile guides (Bressler, 2013). Most of these technologies and interpretive programs were geared towards adult visitors and thus could be difficult for children to access without the assistance of parents or other adults accompanying them. While curators at some of the earliest children’s museums in Boston, Detroit and Hartford were experimenting with inclusion of children’s ideas and participant-based design, children’s ideas and input into the design of exhibits was still largely absent during this period. However, that would change during the era of Big Science and Civil Rights in both Canada and United States; this development is discussed in the next section.

Big Science Exhibits and Educational Partnerships

As educational programs and galleries specifically designed for elementary students and other young visitors began emerging within natural history museums including newer science and technology centers that were opening across the North American landscape during the Cold War and Civil Rights Eras, curators were also influenced by the cross-pollination of educational theory and curriculum development within both formal and informal education (Bell,

Lewenstein, Shouse & Feder, 2009; DeBoer, 1991; Yager, 2007). Schwab's (1978) advocacy led to new curricula and the production of student laboratory kits for teacher use (DeBoer, 1991). Other educational theorists such as Piaget's Stage Theory (1969), the rediscovery and application of Vygotsky's Zone of Proximal Development (1978), Brunner's work on discovery learning (1961 & 1974) in combination with an increasingly professionalized class of museum educators in the new and bigger museums translated to more immersive and hands-on science galleries and programs for schools and young visitors. Many of these same orientations and educational pedagogies would emerge within informal science programs as rapidly expanding networks of public natural history and science museums in Canada and the United States developed; this development is discussed in more detail in the next section. Civil rights and environmental issues also began to influence informal science education. Rachel Carson's book *Silent Spring* (1962) and citizens' movements in health and the environment stimulated a critique on unfettered and big government, corporate, and military-based Big Science as illuminated by increasing calls for citizen-based science programs within models such as STSE described by Aikenhead (2006) and others (Bonney, Shirk, Phillips, Wiggins, Ballard, Miller-Rushing & Parrish, 2014; Pedretti & Nazir, 2011; Toomey & Domroese, 2013).

Like their peers in schools and universities, many museums began addressing issues of elitism and inclusion, including the need to address the long history and role Western Colonialism played in the acquisition and display of their exhibits (Bennett, 2004; Savague, 2010). Increasing cooperation between science museums and school districts reinforced by major science education studies and curriculum development programs in the past four decades both in Canada and the United States influenced the development of informal science education as well. The publication of the national reports *Project Synthesis: An Interpretive Consolidation of*

Research Identifying Needs in Natural Science Education (Harms, 1980) and *A Nation at Risk: The Imperative for Educational Reform* (National Commission on Excellence in Education, 1983) represented a second crisis oriented era of science education in the United States from the late seventies until the national reform and standards movements came to dominate the educational discourse in the United States a decade later (DeBoer 1991; Rutherford & Ahlgren, 1989). Similar conversations about the publication of *Science for Every Student: Educating Canadians for Tomorrow's World* (Science Council of Canada, 1984) in Canada existed as well. While the publication of these documents in both the United States and Canada underscored a desire by both nations to advance scientific knowledge and literacy across its citizenry, other important educational research underscoring partnerships between formal and informal science education continued to foster increased cooperation between museums and school districts (National Resource Council, 2007 & Griffin, 2012).

In addition to the central policy debates occurring during this time, educational researchers developed different models of science education that had an impact on natural history museums and STCs. Educational researchers such as Aikenhead & Ryan (1992), Hurd (1998), Fensham (1985), Hodson (2003), and Yager (1990 & 1996) continued to advocate for student-centered inquiry and a more critically-based pedagogy of practical and citizen-based science reflecting the connections between STS (Science, Technology, Society) and later adding E (Environment). Other more classically oriented and, to some educators, less environmentally and politically controversial approaches such as the STEM (Science, Technology, Engineering, and Mathematics) would find political and policy favour in both nations up to the present (Sanders, 2009; Blades, 2016). In addition to the advancement of both STEM and STS science education models, informal science education organizations such as the National Science Foundation

(1950) in the United States and the Canadian Association of Science Centres (1985) provided natural history museums and STCs the professional networks and partnerships where museum and science educators could collaborate and design curricula and activities for schools during this period. Pedretti (2002 & 2004) notes that the shift of informal science education from object collection and authoritative representation to more critical-based inquiry and engagement fostering additional opportunities for children and the general public to learn about the nature of science (NOS) through the connection of science to personal experience and community contexts.

As noted above, the policy debates around science education coincided with the publication of numerous national documents around science education including the *Common Framework of Science Learning Outcomes K-12: Pan Canadian Protocol for Collaboration on School Curriculum* (Council of Ministers of Education, Canada, 1997) and the *National Science Education Standards* (National Resource Council, 1996; 2012) less than a decade later. The publication of these national frameworks and standards in Canada and the United States also signified the most important divergence in how each country approached formal and informal science education.

Informal Science Education - Canada and the United States Diverge

Science education in Canada and the United States began to diverge after the publication of their respective national frameworks and standards. The No Child Left Behind (NCLB) era in the United States and the publication of the *Next Generation Science Standards* by the NGSS Lead States (2013) signified the apparent apex of the Common Core movement in the United States. In 2015 NCLB was replaced by the Every Student Succeeds Act (ESSA), which shifted assessment and monitoring to the states, further eroding the national science standards movement in the

United States. The recent election of Donald Trump and his administration's stated policy to end Common Core and eliminate the United States Department of Education (Marcos, 2017) likely halts any further discussion around national science standards during his administration. In reverting back to the state level, it is likely that many controversial policies that include alternative (and/or religious) views on the nature of science will be included in some states like Kansas, Oklahoma and Texas (Chanley, 2017; Danilova & Swanson, 2017; Grens, 2017). The emergence of informal religious and alternative science museums such as the Ark Encounter (2016) in Kentucky (400,000 visitors in first four months) and numerous creation museums in different parts of the United States likely clouds the debate around scientific knowledge and literacy in many parts of the United States as well. The presence of large millennium creation museums also impacts traditional natural history museums and STCs in the United States but is not addressed in this dissertation. At the time of this writing for this dissertation, the future of science education as a federal policy in the United States is uncertain.

While the debate and recent history of science education in Canada since the publication of the *Common Framework of Science Learning Outcomes, K-12: Pan-Canadian Protocol for Collaboration on School Curriculum for use by Curriculum Developers* is much less polarized and extreme when compared to the United States, it is not without controversy and/or turbulence. The educational system in Canada is much more decentralized than one in the United States since the Constitution of Canada delegates complete authority over education to its various provinces and territories. Despite this legal framework, similar anxieties exist surrounding the country's international rankings in science literacy and economic output within international contexts (Canadian Education Association, 2013; La Rose, 2013; MacLellan, 2013; Milner-Bolotin, 2008). In his 2014 Delphi study and dissertation, Murray interviewed 134 leading

science educators, researchers, curriculum specialists and other professionals in Canada around the key issue of Canadian identity within science education both in the past and moving forward.

The purpose of Murray's study was to:

...identify the system conditions and principal foundations to develop a Canadian consensus on science education in the Post-Pan Canadian Framework period through forecasting to the year 2030. The study includes the following sub-objectives:

- a) To give definition to and describe in some detail the system conditions that will initiate and influence development of science education in Canada to 2030.
- b) To determine and describe the theoretical foundations and goals for science curriculum in Canada, and;
- c) Provide for a characterization and establishment – a 'logic of consensus' – in Canadian science education from the contributions of an expert panel working anonymously. (2014, p. 21)

Murray notes how the influence of science education and research in the United States often overshadows science education in Canada since World War II and the era of Big Science discussed previously. Aikenhead, in a personal interview with Murray during his research, argued that science education in Canada diverged from the United States with the Science Council of Canada's 1984 publication and study "...except in the accountability movement which doesn't believe anything unless you put a number to it" (2014, p. 3). The rise and fall of the national standards debate in the United States during the No Child Left Behind era and Next Generation Science Standards movement in the United States discussed above suggests another important and ongoing divergence between science education in Canada and the United States. In subsequent articles following the Delphi Study, Murray (2015) is critical of the National

Research Council's Next Generation Science Standards (2013) published in United States as overly bureaucratic and heavily influenced by corporate interests. Murray is also wary of the widely-adopted Science, Technology, Engineering and Mathematics (STEM) programs in many parts of the United States without a more thorough and critical review of its efficacy in science education. Building on Aikenhead's view that "a country must answer its science curriculum questions on its own terms and for itself" (2000, p. 50), Murray (2015) notes the need for a "circumpolar identity" (p. 400) in the curriculum that is distinctly Canadian. He goes on to identify and describe a possible model (and update of earlier STS movements) for Canadian science education: Sustainable Science, Technology, Economy and Environment (SSTEE) as a possible framework for future discussions around science education in Canada.

This may be challenging in the Canadian context as Blades (2016) notes the preponderance of STEM based initiatives within the discourse in science education today. Instead of focusing on overly prescriptive and/or largely mechanistic curricular structures in science education with ever changing acronyms, Blades considers expanding current models of science education beyond their neo-liberal roots with the "philosophical perspective of aesthetics" (p. 26). This is particularly important within informal science settings where the aesthetics and presentation of scientific artefacts forms a key element in inviting visitors to interact and learn within the various galleries of natural history museums and STCs.

While the discussion here would seem to describe national science efforts in the United States as collapsing and a Canadian search for circumpolar identity (Murray, 2015), there are uncomfortable similarities within formal and informal science education in both countries as well. Canada, like the United States, is not immune to the suppression of scientific information or research. While the Conservative Government of Canada (2006-2015) supported STEM

education and the training of more science professionals, then Prime Minister Stephen Harper was often criticized for attempting to prevent scientists from publishing and/or discussing publically funded research related to climate science and the environmental impacts of energy production in the Alberta Tar Sands (Linnett, 2013). The current Liberal Government of Canada and Prime Minister Justin Trudeau reversed the previous Conservative Government of Canada's policy of restricting the publication and sharing of publically-funded science research. Following the election of President Trump in the United States, many Canadian scientists and science educators worked with their American counterparts to ensure that sensitive scientific data is preserved and disseminated. Murray's results from the Delphi Study (2014) in his dissertation around the inclusion of Métis, Inuit, and First Nations' worldviews on science that also acknowledges the importance of sustainability and a recognition of society's impact on global systems suggests an even greater divergence between Canada and the United States in both formal and informal science education moving forward though more research into how scientific research, knowledge, and policy may be evolving in both countries is needed. One historical feature of science education that both Canada and United States share is the emergence of blockbuster exhibits and growing influence of corporate sponsorships have on the development of big science museums and their related educational programming.

Blockbusters, Edutainment and the Museum 2.0 & 3.0 Movements

In addition to the educational discourses, STS, STEM, and participant-based studies that emerged in children's programming in informal settings, other cultural phenomena and technological innovations appeared during the latter part of the twentieth century through the present. The first revolved around edutainment and the emergence of blockbuster exhibits and its corollary phenomenon in informal science education. Blockbuster events like the 1964 World's

Fair in Seattle spawned public interest in science and technology including the foundation of many science and technology centers discussed above. Summer movie blockbusters like *Jaws* (Zanuck & Spielberg, 1975), *Star Wars* (Kurtz & Lucas, 1977), *Indiana Jones* (Marshall & Spielberg, 1980), and *Jurassic Park* (Spielberg, Molen & Kennedy, 1993) helped influence the development of blockbuster exhibits at natural history museums and the new STCs. From 1976 to 1979 the *Treasures of Tutankhamen* traveled around the world with stops in North America including New York, Washington DC, Toronto, Seattle and other major cities in the United States and Canada. The exhibit was unique in that it could be transported, set up in different configurations as required by the participating museums, and included massive publicity campaigns and commercial tie-ins (souvenirs the public could buy). According to Hindley (2015), in its four-month display at the Met in New York, the *Treasures of Tutankhamen* exhibit was seen by 633,500 visitors that also contributed \$110 million dollars to the city's economy (Hindley, 2015). The public and commercial success of *Treasures of Tutankhamen* (1972-1981) served as a model in the subsequent trend of blockbuster science exhibits such as *The Dinosaurs of Jurassic Park* (1993-1997) in partnership with the American Museum of Natural History, Gunter Von Hagen's *Body Worlds* (1995-Present), and *Star Wars: Where Science Meets Imagination* (2005-2014), a joint venture by Boston's Museum of Science and Lucasfilm Ltd. In Canada, *Game Changers* (2016-Present) by the Canadian Science and Technology Museum and Entertainment Arts (EA) explores the history and technology related to video games and is scheduled as a traveling exhibit for the next several years. Each of these blockbuster exhibits relies on public/commercial partnerships and extensive licensing arrangements.

If successful, blockbuster exhibits can translate to a major source of revenue and public interest as well with some of these exhibits being attended by more than thirty million visitors

over the course of their exhibition. While the number of visitors and commercial success of blockbuster exhibits is significant, some education researchers have questioned the educational value of blockbuster exhibits. King (1993) noted the increasingly blurred lines between education and entertainment as museums and amusement parks sought to increase the number of visitors as a “curious amalgam” (p. 49). Some researchers such as Prado (1995) argues that “Disneylandian” (p. 2) nature of museum exhibits emphasizing entertainment rather than education and can negatively impact learning as it relates to culturally sensitive or scientifically complex topics such as climate change or the extinction of different species. Ballofet, Francois & Lagier (2014) discuss the risks and opportunities existing in museum education as the boundaries between museums and amusement parks become increasingly blurred. While children and their families might be the target audience of many of the blockbuster exhibits described above, their input into the design and content of these exhibits remains quite limited to the role of a consumer of the edutainment itself. Most of the traveling exhibits listed here come with their own educational materials, which had the indirect effect of limiting the involvement of the host museum’s educational staff. Interestingly, this was not a major concern for many of the museum curators Ballofet, Francois & Lagier interviewed in their study (2014). Despite this, the authors of this study recommended that museum educators work more closely with the entertainment sector in the future in order to enhance the educational value of entertainment-based exhibits (2014).

In addition to the blockbuster exhibit, one characteristic illuminating the transition from the New Museum Movement that originated more than a century ago to the Museum 2.0 and 3.0 movements of today described by Simon (2010) was the rapid advancement and adoption of digital and mobile technologies into natural history museums and STCs. The Museum 2.0 movement describes the digitalization of galleries and online learning resources that can be

accessed within the exhibits themselves or from a distance (e.g., home or classroom environment). The development of virtual exhibits and digitization of existing exhibits will likely play significant roles in the future of informal science education as well (Clough, 2013; Parry, 2010). Examples of digital and online 2.0 science exhibits such as *Museum Online* (2017) at Boston's Museum of Science and the diverse online exhibits curated by the Museum of the History of Science in Oxford (1995-2017) exemplify educational content created by the museums. In addition to Museum 2.0, Simon (2010) describes and envisions a more participatory Museum 3.0 movement where visitors and the public, using newer mobile technologies and social media platforms, construct and share their own diverse interpretations, discussions, and reactions with the various collections they may be engaged with. Partial examples of participatory Museum 3.0 exhibits include *Beyond the Lab: DIY Science Revolution* at the Science Museum in Kensington in the United Kingdom that focuses on citizen-based science and education (Sparks, 2017). While digital and mobile technologies are creating new avenues for public participation, significant challenges exist including participant access and the accuracy/value of the educational activities participants create (Clinton, Purushotma, Robison & Weigel, 2009). The same researchers note that many ethical issues associated with controversial topics such as gender or racial differences exist in participatory-based models of interpretive design in science exhibits at museums where participants may incorrectly interpret science museum exhibits and artefacts (2009).

The production and sharing of mobile and digital learning content by visitors including young students will likely be a significant area of interest for exhibit curators and informal educators at natural history museums and STCs. As a result of these larger social movements associated with the Museum 2.0 and 3.0 movements, the possibilities of a diverse, public-driven

model of content design and creation within informal science settings, particularly around the interests and ideas of students and young visitors was the subject of this research as described in Chapter 1 and in subsequent Chapters. However, before exploring the specific detail and analysis of participant-based mobile learning presented in this research, it is important to review the field of educational technology tied to the Museum 2.0 and 3.0 movements – Mobile Learning.

Mobile Learning and the Dynabook

In 1972 Alan Kay, a noted computer scientist at the Palo Alto Research Center interested in object-oriented programming and its role in facilitating learning, developed an early mobile learning device he called the Dynabook (Kay & Goldberg, 1977/2001)). Kay, one of the founders of object-based computer programming, was inspired to create the Dynabook for children and education through conversations and research with Seymour Pappert (1993) and his work on the Logo programming language developed at MIT. Kay was also influenced by the ideas of Piaget, Bruner, Vygotsky and constructivist learning. The Dynabook was a device described as:

Imagine having your own self-contained knowledge manipulator in a portable package the size and shape of an ordinary notebook. Suppose it had enough power to outrace your senses of sight and hearing, enough capacity to store for later retrieval thousands of page-equivalents of reference materials, poems, letters, recipes, records, drawings, animations, musical scores, waveforms, dynamic simulations, and anything else you would like to remember and change. (Kay & Goldberg, 1977/2001, p. 167)

The field of Mobile Learning or M-learning (ML) emerged as a distinct specialty within Electronic or e-learning and Technology Education (TE). TE has a short history as an

educational field of research and study (Yore, 2012). Research on M-learning started to appear in bulk with the advent and increasing popularity of laptops, palm devices, and cell phones in the nineties (Crompton, 2013). The emergence of laptops, netbooks, and smartphones expanded the kinds of learning opportunities for M-learning in both science and museum settings (Berge & Muilenburg, 2013; Druin, 2009; Katz, LaBar & Lynch, 2011). Mobile tablets such as, iPad, Kindle, and Google's Nexus currently dominate the field of research, as mobile devices seem to have overtaken laptops and netbooks in popularity at the elementary school level (Crompton, 2013; Murphy, 2011; Murray & Olcese, 2011; Peluso, 2012).

Although quite young as a field of educational research, the body and breadth of research emerging in M-learning is diverse with studies on a wide variety of fields and topics related to both formal and informal education. In the area of museum and science education most of the research is based on M-learning and how its use relates to adults (Kratz & Merritt, 2011; Sung & Lee, 2008). When studies on mobile learning for elementary students in science education, the focus tended to be on the academic effectiveness of certain mobile applications or other educational software (Barak & Ziv, 2013; Chang, Chen & Hsu, 2011). There are other studies examining the effectiveness of having students collecting scientific data and using mobile devices for learning about various scientific topics (Katz, Goldman & Foly, 2011).

Another important area of discourse around M-learning examines how children use mobile devices in their personal lives, school, and other learning environments (Huang & Chang, 2011; Roschelle, 2003). Cultural, educational, and application-based studies tend to focus on how mobile devices and software can facilitate learning and/or the efficient assessment of students in skills and knowledge development (Huang & Chang, 2011; Rochelle, 2003). Several studies examine the benefits and challenges associated with personal use as it relates to learning through

role-play and gaming (Facer, Joiner, Stanton, Reid, Hull & Kirk, 2004; Schwabe & Go, 2005). Other studies point to the use of M-learning as a tool for individualization and support in education including science (O'Malley, 2010). The use of the various media applications to capture different student responses and observations of scientific and museum settings has been studied as well (Katz, Goldman & Foutz, 2011; Roschelle & Pea, 2002; Zimmerman, 2011). However, all of these studies focus on secondary students or adults. While there are examples of students programming and creating their own basic software in the field of computer science (Olivera, 2014), as of this writing there are no studies that explore how children (specifically elementary students) might be involved in the creation of educational software for science and interpretive processes in natural history museums and STCs.

Like the fields of science and museum education, a rising concern over issues of inclusion and equity emerged in the field of M-learning with the notion of a digital divide (discussed on page 4) occupying an important area of research and study (Bennett 1997 & 2004). Other areas of research related to mobile app design explore the pedagogical discussions, emphasis on the area designed, and shifts in mobile learning including research on discovery and problem-based learning (Cahill et al., 2011). Individual and social constructivist learning opportunities (Copeland, 2004 & 2006) and individualized or learner-centered models of M-learning (Hutchinson, Beschorner & Schmidt-Crawford, 2012; McClanahan, Williams, Kennedy & Tate, 2012) are also evident in the literature. It should be noted that other contentious issues of inclusion, access, power, and privacy weave themselves through these various areas of informal science education (Allen, 2003; Coffee, 2008; Reich, Price, Rubin & Steiner, 2010) and M-learning (Attewell & Savill-Smith, 2004; Kukulska, 2012). While the size and scope of this experimental study prevented an in-depth analysis of the complex issues of inclusion and access

as it relates to the design and use of participant-based M-learning software, as discussed in the final chapter of this dissertation, the issue of inclusive mobile design within natural history museums and STCs will likely occupy a significant area of research in the future.

Mobile Learning and Educational Design Theories

Research on the involvement of students and visitors in mobile app design is still emerging. There is already a significant body of work on the various design theories associated with the participation, inclusion or consultation with children in designing software (Nessert & Large, 2004). The most common of these design theories include: user-centered design (Head, 1999; Scaife & Rogers, 1999), contextual design (Beyer & Holzblatt, 1999), participatory design (Carmel, Whitaker & George, 1993), cooperative inquiry (Druin, 1999), informant design (Scaife, Rogers, Aldrich & Davies, 1997), and learner-centered design (Soloway, Guzdial & Hay, (1994). Each of these design theories is explored within the context of the various research methodologies that might be selected for this research. Each of these theories is summarized in [Table 2.1](#) on page 55.

Of the five software design theories listed above, the User-Centered Design (UCD) is the earliest and most common (Nessert & Large, 2004). At its core, User-Centered Design is primarily utilized to test software prototypes and educational technologies that have already been developed for the user. In User-Centered-Design, the primary function is to gather feedback on the effectiveness of the prototype tested or evaluated by users in order to meet the goals of the target audience (Head, 1999). From this stage, adjustments can be made in the process of converting these new technologies into their final form for public consumption. Within the context of interpretive design and young people, the biggest drawback of User-Centered Design

is the limited involvement by children as any educational software was already developed prior to their input and evaluation (Nessert & Large, 2004).

Contextual Design (CD) emerged as way for software developers to more concretely focus on the specific needs of children as the users and significantly differs from User-Centered Design in the sense that information about the users is collected prior to the development of any technology. Beyer and Holtzblatt identified a process of “work modeling” (1999, p. 35) where the technology emerges in stages through the creation of different models from theoretical to early prototypes as listed in [Figure 2.1](#). At each stage the models are further refined and developed until they can be ‘consolidated’ into prototypes ready for formal testing and evaluation.

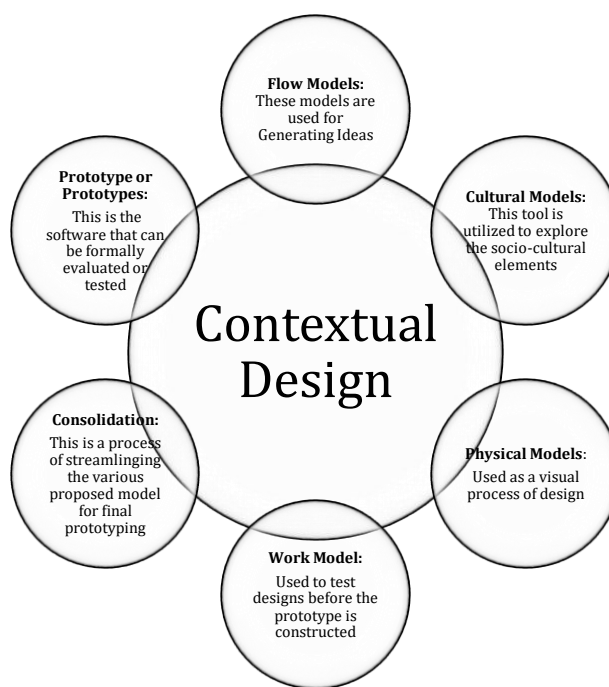


Figure 2.1: Models within Contextual Design.

Beyer and Holtzblatt also note that paper modeling works particularly well in the design phase with young people (1999). According to Carmel, Whitaker and George, Participatory

Design (PD) is a more dynamic process where users and designers form more collaborative roles as co-designers and advocates for both the users and themselves (1993). Participatory Design emerged from research in other fields including education and the social sciences. Two guiding principles govern the process of Participatory Design. The first is an emphasis on mutually based and reciprocal learning where both the designers and users teach each other about both the technical opportunities and desired user experiences. Participatory Design also emphasizes design-by-doing in which the designers and participants work together in all the stages of experimentation, modeling, and design. Similar to Contextual Design described above, Participatory Design utilizes charts, post-it notes, and paper modeling in projects involving young people (1993). As is the case in other design theories, prototyping forms an important element as well within the process of Participatory Design.

Table 2.1

Design Theories for Software Development

<i>Theory</i>	<i>Description</i>	<i>Advantages and Disadvantages</i>
User-Centered Design (UCD)	<i>Software is developed based on an understanding of users, task and environment then evaluated by a user-centred process.</i>	+ Software can be developed relatively quickly. +Software can be adjusted based on feedback. -Software may not be designed around users' interest.
Contextual Design (CD)	<i>A model based on an understanding of the ideal user is created prior to the development of software and then evaluated by real users over a series of prototypes.</i>	+Prior research on user help focuses design. +Prototyping allows different software models to be developed. -More time-consuming development required.
Participant	<i>Process where there is</i>	+Users work directly with designers

Design (PD)	<i>mutual learning, teaching and collaboration in the design and development of software.</i>	+Allows for a more focused prototyping and design process. -More time consuming. -The participating users may not be representative.
Cooperative Inquiry (CI) & Informant Design (ID)	<i>Users act as native informants in the design of software through experimentation and hands on modeling/prototyping.</i>	+Users work directly with designers +Model and prototyping hands on, low tech and more accessible for participants. -More time consuming. -The participating users may not be representative.
Learner-centered Design (LCD)	<i>A process of scaffolding software development that is based on having the users create their own software.</i>	+Allows users to create based on their own interests. -Significant investment of time and technical education related to coding and software construction. -The participating users may not be representative.

Note: Table 2.1 lists and compares the advantages and disadvantages of five major theories of software development.

Cooperative Inquiry (CI) and Informant Design (ID) both push the boundaries of Participatory Design further. Cooperative Inquiry was primarily developed by Allison Druin, Director of the Human-Computer Interaction Lab at the University of Maryland, and attempts to capture the messy world of the workplace (2002). In addition to many of the guiding principles of Participatory Design described above, Cooperative Inquiry incorporates elements of Contextual Design in utilizing observers and recorders to document the process of design and testing. Cooperative Inquiry acknowledges the unique and dynamic perspectives children bring as it relates to the design process (2002). Informant Design was developed by Michael Scaife at the University of Suffix, with his associates in England (Nessert & Large, 2004). Informant Design is closely related to Cooperative Inquiry and parallels many of the characteristics of

Participatory Design. A key difference in Informant Design is the acknowledgment of the key role of users as “native informants” (Scaife et al, 1997, p. 344). In the case of software development with young people as users, Scaife argues that children and teachers act as native informants that consciously and unconsciously inform software designers, “...of aspects of learning/teaching that we are not and need to be told of...” (1997, p. 344).

Informant Design uses a combination of active and technologically-infused methods for capturing the user’s ideas and experiences within design including low and high tech strategies such as flow charts, modeling, and building prototypes capable of peer evaluation. Another important design theory to consider for this research is Learner-Centered Design (LCD), which was advanced by Soloway, Guzdial, and Hay (1994). Learner-Centered Design emphasizes “learning by doing” (p. 37) and advocates that young people are and should be capable of both designing and building their own educational technologies - including software with assistance. To accomplish this, Learner-Centered Design utilizes a scaffolding approach where young users can acquire the knowledge and skills they need to develop the technology with the support of programmers.

They note that, “Good scaffolding is there when the student wants it, and not there when the student wants to work independently” (1994, p. 96). Learner-Centered Design was further modified by Kafai (1999) who noted that young designers and developers often mirrored the same characteristics and concerns about the users’ desires and experiences that their adult counterparts had. However, the same study noted that young designers often had more difficulty addressing the needs of their peers (1999).

This research utilized a qualitative process of informant design (Scaife et al, 1997) whereby participants, acting as informants, created mobile learning content and activities using experimental software developed by the researcher. The use of a qualitative-based study was selected due to the small number of participants and use of experimental software (see Chapter 3 for a full for a description of the research methodology and software utilized in this study). The mobile science activities, participant feedback, and recommendations were integrated into the analysis and recommendations presented in Chapters 5 and 6.

The Need for Research on Children’s Involvement in the Design of Mobile Apps

The history and educational approaches of New Museum, Progressive, and Big Science Museum eras described in the previous sections have left an important legacy in the Museum 2.0 and 3.0 movements. Progressive and social constructivist science educators and interpreters inspired by the ideas of Dewey (1915, 1916 & 1938), Addams (1902), and Copeland (2004 & 2006) emphasize educational software development that embraces authentic educational experiences for civic engagement and participation, lifelong learning, multicultural ways of knowing, and user constructed forms of interpretive design and interaction (Bressler, 2013; Jaganathan, 2013; Zimmerman, 2011). Given that many young visitors may not be aware of the complex cultural histories and conflicts in how scientific knowledge is constructed and shared, a key challenge arises for educators and curriculum designers in mobile learning and design. Key issues in this area of mobile curricular design include features and elements that incorporate other cultural and generational perspectives on the nature of science within diverse American and Canadian contexts discussed previously.

Within both historic and developmental perspectives, the absence of children involved within the interpretive discourse and design of educational spaces and their associated apps, including mobile software in natural history and science museums, is contradictory to many of the educational successes in other areas of informal science education. There is ample evidence that most revitalized natural history museums and STCs discussed earlier have achieved a certain degree of interactivity (Bell et al., 2009; Bennett, 2010; Radar & Cain, 2014; Yager, 2007) by and for young visitors. Furthermore, there is a well-developed history of participatory-based design within informal science education (Bonney, 2009; Griffin and Paroissien, 2011; Simon, 2010; Tanner, Chatman & Allen, 2003). However, despite the increased infusion of digital and mobile content utilized in informal science environments, significant gaps remain around the involvement of young people within the process of interpretive design as discussed on the next page. While the Museum 2.0 and 3.0 movements have shifted the focus of interpretive content by the museum and the adults they are with, many elementary students and young visitors still occupy a dependent role upon the guided experiences and minimally interactive elements currently available within the museum and the adults they are with. As presented in the following paragraphs, the inclusion of students' ideas and participation including mobile digital design initiatives such as the one described in this research can have significant benefits within the science curriculum and learning. The research in this dissertation examined ways educational technology (mobile application development software) would be developed for use by elementary students to co-create educational content and mobile activities within the museum's science exhibits. In this case, teams of students and educators (described in the next chapter) created mobile app prototypes that other elementary students could use within the natural history

gallery for enriched learning around the diverse topics and mobile activities the participating design teams created for peer users visiting the natural history galleries at the RBCM.

This research explored ways natural history museums and STCs can facilitate student involvement and inclusion within in the design of digital mobile content and learning activities for elementary students to use while engage with natural history and science exhibits. For example, as presented in the last two chapters of this study, many elementary students were interested in creating digital activities around the museum's ocean exhibit, which was a new discovery for the participating educators from the Royal BC Museum. The potential design and use of mobile software that enables young designers to co-create mobile content and activities for other young visitors conceivably expands the curricular possibilities for participant-based M-learning software currently available to students visiting science museums as reported in other research (Koerth-Baker, 2011). The curricular possibilities include the development of mobile educational software technologies and curricular design process that meet provincial requirement for digital literacy and citizenship for BC and the inclusion of children's mobile learning activities and ideas within informal science settings like the natural history galleries at the RBCM.

The relatively low cost and increasing ease in mobile app production based upon participant-centered design where young designers explore topics and activities, create paper and digital prototypes, and share completed mobile activities and ideas with peers in the exhibits the apps were created for is another potential curricular area explored in this study. This research also investigated how the participating museum might benefit in understanding how mobile development software could be utilized to guide, monitor, facilitate learning with students' expressed interests for augmented mobile learning within science exhibits and its potential

refinement and further use by other members of the public. The review of the literature conducted for this study within sociocultural, active and M-learning contexts suggests critical gaps in understanding how and why interpretive and educational apps might function as important educational tools capable of digitally and socially mediating learning between educators and students in informal science settings.

Other research suggests that the inclusion of young people's ideas within both the educational design of educational technologies and scientific discourse empowers students both as learners and enactors of scientific knowledge and content (Aikenhead, Orpwood & Fensham, 2011; American Association for the Advancement of Science, 1993; Druin, 2009). Studies on the connection of multi-interpretive processes (Copeland, 2006) and action-based projects (Aikenhead, 2006) examining science education and its relationship to digital citizenship within the body of research is still emerging due to the limited number of studies and newness of mobile technologies (Crompton et al., 2016). While this research is designed to include the ideas of elementary students within the context of mobile software design, few examples exist as of this writing. This is an important field of educational research, as it appears participatory-based design may combine theories on digital citizenship and citizen-based science within emerging Museum and Science 3.0 movements. Other studies within the field of science and museum education have looked at children's empowerment through educational design and problem-based learning, such as case studies on how plants respond to climate change, issues related to Colony Collapse Disorder (CCD) among bees, and endangered fish monitoring/reintroductions, which serve as examples of citizen-based science involving students (Goodnough, 2011; Haines, 2014). This research examines the role mobile technologies and participant based curriculum

design may have on extending participation to include elements of citizen-based science and digital citizenship.

While Nessart and Large (2004) note the various research models and approaches to the involvement of children in software design, there is a significant gap in studies around children's participation in the development of mobile software for museum learning and interpretation. Most interpretive and design processes for children are still largely embedded in transmissive models of scientific interpretation where children's roles in the process primarily fall within the role of user or visitor rather than co-designer and participant. Museum apps for children, if they exist, tend to reinforce this dominant idea of museum interpretation as a transmissive experience that may form a barrier to learning for younger users in a variety of ways. First, since most museum software was designed for adults, the complexity for language and technical operation is problematic for many children unfamiliar with the language or technical skills required to manipulate the software. Second, as discussed earlier, because most museum apps are designed for adults, the vast majority of museum apps currently available represent Guidebook 2.0 and ignore the educational value of role play, imagination, reflective thinking and other informal learning strategies children use to experiment with and learn while immersed in museum environments.

The third barrier revolves around how science is presented in natural history and science museums. Many mobile museum apps, like the exhibits and artefacts themselves, tend to reinforce the idealized recreations and simulacra displayed within science and natural history galleries. These idealized exhibits and the mobile technologies supporting them can omit the dynamics and complexity of naturally occurring systems, leading to the possibility of developing or reinforcing science misconceptions by young visitors. For example, within the natural history

gallery at the RBCM in this study, many of the forest element were constructed from synthetic materials to represent trees and plants in the diorama that normally would have faded and browned over time had they been real specimens. While it is possible, as illustrated in the opening story about a young Neil deGrasse Tyson, to cross the complex boundaries existing between the constructed scientific phenomena and models presented in museums with the scientific phenomena occurring in nature, constructed exhibits may not be clear for all young visitors. Although the vast majority of existing museum apps are primarily designed for adult audiences as digital guidebooks, natural history museums and STCs are beginning to respond to the needs of younger visitors as exhibited in augmented gallery apps for children such as the RBCM's *Woolly's World* (2017) designed in response to preschoolers' requests to learn more about the natural history of young mammoths not currently displayed in the exhibit.

MicroRangers (2016) at the American Museum of Natural History is an app designed for students to explore the exhibits and protect biodiversity.

Finally, and perhaps most importantly for science museums interested in fostering more public participation, the clear majority of current apps fail to foster an active discourse between the institution and their visitors. The absence of more interactive and participatory elements within interpretive museum apps omits the opportunity visitors might have in constructing their own meaning about science exhibits or artefacts within digital form that can be shared with peers and the museum. The dominance of largely transmissive digital guides may also result in the production of mobile content that misses or omits visitor interests in learning. Barriers also exist for young visitors wanting to participate within a natural history museum's social media sites, as many young people may not have Digital 2.0 accounts (Facebook, Twitter, Instagram, etc.). Participant-based museum apps, as explored in this research, may offer young people interested

in creating learning activities and discussing exhibits through the use of mobile apps with more direct and participatory interaction with educators and scientists at the science museum they are exploring.

While many museum and science educators have called for a more participatory model of learning and interpretation by children in these environments (Bressler, 2013; British Congress of Math Education, 2013; Haines, 2014; National Research Council, 2012), more work is needed in the areas of interpretive design and discourse as it relates to the construction and facilitation of active digital dialogues between children and educators that might be possible through the use of mobile learning platforms that include social media elements for community sharing via Facebook, Twitter, or Instagram threads hosted and/or facilitated by the museums or schools. Chapter 3 examined the various research methodologies and design theories that were useful in exploring the various issues associated with this complex process. However, before examining the research methodologies and design theories utilized in this research, it is important to review literature related to mobile learning.

Mobile Learning as an Educational Field of Research

Mobile learning or M-learning was first identified as an educational field of research within the domain of educational technology in 2005 (Crompton, 2013; Druin, 2009). The history and origin of M-learning as it relates to science and museum education research parallels the technology's growing influence in other areas of informal education. In April 2009, there were 35,000 apps in App Store (STATISTICA, 2017). In January 2017, STATISTICA reported that there were more than 2.2 million apps available (2017). While it is no longer possible to sort out museum and science apps at present, based on an estimate conducted in 2014 when the data were available to research directly from the App Store, roughly twenty two percent of the

education apps were in science and eleven percent related to museums. If the ratios are roughly the same in 2017, that would translate to 484,000 apps in science and 242,000 apps related to museums. Although the numbers of educational apps in each of these categories in Google Play is less overall, the number available in science and museum education is significant as well. An informal sampling of science and museum apps in both App Store and Google Play reveals that most apps would be classified as interactive reference works (e.g., *Audubon Trees*, *The Elements*, and *Science Dictionary+* for example), virtual guides (e.g., *Solarwalk*, *The Skeleton 3*, and *SimplePhysics* as examples), scientific or museum games (e.g., *Comet Quest & Brain Quest* representing members of this category), or other forms of edutainment discussed by Nĕmec & Terna (2007).

Within socio-cultural frameworks, including the activity theory and participatory models of digital app design analyzed in this dissertation, a review of the research literature suggests that the creation of educational apps is complex and dynamic (Beale & Sharples, 2002; Garzotto, 2008; Druin 2009). Complexity arises in creating educational software that is flexible enough to be both accessible and engaging for the range and diversity of children using them (Garzotto, 2008; Druin, 2009). Once created, most educational software design also tends to be dynamic as new updates and iterations of educational applications roll out to address any issues arising from a company or institution's initial release (Beale & Sharples, 2002). For example, many educational apps in science education such as Vito Technology's *Solar Walk – 3D Solar System Model* have undergone several updates to make it more user friendly and include new learning opportunities, such as the *Curiosity* rover addition (Vito, 2013). Within the framework of this research, four key areas describe the most important challenges facing mobile curriculum design for children in natural history and science museums.

Area 1: App complexity and technical language.

As noted earlier, many museum and interpretive apps are primarily designed for adult audiences. As a result, the complex academic language and technical aspects of many museum apps predominantly designed for adult visitors often acts as a barrier for younger students attempting to access and learn from the application. This parallels research on the complexity of other science texts described in traditional printed medias examined by Yore, Bisanz, and Hand (2003). For example, while mobile apps such as the *Smithsonian Mobile* have audio, photos, videos, and other multimedia elements, the app tends to be text heavy and lacks elements of exploration and interactivity that research suggests can benefit young people in their understanding of science and interpretation within these environments (Lemke, 2002; Osborne & Hennessy, 2013). Many exceptional learners with low literacy skills and second language learners new to the process of learning and complex academic vocabulary in English or French would likely struggle with many text-based elements of *Smithsonian Mobile* that are not supported by the software or device (Lemke, 2001; Warschauer, 2003; Reich, 2006). Because of these challenges, many current digital guides might be inappropriate educational choices for younger students if those users cannot fully access the information as presented in the app. However, as the results from this study indicate, early findings around the inclusion of young people within the development of interpretive and active software demonstrates the future potential of including young visitors as co-designers. While not specifically addressed in this research project, the potential for creating design teams of other culturally and linguistically diverse students was evident and discussed in the final chapter of this dissertation around inclusive design.

Area 2: The role of play and imagination in learning.

Within sociocultural and cognitive research, a great amount of literature supports the unstructured time to experience, role play, and conduct hands-on experiments that plays a significant role in how children learn science in both formal and informal contexts like natural history and science museums (Gee, 2003 & 2004; Henniger, 1987; Kelly & Sezen, 2010; Vygotsky 1930/2004; Wenger, 1998). While much more research is needed within the context of science education and M-learning, there are thousands of games and digital worlds where children can explore different environments and challenges virtually. Big Fish Game's *Escape Museum* and GR/DD Inc's *Science Museum Splash* are examples of mobile games in this genre. The results of a 2017 search of both the App Store and Google Play discussed above, the author found no examples of science or interpretive apps extending children's learning within the physical space of natural history museums and STCs through active and playful inquiry.

Many scholars in science education have noted the important role that play based learning (Goldhaber, 1994; Vygotsky, 2004), unstructured experimentation/inquiry (Bybee, 2002; Hodson, 1998) and testing various ideas/hypotheses function to positively impact student learning within informal science settings. Other scholars within the fields of user theory and mobile design/learning for students discuss the importance of role-play and unstructured experimentation in software design as well (Bressler, 2013; Druin, 2009; Gee, 2003 & 2004 & Sharples, 2005). The inclusion of elementary students' ideas and activities including the use of imaginative play within interpretive apps in natural history museum and STCs settings forms an important area of personalization and socially-based inquiry within this research linking informal science education and mobile learning and design.

As discussed in Chapter 6, this research illuminated important insights into understanding how natural history museums and STCs might be utilized by their younger users to facilitate more personalized learning and digitally augmented inquiry of the various topics and activities of interest to them. Like the first area above, educational research related to design theory as it applies to young people, was essential in exploring how children can be involved in the mobile curriculum design process. Design theory, play and experimentation will be explored in more detail in the following chapter on research methodology.

Area 3: Science interpretations, narratives and misconceptions.

As illustrated by American Museum of Natural History's *Creatures of Light: Nature's Bioluminescence* or NASA's *Science: A Journey of Discovery*, most existing natural history and science apps tend to be transmissive in nature. While this approach may work well with adults, existing research with children in both formal and informal settings shows that young people tend to favour a more hands on, experiential, and constructivist view of learning that contrasts with mainly transmissive digital apps such as the ones above (Hein, 1995; Hodson, 1998). The complex language and layout in combination with multimedia representations of scientific phenomena and events in science apps like these may leave younger users with incomplete understanding because of the difficulty of accessing all the relevant information and elements they might need to understand the various scientific interpretations of the museum's displays. Some scholars have noted that the over simplification of science materials including electronic curricula may reinforce students' scientific misconceptions as well (Hirsh-Pasek, Zosh, Golinkoff & Gray, 2015).

While the co-creation of scientific curricula including mobile apps may partially address this problem as educators and students work together, the issue of scientific accuracy of materials created by elementary students and educators is important to address and is discussed in Chapter 6 after the results of this research have been presented. The lack of educational input and reflective spaces within these interpretive mobile apps for students and young visitors to authentically engage in through active inquiry either by themselves or with peers ignores the important role reflective thinking and shared dialogue can play in learning (Schon, 1987; Shepardson & Britsch, 2000; Young, 2003). The results of this study presented in the following chapters suggests that the lack of these interpretive elements represents a lost opportunity for science and museum educators interested in assessing how, why, and what young students and visitors are engaged with and learning in these environments.

Area 4: Issues of inclusion, diversity, and participation.

While many researchers in informal education (e.g. Reiche, 2006; Reiche, Price, Rubin & Steiner, 2010; Warschauer, 2003) note the importance of creating inclusive displays and programs in natural history and science museums, the limited cultural and narrow age scope of most current interpretive software programs available to an increasingly diverse student population suggests an additional barrier to learning. For example, Vito's *Solar Walk: A 3D Model of our Solar System* (2013) tends to orient towards Ptolemy's view on constellations and science despite the diversity that exists in many other cultures (Blades & McIvor, 2017; Hodson, 1993; Luft, 1998; Snively and Corsiglia, 2000). Other apps such as LotFun's *Science vs. Magic* (2015) are capable of reinforcing stereotypes that science is predominantly a white male activity.

Given the role mobile apps have played within informal learning in museum settings (Anderson, 2008; Downes, 2006; Selwyn 2007), this research explores its potential for including young visitors within curricular and learning processes. More specifically, by inviting elementary students as co-designers and informants in the design of mobile learning apps within the natural history galleries at the RBCM, this study also provides important insights into whether museum apps designed by elementary students also function as educational mediating tools. More specifically, this research explored how participant-based mobile app design facilitated educational conversations and learning among students and educators as they interpreted science exhibits and constructed mobile learning activities for young peer users the mobile science apps were designed for.

Summary: Mobile Interpretive Apps as Educational Mediating Tools?

The literature review in this chapter illuminated important historic and sociocultural trends in science and museum education. Prior to *Sputnik*, museum and informal science education was dominated by transmissive models of education where scientific artefacts and learning were presented through institutional narratives primarily in the form of a tour and talk. The emergence of children's museums and science centers, combined with the work of social constructivists and science educators like Schwab would begin the process of replacing transmissive and static displays with more active inquiry through hands-on manipulation of specially prepared museum and science exhibits for young people. While the research illuminated some success in the area of student-centered inquiry and authentic inclusion within the design of informal science education programs and displays, there is a significant gap in how different STCs and museums might achieve that goal within sociocultural and diverse contexts for younger students. This is particularly true in the field of mobile and digital learning. Although research demonstrates that

museums and STCs are often early adopters in the use of mobile devices for use within interpretive programs and settings, their use is almost exclusively designed for adult audiences despite the wide availability and use of mobile devices by elementary and secondary students.

This chapter also noted that while there are many excellent mobile science applications to develop scientific literacy, knowledge and concepts through electronic games, virtual models, and other reference tools, the design and application of mobile apps to facilitate learning within informal science settings such as natural history museums and STCs is underrepresented. This includes studies involving elementary students in the design and use of their ideas for M-learning activities within informal science settings by individual students, peer groups or with their family. The research completed for this dissertation and presented in the following chapters explores the potential of mobile science apps to operate as essential mediating tools within participatory curricular frameworks by which elementary students and educators work together in the mobile app design process. In the next chapter, the research methodology utilized in this study about the inclusion of elementary students' ideas and activities for augmented M-learning within the natural history galleries at the RBCM is described.

Chapter 3

Methodology

Chapter Overview: Starting with an examination of the various quantitative and qualitative research methodologies available for sociocultural and participant-based design, this chapter presents the methodology selected for this pilot project. Given the small sample size of this pilot study on students' participation in mobile educational design, the qualitative use of a participant-based case study was developed using triangulated analysis. Within this methodology three analytic tools form the basis for data analysis: research narratives, thematic networks and recursion. The rest of this chapter examines how the case study was constructed and provides a description of the participants, research activities data collected and technology utilized for this dissertation.

I've used an iPad but not in a museum. I actually have one. (Grade 5 Participant, 2016)

In some instances, mobile technologies can be used effectively on field trips and museum visits to augment children's learning by providing access to information during an activity at poignant moments that would otherwise have been overlooked. (Rogers & Price, 2009, p. 14)

However, it has also been observed that children can get distracted when given a mobile device to use in support of another activity. In particular, children can become more isolated from others around them, listening to or reading what are on the mobile device. (Rogers & Price, 2009, p. 14)

Introduction

The history and diversity of research methodologies available for this and other educational research within the fields of informal science and museum education is extensive (Bell et al., 2009; Bonney et al., 2009). Like many other disciplines existing within the field of educational research, the origin of museum and science research can be traced to studies originally developed within the social sciences, most notably psychology and other educational theorists and researchers (Bell, et al., 2009; Bonney et al., 2009). Prior to the launch of *Sputnik*, the majority of educational research in the twentieth century could be described as following a predominantly scientific, linear and positivist model of quantitative research (Ayer, 1959; Popper, 1983; Schrag, 1992). Critiques of a strictly scientific model of educational research began emerging during this same period and would be exacerbated by issues of perceived/actual cultural bias in several important educational studies published around issues such as gender and race as it relates to educational achievement (Fensham, 1985; Lynch & Alberti, 2009). As a result, educational researchers began dipping into the methodological well of the social sciences and adapted qualitative studies and methodologies developed by Lewin (1948) and cultural anthropologists such as Malinowski (1922), Mead (1931) and other early educational sociologists such as Park and Burgess (1925).

While constructivist and qualitative models increased in popularity during the sixties and seventies, the results of many qualitative studies were often discounted by policymakers and educational administrators as subjective, time consuming, and unscientific (Griffin, 2004; Guba & Lincoln, 1994). The emergence of qualitative research methodologies such as ethnographies and narrative research was not without debate or controversy (Guba & Lincoln, 1994; Johnson & Onwuegbzie, 2004). As a counter argument, Lagemann (2000) describes how issues of research bias and objectivity also exist in quantitative studies within socio-economic and cultural contexts

within the history of educational research. The sharp historical differences by educational researchers and policy makers triggered a great debate within the field of educational research. Also known as the incompatibility thesis, this debate occurred during the sixties and seventies among researchers on both sides of the quantitative/qualitative research spectrum (Dawson, 2013; Howe, 1995; Johnson & Onwuegbzie, 2004). The incompatibility thesis raged on and off for decades among scholars, researchers, and educational policy makers until the eighties when a third model of educational research known as mixed methods emerged (Brewer & Hunter, 1989; Creswell, 2012; Crotty, 1998; Patton, 2002).

Given the small number of participants and focus on the experimental design and use of mobile app prototyping software in a single museum setting, a qualitative research methodology was selected for the mobile design initiative and analysis presented in this dissertation. Within the context of this research project, the size and scale of this study dictated a qualitative approach. There are a wide range of qualitative research methodologies that have proven to be useful in the fields of science and museum education as it relates to an analysis of the sociocultural, curricular, and technological aspects of mobile curriculum design including: participatory (Chevalier & Buckles, 2013), action research (Noffke & Somekh, 2009 & 2011), communities of practice (Lave & Wenger, 1991; Wenger, 1998 & 2007), 2011; Kindon et. al., 2013), and case studies (Chadderton & Torrance, 2011). Given the three research questions presented in Chapter 1 and summarized in [Table 3.1](#), the use of a case study for this pilot research project was selected and justified below.

As a research methodology, the case study has a long and diverse history within formal and informal educational research. In empirical research, case studies are often utilized in medical research around specific patients or groups of patients (Elm et. al., 2007). They are also common

in the field of criminology where models are developed based upon the in-depth analysis of different cases (Chamberlain, 2013). The small number of participants and experimental nature of the software (described later in this chapter) utilized for this research most closely aligns with the use of a case study for the following reasons.

Table 3.1

Research Questions in M-learning Project at the RBCM

<p>Educational Roles</p>	<p>What effects do mobile technologies and app design have on the educational roles of students and educators working together to create informal science education content and activities at natural history museums and STCs like the RBCM?</p>
<p>Participant-based Curriculum Design</p>	<p>How might the interpretive pedagogies and the participation of young people and educators in mobile design initiatives contribute towards a co-authored interpretive design process that fosters more socially-engaged and self-directed learning within natural history museums and STCs?</p>
<p>Mobile Design & Learning</p>	<p>What opportunities and challenges exist in the development and use of mobile interpretive apps for facilitating social and self-regulated learning among young people in STC and museum environments like the RBCM?</p>

Note: Key research questions in M-learning project at the RBCM. Other topics and questions emerged through the process of analyzing participant data that is presented in Chapters 5.

First, because the experimental software designed for this research project has never been tested before within educational settings, the use of a single location for initial research best fits the use of a case study. Second, the specific grade level of students and the elementary teachers and museum educators they worked with as participants in this experimental study about mobile app design at a single location is clearly delineated and best suited for a case study within the fields of M-learning and informal science education. Finally, the rich level and variety of data

collected from this experimental research at the RBCM (see Chapter 4 for a description of the data collected in this study) illuminated the value of incorporating a case study that examined data from multiple perspectives. The selection of a triangulated case study allowed for an exhaustive examination of the collected data as it related to the central research questions around the inclusion of elementary students' ideas and activities in mobile science apps for natural history museums and STCs.

While case studies have been in use for nearly two centuries in the social sciences, the use of case study research was integrated into educational studies early in the twentieth century (Chadderton & Torrance, 2011). Defined as “an ‘approach’ to research which seeks to engage with and report the complexity social and educational activity in order to represent the meanings that individual social actors bring to those settings and manufacture in them” (Chadderton & Torrance, p 53). The case study is primarily a way of sampling the diversity of educational experiences learners may have with one underlying assumption; that the experiences and views of one group can provide important insight into educational practice or populations of students as a whole (Chadderton & Torrance). In educational research, the case study is often utilized to evaluate how various curricula might improve learning or more in-depth analysis into the educational experiences of specific individuals or relatively small groups of students.

In the fields of science and museum education, case studies can illuminate the unique value of different educational interventions, technologies, assessments or changes in policy that can be analyzed and critically evaluated for their effectiveness in other educational settings or practices. Case studies in the value of STS-E curricula, problem-based learning (PBL), and specific school/museum partnerships represent a sample of the possibilities in this qualitative field of research. Case studies are also valuable in the study of inclusion and exceptionality in education

including research examining cultural bias, issues of social injustice, or studies on statistically unique minority populations such as exceptional learners where large-scale statistical sampling is impossible due to the relatively small number of students in each minority population (Oaks, 1990; Lynch, 2011). In science education, case studies have been extensively used to examine differences in the proficiency of students in gender specific and heterogeneous classroom settings and topics (Lynch, 2011).

Phil and Heather Hodkinson (2001) summarized the strengths and weaknesses of case study research. In terms of strengths, they note that:

- Case studies can provide insight and a more in-depth examination of the complex interrelationships within a distinct population, curriculum or educational process.
- Case studies are grounded in reality where the testimonies and experiences of participants can be more authentically examined.
- Case studies allow for diverse sampling of distinct groups or individuals within larger populations. They can be chosen on the basis of providing insight into the population as a whole or contrasting the experiences of a minority group from larger populations.
- Case studies illuminate important characteristics, experiences, and/or insights that can be used for deeper understanding and application within larger populations.
- Case studies can illuminate causal relationships that might be incorporated in the construction of a theoretical model and/or approach within the field of education.

Limitations to the use of case studies in educational research include:

- Because of relatively small sample size and the variety of data utilized, case studies are often limited within a statistical or numerical sense.
- The cost and sheer amount of data utilized in many case studies may make it both expensive and difficult to complete within a limited time frame.
- Because of the unique nature of most case studies, it may be difficult to generalize within the context of the larger populations it attempts to study.
- Because of the specificity of most case studies, the results may be dismissed by proponents of opposing and/or contrasting viewpoints.
- The individual experiences and effect researchers may have while conducting their research on a particular-case study are often omitted, hidden, or under-represented.

The Research Methodology

Within this triangulated case study, the research and data collection methods were selected for their use in analyzing elementary students' ideas and designs for mobile interpretive apps within the natural history galleries at the RBCM. This research was also interested in analyzing whether student participation in the mobile design process would affect the views the participating educators had on curricular design and the use of M-learning in the natural history galleries at the RBCM. In this triangulated case study, the experimental process revolved around the observation, data collection and qualitative analysis (described below and in the next chapter) of the curricular and technical challenges elementary students and educators faced when designing mobile learning software together within the natural history gallery of the RBCM. More specifically within the contexts discussed above, the case study utilized the process of informant design (ID) whereby elementary students' ideas and activities were integrated into the

prototyping app software that allowed different design teams composed of students and educators to create and share different interpretive activities within the museum's natural history galleries. The process of constructing this case study is described in the next section.

Merriam (1998) states that ethnography is “a sociocultural interpretation of the data” (p. 14). Punch (1998) further extends the importance of naturalistic cultural interpretation, noting, “to understand any group, or any culturally significant act, event, or process, it is important to study the behaviour in its natural setting” (p. 161). Because this research examined how the design and use of mobile apps might transform the educational roles of participants when elementary students are invited to participate as co-designers, it was essential to place this research within the educational setting and processes of the museum itself. As such, the natural history galleries at the RBCM effectively functioned as naturalistic settings by which the researcher could observe and collect essential data for interpretation. However, a research project of this scope is complicated by the fact that, by its very nature, informal education tends to be voluntary, dynamic and transitory as students and children may only visit the natural history or science museum once or infrequently. The limited time participants had to design apps, in combination with the short amount of time future peer users might have to access and use student-created content and activities exists as a challenge within participant-based curricular design at natural history museums and STCs. In sampling nomadic and transitory populations of young people and the design teams as they worked throughout the museum's different galleries, this research adopted a purposeful sampling approach (Merriam, 1998). In case studies, purposeful sampling, is “based on the assumption that the investigator wants to discover, understand, and gain insight and therefore must select a sample from which the most can be learned” (p. 61). In this research, a core group of elementary students (Grades 4-5), elementary

teachers and museum educators interested in mobile design and learning were recruited within a process described later in this chapter.

As presented in the following section, this case study explores the various factors related to how educators and interpreters in STC and natural history museums might involve elementary students within the process of creating interpretive apps for young people. These factors include the unique educational roles young people occupy as both learners and visitors within STC and museum environments, the process of participatory interpretive design including young people, and an examination of the possibilities and pitfalls of utilizing mobile devices and science apps within these complex informal learning environments. Understanding the interplay between the three factors: educational roles, interpretive design, and mobile learning forms the central tenets of this research with the results offering new insights into the area of mobile curricular design and the participation of young people in STCs and museums.

Developing the Case Study

Yin notes that: “A case study is an empirical inquiry that investigates a contemporary phenomenon in depth and within its real-life context, especially when the boundaries between the phenomenon and context are clearly evident” (2009, p 18). Within the context of educational research Creswell identifies case studies as a form of specialized ethnographical research though there are important differences in how the topics, objects and procedures are established (2012). While Stake focuses on case studies as centering on research objects (1995), Merriam emphasizes the procedural nature of educational case studies (1998). The long history and significant use of case studies within the fields of museum, science education, and E-learning, provides many examples that might form the foundation upon which to base this research including studies such as Steinbock, Eijadi, McDougall’s (2007) work on the efficacy of a

particular science program or the use of digital software examined by Marty, Douglas, Southerland, Sampson, Alemanne, Clark, Mendenhall, Paz & Yu (2012).

Within this socio-cultural and ethnographic model for developing the case study, the various research and data collection methods related to triangulated analysis and the use of research narratives, thematic networks, and recursion (described in detail in Chapters 4 and 5) were selected. In this case the experimental process revolved around the observation, data collection related to the participant's role, curricular processes, and technological challenges and opportunities elementary students and educators experienced when co-designing mobile learning software in the natural history galleries of the RBCM. Due to the limited availability of students and educators to participate in this study, an informant design (ID) model of software development was utilized where students' ideas and activities were integrated into existing prototyping app software specifically developed for this research. The prototyping software is described later in this chapter.

Creswell (2012) describes three distinct models of educational case studies: intrinsic, instrumental, and collective. Intrinsic case studies focus on unique or distinct educational elements or characteristics of a specific setting or group. Within science education, an intrinsic case study might revolve around the efficacy of a science program for students within a specific museum setting such as Steinbock, Eijadi, and McDougall's (2007) examination of the Net Zero Energy Building at the Museum of Minnesota. Instrumental case studies explore the use of a specific tool or intervention and their influence on single or multiple educational settings as exemplified by Marty et al's (2012) case study on using the science software *Habitat Tracker* in environmental education.

Table 3.2

Steps for M-learning Research Initiative

Step	Key Element or Process	Example in This Research Project
Step 1:	<i>The researcher identifies the problem and prepares a proposal for examining the topic, and solicits approval for research.</i>	What are the possibilities and pitfalls associated with involving young people in mobile interpretive design from sociocultural, pedagogical, and technological design frameworks? The HERB application for research was constructed and approved beginning the process of site selection and participant recruitment (see Appendix B).
Step 2:	<i>The case or cases are selected and the central research activities are conducted.</i>	Participant-based mobile design initiative for student interaction within natural history galleries at a participating museum. See Table 3.3 for a specific description of the research activities and timeline.
Step 3:	<i>The types of data are selected and collected.</i>	Multiple data sources will both be selected and collected including surveys (pre/post), observations, journals, educational artefacts, and interviews.
Step 4:	<i>The type of data analysis is selected (holistic), a detailed description of the case is constructed/ described, and key issues and/or themes are analyzed</i>	This project examined the above data sources within sociocultural, curricular and user theories through the process of <i>triangulated analysis</i> described in Chapter 5. Themes related to educational roles, participant-based design, and mobile technologies/learning emerged as the central frameworks within this instrumental case study.
Step 5:	<i>The researcher's report on the meaning or significance of the case is shared</i>	This research will primarily be shared within the context of a dissertation though it is hoped several related articles and professional presentations would be shared as well.

Note: Each step for this research project is described with examples of how the research is analyzed and shared within academic and professional communities.

Collective case studies are the critical aggregation, analysis and reflection of multiple cases in order to illuminate important insights or issues within larger educational systems. Within informal and science education collective case studies such as Crompton, Burke, Gregory, and Gräbe's (2016) systematic review of the use of mobile learning in science is an example of the use of a collective case study in education. The case study in this dissertation examining the participation of elementary students within the design of mobile interpretive apps for other young people in the RBCM's natural history galleries; since this case study involves an intervention, this research is therefore an instrumental case study within the sociocultural and interpretive and mobile frameworks explored in Chapters 1 and 2.

The development of this triangulated case study follows the steps for a case study described by Creswell (2012) modification of Stake's (1995) earlier work on developing case studies presented in [Table 3.2](#). As stated in the previous chapters, this research draws upon elements of other curricular and user-based design frameworks where the primary researcher, museum/science educators, software designers and young people work together to discuss, design, and develop mobile interpretive software for the participating museum.

In addition to conducting research, the author participated within the roles of: program facilitator, technical support, team advisor, and substitute educator (for one session where the teacher was absent). The following sections explore how the various ethical issues were addressed and provide a description of the research site, participants, experimental activities and a summary of the unique prototyping software developed for the project. The research data and process of triangulated analysis are presented in Chapters 4-6 and the results, interpretation and summary of this research are presented in Chapter 6.

Ethical Issues Associated Within This Research

As with any research methodology in the social and human sciences, important critiques and challenges exist within case studies conducted in informal settings. This is particularly relevant in research involving young people as participants for a variety of reasons. In addition to the challenges around using a case studies methodology discussed in the previous section, issues of *power-over* positions relating to research that includes young people should be addressed. In both formal and informal educational settings like natural history and science museums, educators and researchers typically wield a power-over the relationship with students they may be working or conducting research with. Although originally developed for Participatory Action Research or PAR, Arnstein (1969) and Hart's (1992) Continuum of Power serves as a useful tool in identifying the level of participation and various ethical issues associated with the participation of students in educational research. As [Figure 3.1](#) illustrates participant-based research can be viewed along ladders of participation and its application in describing the level of student participation within the mobile design initiative and case study at the RBCM.

The technical complexity, coding, and limited time available to create the experimental prototyping software (described later in this chapter) for this research project precluded the involvement of elementary students in the creation of the prototyping app itself. For this short-term experimental study, the desired level of participation along the Continuum of Power was adult initiated co-learning with elementary students participating within the interactive design of mobile learning activities in the natural history gallery of the RBCM. However, student recommendations for improving the software were included within the final discussion on improving the design and use of mobile prototyping apps discussion in Chapter 6. Key ethical

topics that were identified and addressed in this research included issues of power, marginalization, and tokenism.

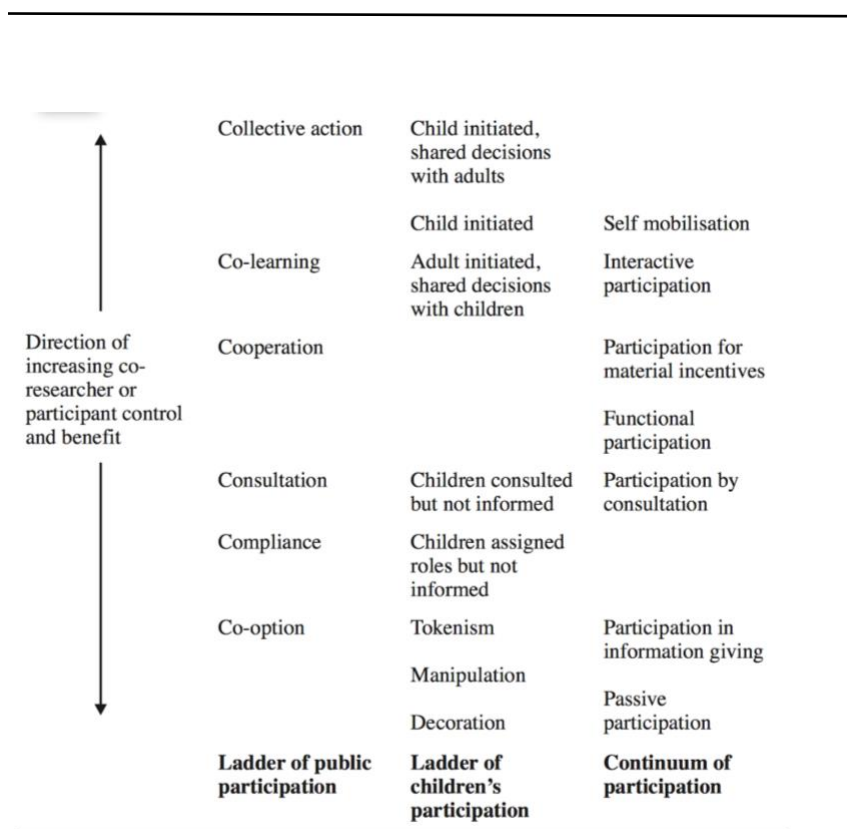


Figure 3.1: Continuum of Power in Children's PAR (Arnstein, 1969; Hart, 1992; Pretty, Guijt, Thompson & Scoones, 1995)

The students and educators recruited for this case study occupied different cultural and institutional roles within schools and museums, creating issues of unequal power between the participating children and adults. Each ethical issue identified above was addressed within the HERB process and is summarized here. Multiple checkpoints for students and educators to withdraw in the research project and activities were integrated into the design of this research project. Because the focus of this study revolved around the ideas, designs and participation of young people, the elementary students were allowed to self-select the peer groups and the educators they wanted to work with. While some elementary students initially felt intimidated

with the idea of partnering with adults in this project as exemplified in comments such as, “At first I thought working with teachers will be scary” (Elementary Participant, 2016). Others responded that they enjoyed designing activities with educators. For example, one Grade 4 participant desired more power in the level of student participation by writing, “Let the kids do all the work unless they need help” (Elementary Participant, 2016). Comments like these could also be interpreted as this participant feeling frustrated at not being able to create the activities he or she wanted thus representing a lack of power. However, when this individual’s comment was aggregated with peer statements around selecting their team’s topic, this sense of empowerment achieved by many participating children in this study is fully analyzed and discussed within the research presented in subsequent chapters.

The second ethical issue revolved around marginalization. Bergold and Thomas (2012) define marginalization in educational research as “groups whose views are seldom sought and voices rarely heard” (sec. 3.3). Again, because the focus of this research was on the ideas, designs and participation of elementary students, issues of participant marginalization were addressed by having each of the design teams (described later in this chapter) focus on the ideas and activities of students with adults playing a supporting role within the Informant Design model. A key inquiry within the research analyzed and presented in the following chapters explored how students’ ideas and voices were enacted and valued within the mobile design process including any extent that students’ ideas were or were not marginalized.

Tokenism was the third ethical consideration in this project. Hart (1992) discusses the pitfalls related to tokenism in educational research where student and young people’s ideas are largely symbolic and undervalued. This research sought to avoid the issue of tokenism with many of the same strategies utilized to address marginalization discussed above and by having the

members of each design team present their ideas and digital app prototypes to the RBCM and the participating school as a community sharing project. This practice follows Hart's ideas on the process of authentic empowerment for young people by sharing their thoughts and ideas with authority figures and other community members (1992).

In addition to addressing the ethical issues above, the challenges of conducting research within the informal setting of the RBCM had to be addressed. Research projects within informal settings like natural history museums and STCs are likely to have increased complexity because of the dynamic and dispersed nature of young visitors and participants engaged within the institution's large and diverse galleries. The huge gaps in experience, vocabulary, and scientific knowledge existing between the participating educators and elementary students involved in educational research projects like these can bias the value of the contributions and insights of elementary students who may be new to the topic and educational activities that different design teams were creating. The research analysis presented in Chapter 5 illuminated how different teams supported students new to the content and mobile learning activities they were creating. In designing the proposal, key issues in the domain of knowledge as it relates to an inclusive and empowering process for all the participants including children were identified and laid out in advance through the Human Ethics Review Board (HERB) process. Each of the ethical issues discussed above were addressed within the ethics proposal and certified by the.

In addition to the ethical issues addressed above, in order to protect the identity of the participants of this mobile design initiative, the names of all participants were anonymized to their team names and roles. Similar anonymizing processes were put into place to address the affective, intellectual and cultural domains as well as it relates to safeguarding the personal identities of the participants in this case study. All of these protective measures were

incorporated into the *Application for Human Participant Research* submitted and certified by the University of Victoria's HERB (see [Appendix A](#)).

Research Site & Participants

The experimental mobile design initiative was conducted at the Royal British Columbia Museum (RBCM) located in Victoria, BC. In 2015, the RBCM revised its overall learning plan to include the development of more digitally based learning resources and programs. The plan itself states:

Goal 2: Strengthen our digital infrastructure and reputation - Our digital presence is the virtual face of the Royal BC Museum, supporting our reputation and by extension, that of British Columbia. It is the public portal to information, virtual exhibitions, social media sites and, increasingly, to our collections, our experts, our educational programs and even to our commercial activities. This being the case, online visitor volume is a strong indicator of our success in becoming a modern, accessible museum. (Royal British Columbia Museum, 2015, p. 9)

Because this dissertation examined M-learning as it related to informal science education, this project centered on education and learning directly connected with the museum's Natural History Gallery for the mobile design project. The RBCM was selected as the primary research site for its accessible location for research, a well-defined and historic partnership with the surrounding school districts, and the recent development of the museum's 2015 learning plan emphasizing the enhancement and use of digital education.

As a part of its learning plan, the RBCM recently hired a digital educator who was very keen to participate in the research project reported in this dissertation (RBCM, personal communication, Jan. 20, 2016). The director of the learning team also supported this project

through staffing and funding as well. She noted that one of the missions of the RBCM is to support scholarly research, which includes the field of digital education. Another museum educator expressed an interest in using this research to explore the possibility of developing digital camps for students (Hammond-Todd, meeting notes, March 31, 2016).

In addition to the institutional and staff support from the RBCM, another key factor included the researcher's previous role as a learning team volunteer within the Natural History Gallery which provided regular access throughout the process of research design, implementation and analysis. As a learning team volunteer, the researcher was already familiar with the natural history exhibits and science education program. It should also be noted that the idea for this research and early informal design of the prototyping software was created by the researcher and another graduate student for the Natural History Gallery prior to its use in this project. The idea of utilizing the prototyping software in partnership with students and educators was based on earlier observations and interactions with young visitors exploring the gallery, which also served as a source of inspiration for this research project.

Participants in This Study

This mobile design project involved participants from the RBCM and the school district. Of the two schools that initially agreed to participate, one had to withdraw due to scheduling conflicts thus further limiting the applicability of this case study. However, while the project initially envisioned the participation of elementary students and educators from multiple schools within the large urban school district, it was ultimately decided to focus on a single participating elementary school because the museum expressed an interest in creating educational programming that modeled museum educators and learning team volunteers working with a single class at a time. This proved to be beneficial as the participating school was very excited

about involving more students and teachers in the project. This also made the logistics and support of the participating students, educators, and learning team volunteers much easier. In addition to the thirteen students and six teachers participating in the mobile design initiative, three museum educators and two learning team volunteers from the RBCM participated as well.

It should also be noted that a scientific advisor from the RBCM was initially proposed but not approved for this project due to budget constraints and other commitments by the science curators and researchers at the RBCM. The lack of a science advisor in this project will come up again in the results and findings shared in Chapters 5 and 6. As the primary researcher and facilitator of this experimental project, I participated as well. Each group of participants and my role as the principal investigator are described in detail below.

Young participants.

For this study on fostering the increased involvement of young people within natural history and science museums through mobile learning initiatives, young people between the ages of 10 and 12 were recruited. With the exception of pre-planning sessions within the research process described below, thirteen Grade 4 & 5 students were recruited from a single elementary school in a large urban school district. Five of these participants were Grade 4 students and seven were in Grade 5. Similarly, five of the participants were girls while eight were boys. While this small sample does not represent the school's total socioeconomic and cultural diversity, the school's assistant principal noted that the students participating in this project come from a diverse range of students including several second language and gifted learners (S. Jun, personal communication, February 16, 2016). Members of this group were recruited based upon their interest in designing interpretive activities for peers and a willingness to work in teams with adult educators and programmers. This group significantly contributed to the design, content, and

initial testing of the mobile app prototype that they and their peers designed; this prototyping software is described in later in this chapter.

Adult participants.

Elementary and museum educators.

In addition to the participation of elementary students, six elementary teachers from the same elementary school volunteered to participate in this research. Because of scheduling issues, two teachers opted to share a single position within the design teams described below. All of the elementary school teachers participating in this project were female. While most of the teachers knew the students involved in this project from previous experience, only two of the teachers worked directly with the elementary students as their classroom teacher. Five out of the six teachers were generalists with experience in either the primary (two of the teachers) or intermediate (four of the teachers) levels. One teacher worked with exceptional and gifted learners. Because students were allowed to select the peers and educators they wanted to work with, the teachers may or may not have worked with the students they taught at the elementary school. The decision to let students self-select including possible effects on the outcome of this study, is further described in Chapter 5. The role of elementary teachers was to assist young participants in designing activities linked to the BC science curriculum.

In addition to the six elementary teachers, three museum educators and two learning team volunteers participated as well. As noted earlier, each of the museum educators was involved with the approval of the RBCM's Learning Department. All the participating museum educators (Learning Program Developers) had significant experience working with school programs as either current staff members or learning team volunteers that regularly worked with elementary school groups visiting the RBCM. Two of the three Learning Program Developers have been

involved in the development of digitally-based interpretive programs as well. One participating museum learning team volunteer was a retired school teacher and also managed educational programs in smaller museums in other communities.

In designing this research project with the RBCM, the researcher and RBCM's Learning Department discussed the possibility of involving informal science and museum educators from other institutions. However, it was decided to focus on the participation of experienced learning team volunteers within the RBCM because of their desire to develop a site-specific model. As a result, two experienced learning team volunteers familiar with the RBCM school programs were recruited by the Learning Program Developers to participate in this project. Like the participating elementary teachers, their role in this project was to support the design, content, and activities elementary students created within the interpretive frameworks and goals of the museum's master plan for digital learning and interpretation.

Scientist or science advisor.

While this research project initially envisioned the participation of either a naturalist or ecologist to act as a science consultant for the mobile design initiative, unfortunately funding and other institutional commitments prevented the participation of a science advisor for the mobile design initiative. This omission of a science expert may have been important within the context of scientific accuracy and mentoring. The omission of a scientific expert within mobile app design related to informal science education is discussed in Chapter 6.

Researcher.

As the primary researcher in this project, I participated in this project as well. In addition to recruiting all the participants listed above, I was responsible for ensuring that the project respected the diverse views and contributions of all the participants by adhering to the research

and ethical guidelines described below and certified by HERB in [Appendix A](#). As the primary investigator for this research project, I was responsible for facilitating, supporting, documenting, evaluating, and disseminating the final results of this study. Issues of research bias were identified and addressed through the process of recursive analysis presented in Chapter 5.

Participant Activities and Timeline

As described in the research timeline on [Table 3.3](#), once permission to conduct the research was granted by the University of Victoria and approved by the school district and the RBCM, recruitment of the adult participants began in January of 2016. As summarized in [Table 3.3](#), all participant activities were completed between January 4th and May 25th in 2016. Adult participants from the RBCM and the elementary school were recruited from January 10th through March 10th. Once the principals and teachers agreed, letters of invitation were sent out to students and their families as required by the University of Victoria's Human Research Ethics Board guidelines. Thirteen elementary students in Grades 4 and 5 agreed to participate in the experimental mobile design initiative at the RBCM with permission granted by their families using recruitment letters in [Appendix B](#).

The mobile design activities ran once weekly after school for four consecutive weeks. While initially designed to run three hours each week, after consulting with the adult participants, principals of the school, and the participating educators from the museum, it was decided to shorten the mobile design project to two hours after the first week. This decision was made because of the reported exhaustion by participating students and educators after having already completed a full day of learning and teaching at the school. Despite the loss of time allocated for research and participant activities in the original HERB application, all the participants were able to complete their digital app prototype and complete every survey and

interview tool utilized in this case study. This research exists within a one-year time frame with the bulk of data being most intensively collected over three months in March, April and May of 2016. The research calendar is described in specific detail on Table 3.3.

Table 3.3

Timeline for the M-learning Project at the RBCM

<i>Summer 2015</i>	The HERB application was completed for submission.
<i>Aug-Oct 2015</i>	The HERB was submitted and revised for approval. Once revised and approved the research project began in earnest with requests of approval from the RBCM and the school district. Sample participant letters for young participants, their families, educators, and other adult participants are attached at the end of this document (Appendix B).
<i>Nov 2015-Jan 2016</i>	Permission by the RBCM and the school district was granted.
<i>Jan – Mar 2016</i>	Elementary and museum educators from the school district and RBCM were recruited according to HERB guidelines. Based on recommendations from the RBCM and elementary principals within the school district, it was decided to focus on recruiting elementary teachers from one school for this project. All the adult participants were recruited during this period.
<i>Mar 31, 2016</i>	Pre-interviews and planning with educators (1 hour)
<i>Thursdays in Apr 2016</i>	<p>Week 1: Project goals & generating ideas (3 hours) - Participants were presented with the mobile design challenge, reflected on their experience with iPads and the RBCM, toured the natural history gallery, and generated their ideas for potential mobile app activities using a variety of organizational tools including: word walls, drawings, discussions (whole group/small teams)& decision making.</p> <p>Week 2: Paper prototyping (2 hours) - Participants designed low-tech prototypes in small groups (3-4 students, 1 elementary teacher & 1 designer) with the museum educators. The researcher rotated among different design teams in the natural history galleries and a large classroom. Prototyping involved the following activities: activity/goal setting, flow charts, mapping and paper based prototyping design.</p>

Week 3: Media and element production (2 hours) - Participants identified and created all the media elements necessary for the construction of their mobile app prototypes. The media elements they constructed were transferred from paper-based models to digital app prototypes during weeks 3 and 4. Activities this week included: scripting, video/audio production, photography, and media design.

Week 4: Refinement, sharing, testing, evaluations/reflections (2 hours) - During the first half of the final week the educational app prototypes were refined, shared and tested among the participating teams. Each design team had the option to share their work with officials from the participating museum, school officials, and parents during the final activity. The mobile design project concluded with group/individual evaluations and reflections.

May 2016

Post-interviews with Museum and Elementary teachers (1 hour) – During the month of May individual and small group meetings with museum and elementary teachers were conducted. During this time, post-interviews were completed, recorded and transcribed for data analysis.

Note: Timeline for the M-learning project at the RBCM with general description of the research activities for each session.

Description of participant activities.

The main participant activity analyzed for this research was the creation of an experimental Mobile Design Camp and after-school activity for students and educators. The elementary students were allowed to select the peers and educators they wanted to work with throughout the Mobile Design Camp because of the informal nature and limited time available to complete this project. Many researchers note the importance of including young people as equal members of cooperative and participatory-based design teams (Churchill, King & Fox, 2016; Druin, 2009; Fails, Druin & Guha 2010). Five design teams consisting of two or three elementary students, one elementary teacher, and one museum educator formed during the first week of design activities (see timeline above). Each design team described below was anonymized for the

purpose of reporting this research. Members of each design team are referred by their team name and role within the team (for example student or museum/elementary designer). One additional benefit of using multiple design teams is that the work, experiences, and data collected from each design team, when later analyzed, formed a micro-case within the larger study. Each design team, as well as the mobile activities they selected and designed, is described in the following sections. The research analysis and discussions of how the members of each design team approached the challenge of designing and creating different interpretive content and mobile activities is presented in Chapter 5.

Design teams.

Design Team #1.

Membership in this design team included three male students. All the students on this team were in Grade 5. The adult members included a museum educator from the museum and a Grade 3 educator from the participating elementary school. The members of this design team decided to create two interpretive activities based on separate adventures where young visitors had to find specific species in two different natural history exhibits. The first interpretive app activity is entitled *The Beach* and encouraged young visitors to explore the intertidal pool and marine life related to the beach exhibit. The second interpretive app activity, *The Sub* is designed around the RBCM *Ocean Station* exhibit, where users had to find and photograph specific marine animals.

Design Team #2.

This team included two male students. One student was in Grade 4 and the other in Grade 5. The adult members included a museum educator and a Grade 1-2 educator from the participating elementary school. This team had a unique challenge where the both formal and informal educators had to be absent during two of the four design weeks. As the primary

researcher and facilitator, I supported this team when an adult member was missing. While my ability to make field observations and advise other teams was more complicated during the first week and is discussed in Chapters 5, the educators were successfully able to work together and communicate with each other in developing a plan to support the student ideas and activities during the second week. The members of Design Team #2 decided to create two interpretive activities. The first interpretive app activity is entitled *Old Bones and New Bones* and encouraged young visitors to learn about different fossils and skeletons in the Natural History Gallery. The second interpretive app activity, *Bones on the Outside and Bones on the Inside*, was designed to teach visitors about the difference between animals with endoskeleton or exoskeletons by comparing different animals in the gallery.

Design Team #3.

Membership in this team included two male students and one female student. All three students were in Grade 4. The adult members included a museum educator and a Grade 4 educator from the participating elementary school. Design Team #3 decided to create two interpretive activities about different types of otters and marine life exhibited in the beach and marine exhibits. The first interpretive app activity, *Otters of Wonder*, focuses on having users learn about the ecology and differences between river otters and sea otters. The second interpretive app activity, *Weird & Wonderful*, examines the diversity of marine invertebrates found in the RBCM's tide pool and *Ocean Station* exhibits.

Design Team #4.

This team included two female students. Both student members of this team were in Grade 5. The adult members included a museum learning team volunteer who also worked as a teacher and a Grade 4 educator from the participating elementary school. The members of Design Team

#4 decided to create two interpretive activities based on terrestrial and aquatic animals displayed in the Natural History Gallery. The first interpretive app activity entitled *The Land* encouraged young visitors to find and learn about different terrestrial animals on display. The second interpretive app activity, *The Water*, provided students with directions and clues to find and learn about aquatic animals in different parts of the Natural History Gallery.

Design Team #5.

This team also included two female students. One student was in Grade 4 and the second in Grade 5. The adult members included a museum learning team volunteer with extensive experience working and running other museums and a Grade 4 educator from the participating elementary school. This design team decided to create two interpretive activities connected to marine life and ecology. The first interpretive app activity is entitled *Ocean Adventure* that encouraged young visitors to learn about different marine life found in the *Ocean Station* exhibit. The second interpretive app activity, *Tide Pool* was designed around the tide pool exhibit where users have to find and photograph different marine animals.

It should also be noted that the fossil exhibit was dismantled and removed from the gallery in the middle of this project making the designing activity much more challenging for the teams creating activities about fossils and prehistoric life. Because the new prehistoric exhibit was still under construction and unavailable to the design team, it was decided by the researcher, museum educators and adult members on the team to have Design Team # 1 and Design Team #2 complete their activities assuming the earlier prehistoric exhibit.

Design and Use of Interpretive Software

In addition to the site, activities and participants described above, this research utilized experimental software as well. For this project, a mobile interpretive prototyping

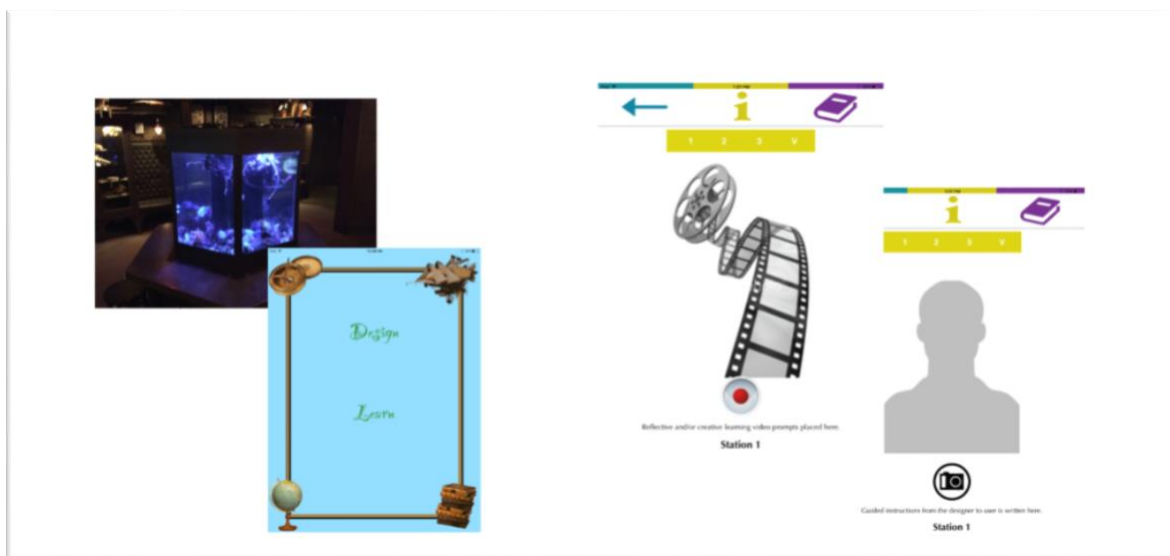
software application, *Design & Learn*, was developed in collaboration by the primary researcher and another graduate student at the University of Victoria, Noel Feliciano, in 2016. The IOS based museum design tool and learning prototype, *Design & Learn*, was specifically developed using XCode (Version 7.3.1). The central features of museum prototyping app included the following elements.

Geographic Interface

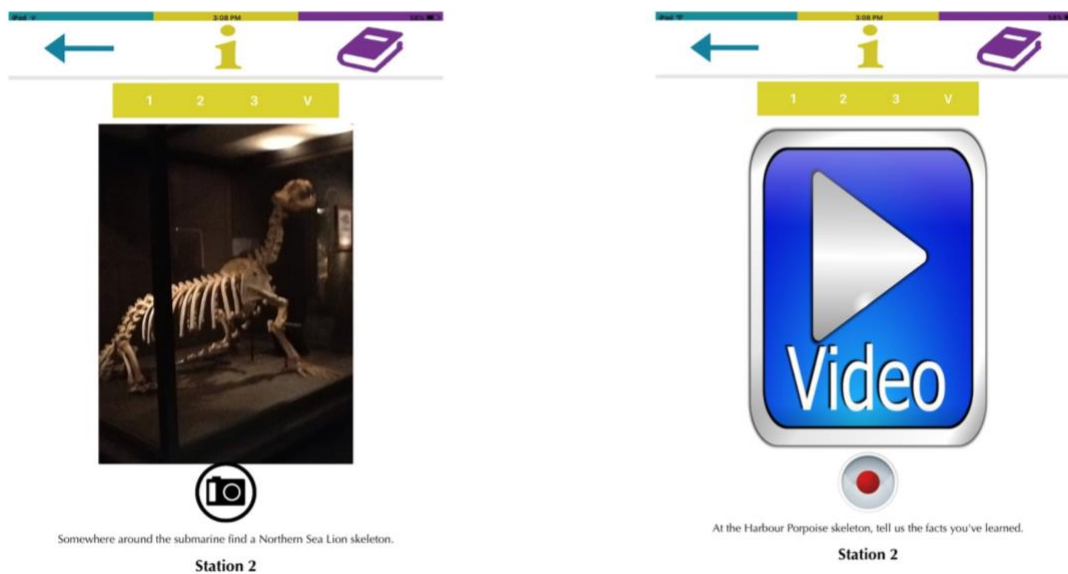
The museum prototyping app is designed to operate within the specific geographic environment of the museum or STC itself. The app, *Design & Learn*, was designed to be created and shared within the natural history exhibits at the RBCM (see [Figures 3.2 - 3.5](#)). In order to increase the ease of use by the participating elementary designers, the geographic interface are the physical exhibits themselves (for example, the Grizzly Bear within the forest diorama) rather than a geo-positioning system used in other museum applications. Young designers built the exhibits for visiting peers to interact and use within specific exhibits or artefacts in the different galleries.

Emphasis on inquiry-based feedback

The museum prototyping app allowed designers to create digital content and learning activities that encouraged visiting peers to interact and reflect on the topics, displays, artefacts or specific exhibits each interpretive activity the design teams created. Elementary students from other design teams used the iPad 2's multimedia capabilities (primarily through photography and video recordings, to share their thoughts and ideas about displays and activities using a combination of multimedia feedback and interactive e-books as shown in [Figure 3.6, 3.7 & 3.8](#).



Figures 3.2 (left) & 3.3 (right): Screenshots of design (3.2) and user (3.3) display functions.



Figures 3.4 (left) & 3.5 (right): Screenshots of exhibits (3.4) and user screen functions (3.5).

Digital Capture for Research

During this research the *Design & Learn* app was created and structured to capture all multimedia elements (photos, text, and videos) that each design team created in this study. The purpose of capturing all videos, text and photos was to collect and analyze the different media elements teams were creating and how each design team utilized them within the process of creating mobile app prototypes. The development and use of this digital interpretive design and prototyping app provided important insights into how mobile devices represent complex educational and mediating tools discussed in Chapters 2 and 6.



Figures 3.6 (left), 3.7 (center) & 3.8 (right): Sample multimedia elements from the interactive e-book (Fig. 3.6) created by Design Team #2 around the topic *Old Bones and New Bones*. In this version of *Design & Learn* each team created the text and provide some initial photos (Fig. 3.7). Peer users completed the e-book when exploring the exhibit through photography and video activities (Fig. 3.8).

Because of the dispersed nature of having different design teams working at different exhibit areas within the RBCM's Natural History Gallery, this tool was critical in capturing participant data for the purpose of narrative and thematic analysis, presented in Chapter 5. In addition to the *Design & Learn* app, some teams also created informal video recording and reflections using the iPad 2 that complemented the material they created at different stations (locations) using the interpretive app itself.

The iPad system was selected for this study because of its popularity in educational systems and use within different educational settings including the elementary school selected in this study. While many elementary students were familiar with iPads and their use at school and home, very few used iPads within informal science exhibits including the RBCM. These participant responses around their previous experience with using iPads in museum settings are discussed in more detail in Chapter 6. It should also be noted that, for the purpose of protecting our participants' personal information and identity, the software was designed to operate independently on each machine. All user data, digital media, and the app prototypes created on each iPad 2 with the prototyping software was erased from each iPad once the data had been collected and stored by the researcher on a secure flash drive for data analysis as described in the HERB guidelines.

Chapter Summary

This chapter explored the history and design of the educational research methodology selected for prototyping research within informal science settings. While most educational research prior to *Sputnik* was quantitative and largely positivist in nature, alternate qualitative and post-positivist research models based on social constructivism, educational complexity and participant inclusion began to emerge in museum and informal science education research during

the Great Debate in educational research. The Great Debate coincided with the transformation of static displays and predominantly transmissive learning activities being updated and replaced with more active inquiry and development of specially prepared museum and science exhibits for young people. Within the critical and often contentious discourse existing among various methodological paradigms, this research followed a qualitative approach based upon the small sample size of this experimental project and the complex educational, pedagogical and technological factors students and educators navigated in co-creating mobile science apps as a case study built upon the model of an analytic triangulated analysis and ethnography. Merriam (1998) states that an ethnography is “a sociocultural interpretation of the data” (p. 14). Punch (1998) further extends the importance of naturalistic cultural interpretation in noting, “to understand any group, or any culturally significant act, event, or process, it is important to study the behaviour [sic] in its natural setting” (p. 161).

Within this view a research project of this scope is complicated by the fact that, by its very nature, informal education tends to be voluntary, dynamic and transitory as students and children may only visit the natural history or science museum once or infrequently. In selecting the nomadic and transitory populations of young people and the design teams as they worked within the museum’s different galleries, this research adopted a purposeful sampling (Merriam, 1998) approach of the specific artefacts, activities and ideas each design team created and shared. In case studies, purposeful sampling, is “based on the assumption that the investigator wants to discover, understand, and gain insight and therefore must select a sample from which the most can be learned” (Merriam, 1998, p. 61). The next chapter presents the variety of data collected for this case study including a description on how the data were organized and prepared for triangulated analysis.

Chapter 4

Research Data & Organization for Analysis

Chapter Overview: This chapter describes the diversity of participant and other research data collected from the mobile design project at the RBCM. The collected data included participant interviews, survey responses, learning artefacts, multimedia elements, video recordings, paper-based app models and the final digital app prototypes created by five different design teams. A detailed description of each type of data utilized in this triangulated case study is presented including a brief discussion on data were organized for analysis are also presented. Issues of research bias including how it was addressed through the process of experimental modification is discussed within the process of data analysis discussed in Chapter 5

I hope they (the museum) can learn something. (Grade 5 Participant, 2016)

Unlike experimental, survey, or historical research, case study does not claim any particular methods for data collection or data analysis. Any and all methods for data collecting, from testing to interviewing can be used in a case study, although certain techniques are used more often than others. (Merriam, 1998, p. 42)

Overview of Data

The process of collecting data for the mobile design project was complicated by the creation of multiple design teams and the dispersed geography of the RBCM's Natural History Gallery. Both the NRC and CAISE discuss the challenges associated with participant-based research as it relates to data collection in museum and informal settings (Bell et al., 2009; Bonney et al., 2009). These include the diversity of exhibits existing within different natural history and science

museums, the limited time most visitors spend at science exhibits, and the challenge of creating research and assessment tools that work in within informal science settings.

During the mobile design project, each design team was encouraged to explore and develop their paper and digital prototypes within the natural history gallery itself. Because participants and design teams were simultaneously working in many different areas of the natural history galleries at the RBCM, direct observation of all participants and activities in this study by the researcher was not always possible. In addition, there was a tendency by the younger participants in this study to write or share short and incomplete comments in both the survey and interview processes. Although the lack of direct observation of each design team in action was challenging, the recording capabilities of the *Design & Learn* app, in combination with other data collecting methods such as the use of surveys, video/audio recordings, and participant interviews described in this chapter helped mitigate the challenges related to dispersed design by different teams. Many of the survey and interview questions developed for the adult participants were also modified and adapted for use with Grade 4 and 5 students participating in this project (see [Appendix C](#)), which allowed the researcher to collect data on the same topics, from the perspective of either a participating student or educator. The most significant changes for student surveys revolved around reducing/simplifying the language of survey questions to the reading and comprehension levels of the Grade 4 and 5 students and breaking up the surveys into more accessible forms for elementary students. For this project the modified single form used by adults was sub-divided into two smaller surveys ('check-in' and 'check-out' versions²) for elementary students (see [Appendix C](#)).

² Check-in and check-out in education typically refers to pre- and post-assessment activities. In this case study, check-ins and check-outs were used to collect student participant data via short surveys.

Table 4.1

Population, Recruitment & Data Analysis

<i>Population</i>	<i>Recruitment, Activities & Documents</i>	<i>Data & Analysis</i>	
12-15 Elementary School Students (9-11 years old)	<i>Participants were invited through letters to participate based on their previous experiences in school programs at the museum.</i>	Ethics Review Forms for: <ul style="list-style-type: none"> ● University of Victoria ● School District ● Participating Museum 	U S P
Participants worked in: whole groups, small groups & individual activities	<i>Whole, small, and individual activities based in the galleries and in an onsite classroom at the participating museum.</i>	Permission Forms & Record Keeping System	
	<i>Permission/Ethics completed through participating institutions: UVic, the school district & RBCM.</i>	Data Collected: pre & post interviews/surveys, video/audio recordings, educational artefacts, media/software elements.	
	<i>Letters of invitation to students/teachers, pre/post surveys, scripts for interviews/evaluations</i>	Database and analysis constructed through research narratives, thematic networks, and recursion.	
Elementary teachers (Grades 3-5)	Same as above	Same as above	
These participants worked in: whole groups, small groups & individual activities			
Museum Educators/Interpreters	<i>These participants were invited through letters to participate based on their previous experiences in school programs at the museum.</i>	Ethics Review Forms for: <ul style="list-style-type: none"> ● University of Victoria ● Participating Museum 	U P
These participants worked in: whole groups, small			

groups & individual activities	<p><i>Permission/Ethics completed through participating institutions: UVic, the school district & RBCM.</i></p> <p><i>Letters of invitation to students/teachers, pre/post surveys, scripts for interviews/evaluations</i></p>	<p>Permission Forms & Record Keeping System</p> <p>Data Collected: pre & post interviews/surveys, video/audio recordings, educational artefacts, media/software elements. Database and analysis constructed through research narratives, thematic networks, and recursion.</p>
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Note: Summary of research populations, data, and analytic processes. The central column describes the recruitment process and activities. The right column lists examples of the types of participant data collected.

In addition to the data collection tools and protocols described below, this project utilized a collaborative collection method where participants in each of the five design teams described in the previous chapter could create and submit data in either the classroom or natural history exhibits where the members of each design team worked. While the population sample for this study was too small for quantitative analysis, [Table 4.1](#) illuminates the rich matrix of layered qualitative and descriptive data collected for this study including interviews, focus groups, surveys, video/audio recordings, educational artefacts, digital-app prototypes, participant notes, and the researcher's field journal. Each is described in detail in the following section.

Interviews

In noting the value of interviews within qualitative studies, MacNamara states that well-designed interviews allow researchers to pursue information around the central topic or activity in greater detail (1999). Interviews can illuminate the stories and experiences of the respondent and communities being researched (1999). Within a sociocultural context the interview is an interactional process by which the respondent and interviewer construct meaning (Kvale, 1996).

Meaning is constructed from a more in-depth analysis not only of the research topic or activity, but the interactions, thoughts, and experiences of the participants as well (1996). For this project, the researcher utilized several different interview types described by Cresswell including pre/post interviews and written surveys (2012). Each interview type is discussed in detail below.

Pre/post interviews.

With the exception of one participant all of the museum and elementary teachers in this project participated semi-structured pre- and post interviews in this research project. The pre-interview was structured as a focus group (Cresswell, 2012) where respondents participated in a semi-structured discussion around the design and use of digital apps and mobile design initiatives for elementary students. Each of the questions for the pre-interview focus group is listed in [Appendix C](#). The post-interviews for museum and elementary teachers were conducted separately. Five of the six elementary teachers participated in the post-interview that was also structured as a focus group. Because of scheduling conflicts, the museum educators and learning team volunteers had to be interviewed individually and, in one instance, pairs.

While the need to conduct museum interviews individually with museum educators may have omitted group interactions and reflections, the cross-comparison integrity was maintained in this study by using the same focus questions in each interview. Each of the questions for the pre- and post-interview focus groups is included in [Appendix C](#). All of the interviews were digitally recorded (audio) and transcribed for the process of triangulated analysis presented in Chapter 5. For the purpose of comparison and analysis, the educator interviews were aggregated into two groups: formal (elementary teachers) and informal (museum educators). Interestingly, no formal student interviews were utilized in this research as the initial experimental focus revolved around a formal analysis of the specific mobile content and activities young people co-

created with educators. The omission of student pre- and post-interviews was a significant weakness in the final analysis and is discussed in more detail in the area of future participant-based research presented in Chapter 6.

Participant Surveys

There is a long and extensive history of the use of surveys in educational research. For researchers, surveys can provide a wide variety of descriptive, evaluative, and reflective information that can be utilized in both quantitative and qualitative formats (Creswell, 2012; Merriam, 1998; Stakes, 1995). Given the small size of this project, research surveys were developed for every student and educator participating in this project utilizing both descriptive and open-ended elements (Cresswell, 2012). For elementary students, the surveys were divided into short five to ten-minute check-in and check-out responses that students completed during each week of the mobile design initiative. Surveys for educators, like students, contained both descriptive and open-ended elements. This follows Froddy's (1993) argument that open-ended questions allow the advantage of exploring spontaneous discoveries beyond the more structured format of closed and/or Likert scale questions by respondents. One important disadvantage, Froddy (1993) states, is that open-ended questions often take more time to code and analyze. Each of the surveys for elementary and museum educators was completed after each session of the four-week project (see research calendar on page 95). Once completed, the data contained in all the surveys were compiled and aggregated within a thematic data base according to question and topic for the process of triangulated data analysis presented in Chapter 5.

Video & Audio Recordings

The use of video and audio recordings within educational research runs concurrently with both the development and refinement of these technologies. Video and audio recordings are

utilized in many different ways including participatory-based use, videography, elicitation, and field recordings/observations (Jewitt, 2012). For this research, audio recordings were primarily used to record interviews with museum and elementary teachers. During the mobile app design activities, video recordings were made within either a classroom or natural history exhibit setting when the teams were together in order to capture different team actions. Video recordings were later transcribed for data analysis.

In addition to the recordings above, design teams were encouraged to record their ideas, thoughts, reflections and reactions when using interpretive apps that other teams designed. The technique of participant-based video recording (NCRM, 2012; Shrum, Duque & Brown, 2005) was utilized because of the complexity and difficulty of recording participants while they worked in different areas of the Natural History Gallery. While the frequency and quality of team video reflections and recordings vary, for this research every team's video reflections were included within the database for the purpose of analysis. All the video and audio recordings were downloaded and copied into a research database. These recordings were also transcribed and coded for analysis.

Educational Artefacts

Educational or learning artefacts are objects that students create within individual and social processes of learning. Examples of educational artefacts within the fields of museum and science education include charts, posters, or other models. While most researchers describe educational artefacts as representing a concrete or physical form and symbol of learning (Creswell, 2012), the emergence of multimedia technologies and production suggests that educational artefacts can be digital as well (Druin, 2009). As a result, in this study the following description of the educational artefacts collected include both physical and digital learning

objects created by the design teams. The participants in this study generated a wide range of educational artefacts including posters, charts, mind maps, organizing tools and paper/digital app prototypes that are all described in detail below.

Posters & organizing tools.

During this study each team created posters, mind maps, and other paper-based organizing tools that informed each design team's ideas and activities that the participants on that team wanted to create together. [Figure 4.1](#) and [4.2](#) show examples of some educational artefacts in this category. In this example, these are project organizing charts from Design Teams #2 & #5. As part of the research and data process, each of these educational artefacts was collected and photographed in preparation for triangulated analysis.

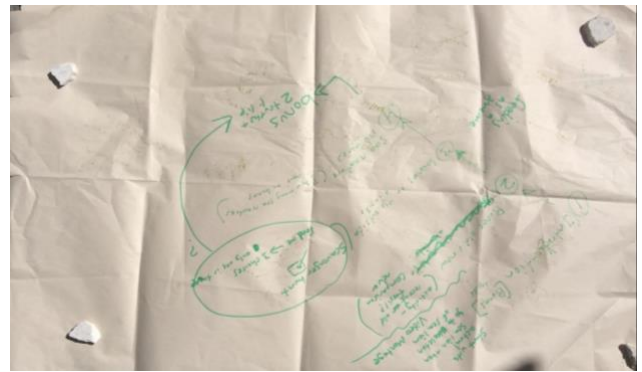
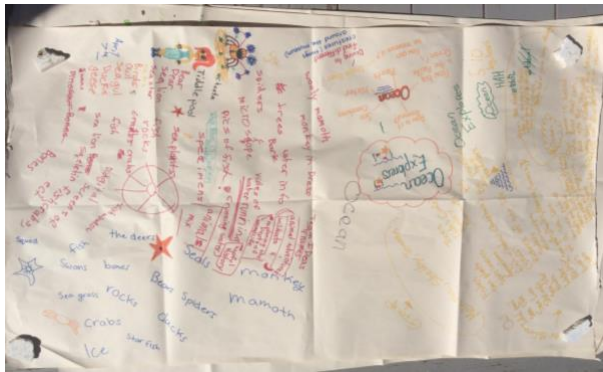


Figure 4.1: Samples of concept posters for mobile activities and planning used by different design teams as they began creating their prototypes.

Paper app prototypes.

Paper based modeling forms an important component within the context of user theory and informant design. The use of paper prototypes is well documented within User Theory and software design (Druin, 2009). Nessart and Large (2004) note the low cost and efficiency in creating models with paper. Carmel, Whitaker & George (1993) point out that the use of paper

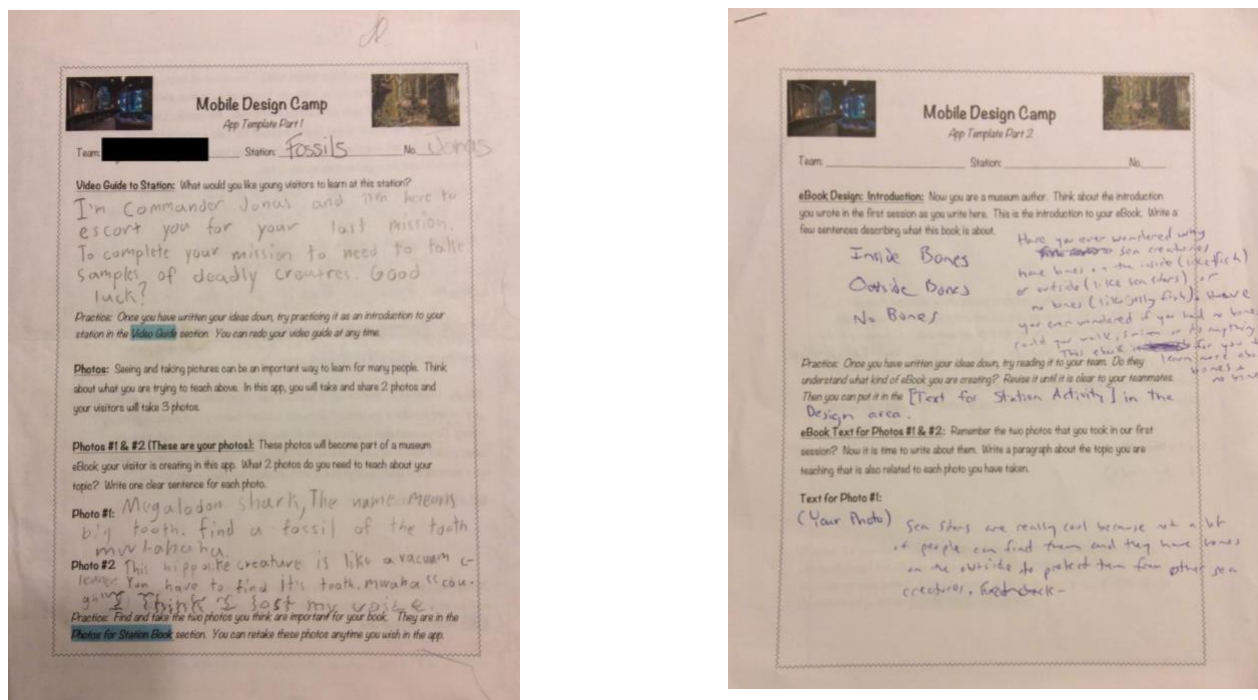


Figure 4.2: Examples of paper app prototype frameworks.

prototyping allows participants including younger students to both visualize and manipulate the software they are designing.

For this research, teams created paper prototypes utilizing an app prototyping framework developed by the researcher (see [Appendix D](#)). The process of paper modeling allows students to explore different ideas and activities before committing them to digital form. For the sake of expediency and due to the limited amount of time available for this study, the paper prototypes served as a framework upon which each design team could create a functioning model that was already in a form for digital conversion using the *Design & Learn* app. [Figure 4.2](#) is an example of the paper based activity frameworks Design Teams #1 & #2 utilized in creating and organizing their design. Like the posters and organizing tools, each of these educational artefacts was collected and photographed for analysis with the results discussed in Chapters 5 and 6.

Digital app prototypes.

In addition to its ability to function as an interpretive app prototyping tool, the educational software *Design & Learn* was programmed to be utilized as a rich source of data for this project. The software recorded all photos, text, and multimedia elements that each design team created as they developed their interpretive app. For the purpose of data analysis, a complete screen recording was made of each design team's digital app prototype using *Reflector 2*. At the time of this research the Mac OS software did not allow the direct capture of a screen recording by older iPad 2s without the purchase of a third-party app. *Reflector 2* was selected for its ease of use in accessing the iPad's 2s *Airplay* features. While there was some audio lag in the screen recording of each design team's digital app prototype with *Reflector 2*, overall, the quality of each recording was satisfactory enough for the process of *triangulated analysis* presented in Chapter 5.



Figure 4.3: Examples of digital activity prototype home screens from two design teams. The home screen is in the center. Sample design screens are on the left. Sample user screens are on the bottom and sample multimedia sharing screens are on the right of each team's Figure.

In addition, screenshots of all digital elements including text, photos and video recordings created by the designers of each team's app prototype were recorded as well. Multimedia elements, primarily photos and videos, were downloaded from each design team's iPad as exemplified in Fig. 4.3. Once recorded and downloaded, multimedia elements were placed within the database for the data analysis and discussion presented in Chapters 5 and 6.

Participant notes.

In addition to the all the elements above, the educators were presented with their own notebooks for this project. While the educator notebooks were considered a private resource for educators to use as they worked on the project with other educators and students, if they wanted to share thoughts, ideas or suggestions with the researcher about the project, they were welcome to submit their notes either digitally (using the team's iPad) or by handing in any written pages the participating educator wanted to share with the researcher. Submitted notes were photographed and added to the database for analysis.

Researcher's observations & field notes.

The direct observation of the participants and design teams formed another important source of data for this project. This was particularly important while the design teams were dispersed and working in the natural history gallery. Within this context, the direct observation of dispersed participants engaged in learning and design in different areas of the natural history gallery forms a low-inference source of data (Turner & Meyer, 2000). The use of low-inference data can be a valuable way to collect information when attempting to understand new observed phenomena in research but must be confirmed using other high-inference sources (2000) of data such as survey responses, interviews, and participant recordings. Direct observations for this research project were recorded via field notes, photographs, and a journal. Although Stanger

notes the subjective nature of a researcher's observations and field notes are "...far from being a first line of defense in the search for objectivity...they can illuminate important discoveries in the critical and reflective observation of others" (1996, p. 4). For the purpose of triangulated data analysis described in the following chapters, my observations and field notes were created using the IOS iBooks app and a physical notebook. Researcher journal entries and observations were utilized throughout the experimental and data collection phases including the process of triangulated data analysis presented in Chapter 5. Issues of research bias and the impacts/effects of experimental modifications were directly addressed within the process of triangulated analysis and recursion discussed in Chapter 5 (see pages 148-149 and [Table 5.4](#)).

Chapter Summary

Each of the five design teams participating in the mobile design project produced a wide variety of data for analysis including: participant interviews, surveys, video/audio recordings, learning artefacts, multimedia elements (photos and video recordings) and copies of the digital activities each team created. While most of the data were facilitated and collected by the researcher, the process of having teams dynamically operating in either classrooms or the museum's natural history galleries required some dispersed and reflective data collection in the form of photos and video reflections completed independently by members of each design team. As a result, the data reflect both uniform and differentiated characteristics for analysis depending on what data each team created/submitted outside of the facilitated data generated through guided activities by the researcher such as surveys and interviews. Once all the data were collected and transcribed, the process of triangulated analysis around the central research questions presented in Chapters 1 & 3 commenced. The process of triangulated analysis utilized thematic networks, recursive analysis and the creation of three research narratives that examined the influence

mobile science apps might have on elementary students' educational roles, mobile curricular development and M-learning presented in Chapter 5.

Chapter 5: Triangulated Analysis & Results

Chapter Overview: The chapter begins with an overview of the analytic tools utilized in the process of *triangulated analysis* as a non-linear form of data analysis and interpretation utilized to identify and locate meaning within data. After discussing each analytic tool used in this study (thematic networks, recursive analysis, and research narratives), the results from triangulated data analysis are presented and interpreted. Participant data was coded for thematic network analysis and discussion. Recursive analysis describes the dynamic process of experimental modification and reflection based on simultaneous data collection, participant feedback, observations and analysis throughout the research process and is presented in the middle of this chapter. The chapter concludes with a discussion on construction and use of research narratives in this study exploring educational roles, participant-based curriculum design, and m-learning.

Yes because we put some facts in that helps you learn more about the museum um [sic] and it's still fun. (Grade 5 Participant, 2016)

But it's a really good one and I think one of the main take aways [sic] from this is as much about the interaction between educators as it is with the kids...or it is with the technology. (Museum Educator, 2016)

Applying thematic networks is simply a way of organizing a thematic analysis of qualitative data. Thematic analyses seek to unearth the themes salient in a text at different levels, and thematic networks aim to facilitate the structuring and depiction of these themes. (Attride-Stirling, 2001, p. 387)

As we make our way through life, we have continuous experiences and dialogic interactions both with our surrounding world and ourselves. These are woven

together in a seamless web, where they might strike one as being overwhelming in their complexity. One way of structuring these experiences is to organize them into meaningful units. One such meaningful unit could be a story, a narrative. (Moen, 2006, p. 2)

Organization & Analysis of Data

As presented in the previous chapter, during each phase of research presented here, a wide range of qualitative and descriptive data were collected including: interviews, surveys, recordings, educational artefacts (both physical and digital), research observations, and field notes. The research activities, processes, and data elements are summarized in [Figure 5.1](#). Once all the data were collected, digitized, and transcribed they were ready to be triangulated and analyzed as described and recommended by Tindall (1994). Tindall notes that data triangulation emphasizes “collecting accounts from different participants involved in the chosen setting, from different stages in the activity of the setting and ... from different sites of the setting” (p. 146). Method triangulation involves the “use of different methods to collect information” (p. 147). Theoretical triangulation revolves around the importance of acknowledging the value of multiple theories (1994), which in this case are linked to: educational roles, curricular/interpretive pedagogies, and user design.

The purpose of triangulation in educational research, similar to its application in geography and mapping, is to identify key elements and/or factors related to the subject being studied and analyze them from multiple perspectives in order to attain a greater understanding of the topic or educational process being studied. Patton (2002) expands this further through the presentation and use of *analyst triangulation* where multiple analysts are utilized within the context of

research. Within this case study thematic, recursive, and narrative analysis form the central pillars for triangulated data analysis. The process of triangulated analysis was utilized to examine the influence of mobile technologies and applications within participant-based mobile curricular design using three different analytical tools. As illustrated in [Figure 5.1](#), the process of

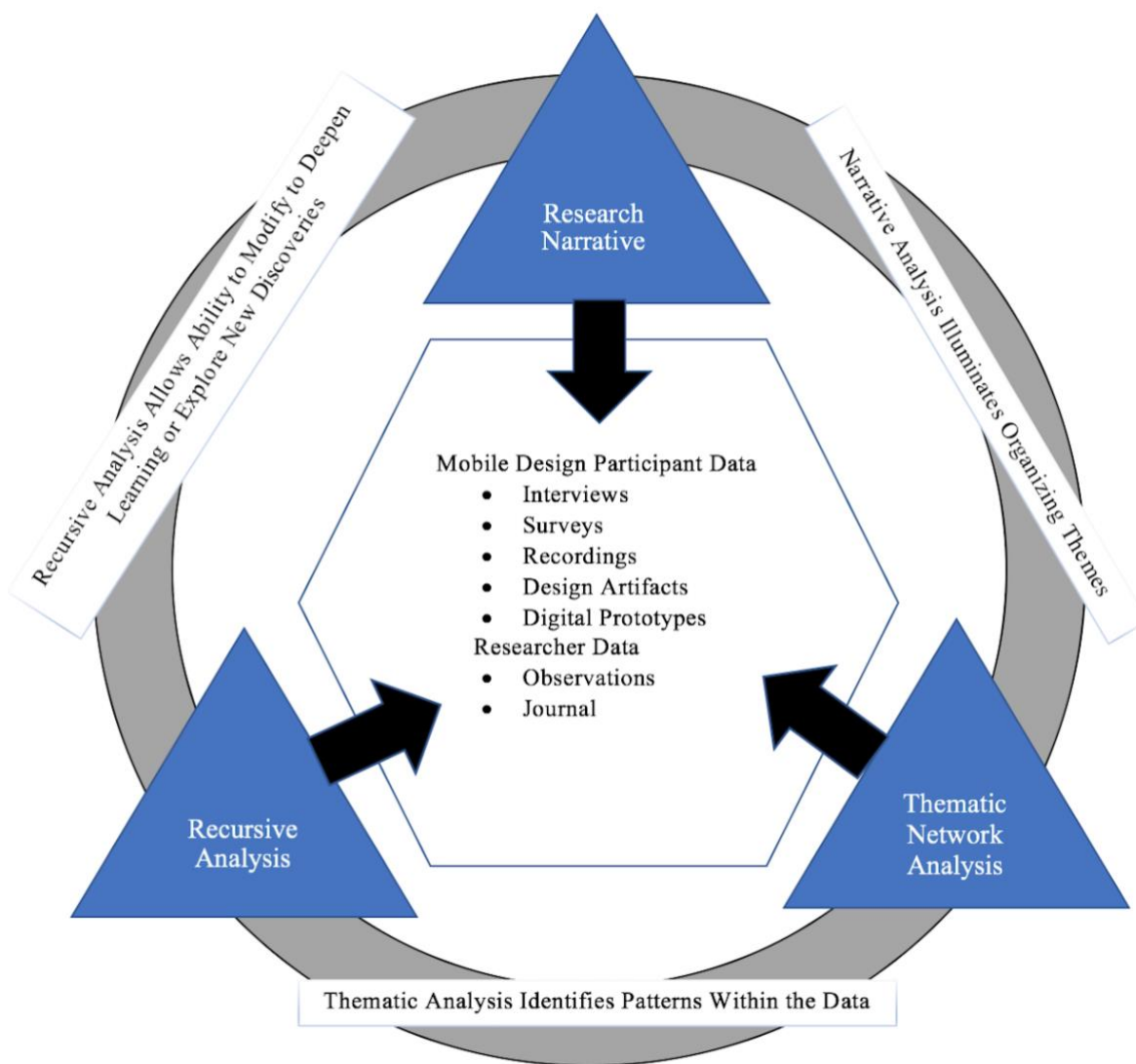


Figure 5.1: The process of analytic triangulation allowed for a more in depth critical analysis of participant experiences, data, and observations made by the researcher with each form of analysis contributing significantly to key findings within this research.

triangulated analysis utilized in this study was non-linear in nature as each analytical tool elucidated insights and information on the nature of participant-based mobile app design and learning which could be further analyzed by other selected analytical tools.

For example, as discussed in this chapter, the process of coding and thematic network analysis provided important insights into the process of constructing each of the research narratives that emerged in this research. At the same time, the process of dynamic recursive analysis involving the modification of the experimental process altered the final research narratives and analysis as well.

Table 5.1

Summary of Data and Analytical Tool Selected for Analysis

<i>Source of Research Data Collected</i>	<i>Participant Source</i> <i>S= Student (n=13)</i> <i>E= Elementary Teacher (n=6)</i> <i>M= Museum Educator (n=5)</i> <i>R = Researcher (n=1)</i>	<i>Analytical Tool Used</i> <i>N = Research Narrative</i> <i>T = Thematic Network Analysis</i> <i>R = Recursive Analysis</i>
<i>Participant Surveys</i>	S, E, M	T, N
<i>Interviews</i>	E & M	N, R
<i>Video/Audio Recordings</i>	S, E, M	N
<i>Educational Artefacts*</i>	S, E, M	N, R
<i>Participant Notes</i>	E	Not used due to single sample
<i>Research Observations & Field Journal</i>	R	N, R

Note: This table summarizes variety and source of data collected and includes the selection of the analytic tool utilized for triangulated analysis.

*Educational artefacts refers to all the physical and digital material the participants in this study created including: idea poster, learning maps, paper models & digital prototypes.

Tables 5.1 and 5.2 summarize how the data were examined through the process of triangulated analysis. As evident in Table 5.1, some data, such as the participant interviews,

educational artefacts, and digital medias, were examined using multiple analytic tools. The key exception to this case related the thematic network analysis and the use of participant surveys described in the next section. Recursive analysis of the data primarily revolved around their value in dynamic reflection, evaluation and modification by the researcher in order to arrive at a greater understanding of the potential use and influence of mobile science apps in science museum settings (see pages 141-149 for a complete discussion on the use recursive analysis in this study). The use of research narratives describes the experiences and ideas of participants within the context of an evolving story constructed and interpreted by the researcher acting as both author and participant in this research.

Table 5.2

Coding of Data by Selected Analytical Tools

<i>Source of Research Data Collected</i>	<i>Analytical Tool Used</i> <i>N = Research Narrative</i> <i>T = Thematic Network Analysis</i> <i>R = Recursive Analysis</i>	<i># Analyzed, Data Use & Analysis</i>
<i>Participant Surveys</i>	T, N	n=23 Thematic Coding (T)
<i>Interviews</i>	N, R	n=10 Transcribed, Coded (N, R)
<i>Video/Audio Recordings</i>	N	n= 5 Transcribed (N)
<i>Educational Artefacts*</i>	N, R	n=75 PD, ID & M-learning (N,R)
<i>Participant Notes</i>	Not used due to single sample	NA
<i>Research Observations & Field Journal</i>	N, R	n=1 Narrative Construction (N)

Note: This table summarizes variety, number and types of data collected for the mobile design project.

*Educational artefacts refers to all the physical and digital material the participants in this study created including: idea poster, learning maps, paper models & digital prototypes.

The selection of each of these analytic tools also acknowledges the impact, perspective and role of the central researcher which, as described in Chapter 3, is often omitted in educational research. [Table 5.2](#) lists the variety of data (including the number of data in each category) and the analytical tool by which each category was examined. As an example, all 23 participant survey responses were utilized within the process of thematic network analysis discussed in the next section. Participant interviews with both the museum and elementary teachers were transcribed and utilized in the development of three research narratives (see [Appendix H](#)). Photos of educational artefacts and multimedia elements including screen recordings of the digital app prototypes each team created were utilized in the process of evaluating mobile learning and participant-based curricular design. Despite the non-linear nature of triangulated analysis, for the sake of efficiency in reporting the results, the summary of data analysis presented in the following sections is based around each analytical tool utilized beginning with *thematic network analysis*.

Triangulated Analysis Section 1: Thematic Networks – Analysis and Results

Thematic analysis as an analytic tool explores, “themes and concepts indicated by the data” (Merriam, 1998, p. 202). In this case study, Sterling’s (2001) analytical model of thematic network analysis was utilized because of its value as research tool for organizing, analyzing and understanding complex qualitative data sets within thematic and visual contexts. Once constructed, thematic networks provide a visual reference for discussing the complex themes and relationships illuminated from the data including the identification of future research or action on the topics or processes being studied. [Figure 5.2](#) illustrates a general model for thematic network analysis. In thematic network analysis, the global theme represents the central topic or focus of the study. In this research, the global theme revolved around the design and use of mobile

interpretive apps as educational mediating tools. Orbiting around the global theme in [Figure 5.2](#) are satellite organizing themes directly related to the central topic being studied.

At this point Sterling's model of thematic networks was modified by replacing the term basic theme with thematic elements to minimize any potential confusion from the repetitive use of the term theme. This usage more accurately describes Attride-Sterling's (2001) description of this level as those "lowest order" (p. 389) elements or concepts derived from the interpretation of

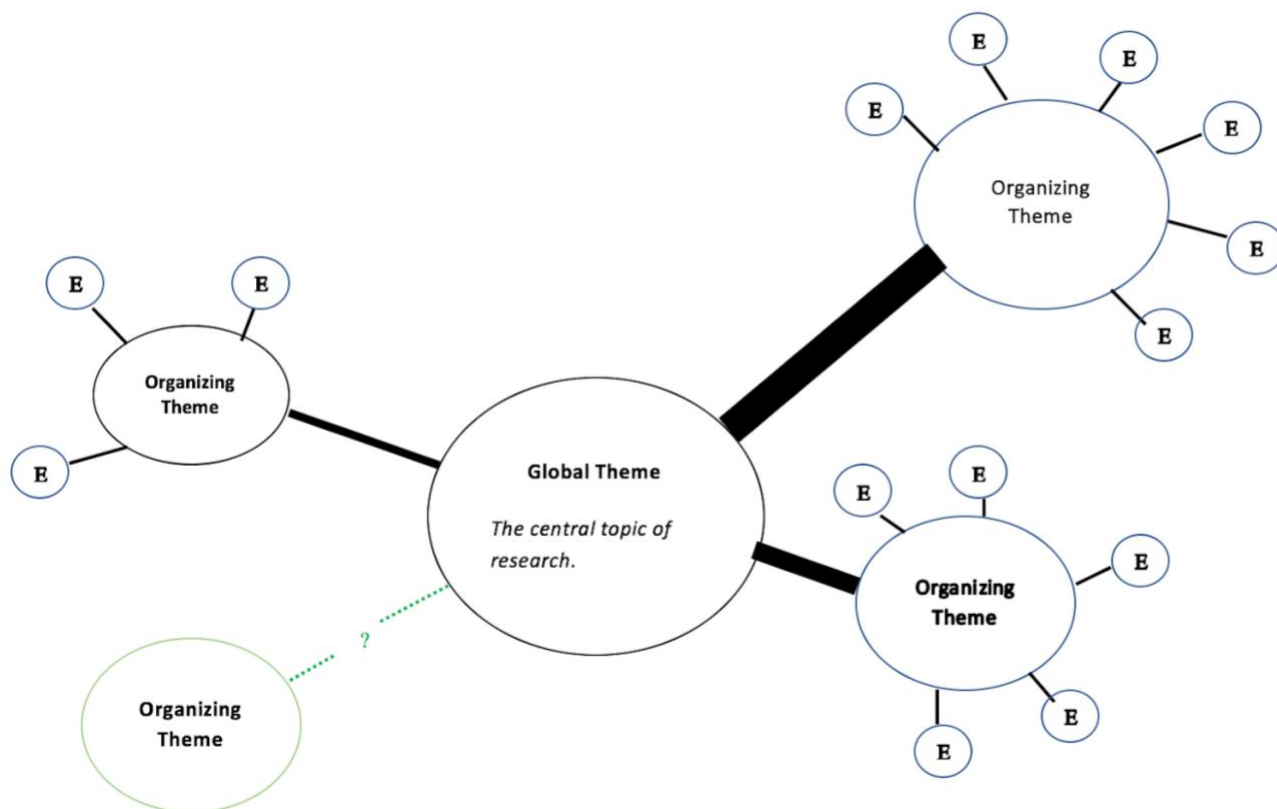


Figure 5.2: Attride-Sterling's model of thematic network analysis around a central research topic or *global theme*. An associated network of key *organizing themes* and *thematic elements* is connected to the global theme for analysis. Unknown and/or incomplete themes often emerge within the process of data analysis.

raw data and other artefacts produced by thematic network analysis. Merriam (1998) writes that, “themes are concepts indicated by the data” (p. 165). As a form of inductive analysis (Patton, 2002), a thematic approach allows for the illumination of themes within collected data rather than being specified prior to analysis

Eisner (1991) illuminates important linkages between thematic and narrative analysis presented later in this chapter by stating, “the thematic structures derived inductively from the material... can provide the conceptual hubs from which the story can be told” (p. 191). As a result, thematic network analysis (Stirling, 2001) not only serves as an important analytical tool in discovering the structural patterns and thematic interrelationships existing within coded participant data, but is also essential in constructing and validating research narratives as well.

Coding participant data.

The participant surveys (see [Appendix C](#)) for elementary students, teachers, and museum educators were selected for coding and thematic network analysis. As illustrated in [Figure 5.3](#), participant responses and comments were coded and analyzed within three organizing themes: educational roles, participant-based curriculum design, and M-learning. While the global and organizing themes are directly related the central topic and research questions examined in the first chapter, the identification of the various thematic elements surrounding each organizing themes emerged from the coded analysis of participant surveys and interviews. As discussed in the following sections, it was often necessary to make repeat passes over participant data in order to identify and understand all of the thematic elements represented within the constructed thematic network.

The raw data for each organizing theme are presented as thematic screenshots and summarized in tabular form in [Appendices E & F](#). The analysis of coded data includes a

discussion of the thematic elements connected with each organizing theme. [Figure 5.3](#) presents the thematic network of the organizing themes emerging within this study. Screenshots of the raw thematic network analysis (see [Appendix F](#)) determined how different thematic elements interacted with each other and the overall global theme: the design and use of mobile interpretive apps as important mediating tools within informal science education. The first organizing theme examined how the educational orientations and roles of the participants (operating as elementary

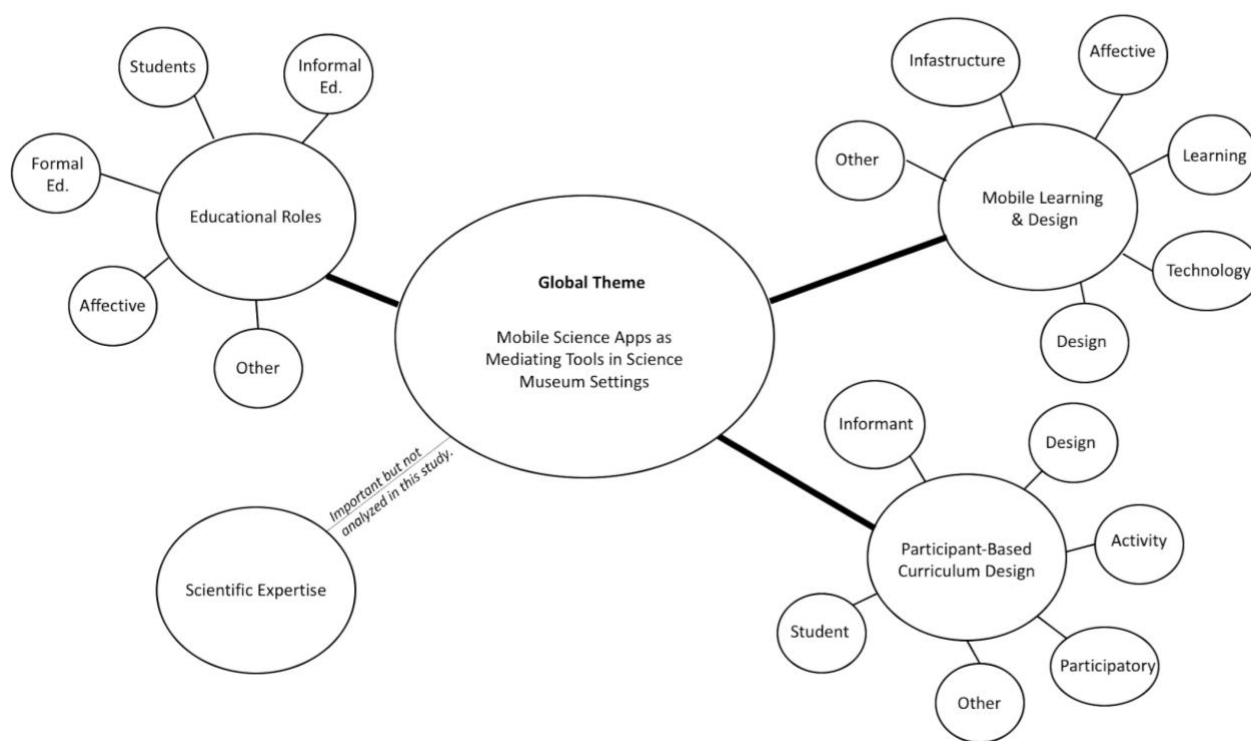


Figure 5.3: Thematic network showing the thematic elements and organizing themes associated with the global theme of mobile science apps operating as mediating tools in science museums settings.

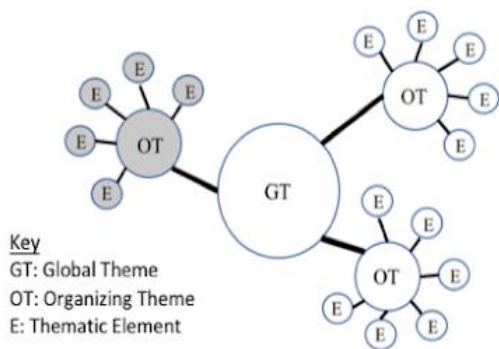
student, elementary teacher, museum educator) were affected by the design and use of mobile science apps when students were invited to participate within new educational role as co-designers of educational content and activities.

For the purpose of analysis and discussion, participant responses (students, teachers, and museum educators) were coded, analyzed and presented within each organizing theme and discussed in the associated sections below. While most of the coding was pre-assigned, some coding within the data such as affective and other thematic elements emerged inductively from multiple passes and analysis of participant data. Thematic elements and the frequency of participant comments were converted to pie charts (orange for student comments, green for elementary teachers and blue for museum educators) for each element connected to the organizing theme it is associated with. The analysis of each organizing theme within the global thematic network is presented in each of the following sections starting with educational roles.

Organizing theme - Educational roles: Analysis & findings.

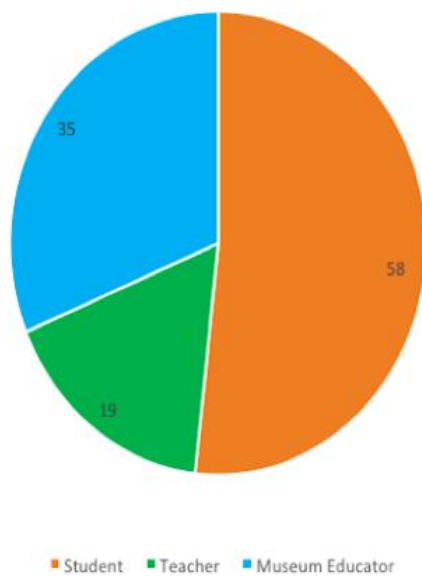
Educational roles, as an organizing theme within sociocultural frameworks, describes how a person's educational identity and role are influenced within the cultural institutions (in this case the RBCM) they operated within. For the purpose of thematic network analysis presented here, the primary researcher examined how participant responses on surveys (see [Appendix C](#) for surveys and [Appendices E & F](#) for tables of raw data and screenshots of the coded data) illuminated thematic elements related to the educational roles of the participants in this study. More specifically, the analysis looked at whether mobile design app and technologies influenced participant perceptions about their educational roles within the process of mobile app design.

[Figure 5.4](#) presents participant data related to the organizing theme of educational roles. Thematic codes were organized by topic and statement frequency within the data set. The participant data were examined in order to identify and confirm the presence and rate of each thematic element (as a percentage) within the organizing theme of educational roles.

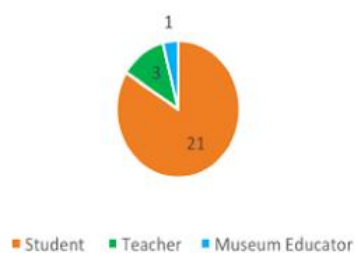


Educational Roles - As a guiding theme educational roles describe roles, institutional affiliations and beliefs students, elementary teachers, and museum educators have that are connected to formal and informal educational systems.

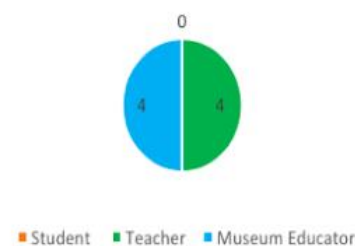
Organizing Theme – Participant Comments about Educational Roles



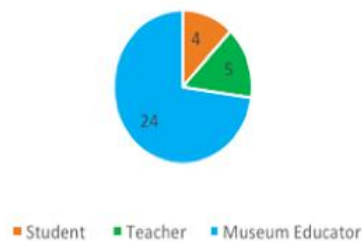
Thematic Element - Role as Student



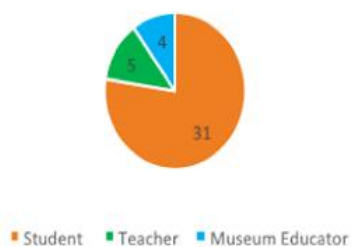
Thematic Element - Formal Education



Thematic Element - Informal Education



Thematic Element - Affective



Thematic Element - Other Comments



Figure 5.4: Participant data around the organizing theme of educational roles.

Additional analytical passes over participant data, including unique observations, ideas, and statements made by the participants in this study, illuminated previously unknown thematic elements as well. [Figure 5.4](#) presents the coded analysis of the organizing theme: educational roles.

As evidenced in the analysis of the first organizing theme, the following thematic elements emerged from the initial coded word analysis and frequency of participant responses: formal education, informal education and the roles/position of students. For example, participant comments were coded as informal education if participants' responses discussed museum education or learning in the gallery directly. Two additional thematic elements were identified during a second review of the data. Affective comments made by participants were identified as an important thematic element where participants expressed emotional comments directly related to cultural topics and their roles as either students or educators. In addition to the affective realm, other comments were also coded and identified if they expressed an emotional response (i.e.: Cool!) or could not be easily identified as one of the thematic elements described above. Many of these statements categorized as other, while being conversationally or textually related to the organizing theme, were characterized as having a weak, indirect or otherwise unknown relationship to both the organizing and global themes.

Within the first organizing theme of educational roles presented in [Figure 5.4](#), the frequency of participant comments is described as follows. There were 58 comments by students and 54 by educators within the organizing theme of educational roles. Most of the comments by students revolved around affective comments (31) with responses relating to their educational role as students being the second most frequent (21). Less frequent thematic elements included

statements by students around informal education (4). There were two comments identified as other.

The most common response for elementary teachers within this organizing theme revolved around their thoughts and ideas related to informal education (5) with affective statements (5) and comments about formal education (4) coming in second and third respectively. The least frequent thematic elements within this organizing theme for educators related to students (3) and other at one. For museum educators, the most frequent comments revolved around informal education (24). Formal and affective statements were both tied at four each. Like their teaching peers, comments made around students by museum educators were the least frequent at one. There were two statements that could be classified as other. From the thematic analysis of the survey data of respondents, the participating students and museum educators were strongly orientated towards their role as either a student or informal educator respectively. No Grade 4 or Grade 5 students made any comments about formal education illustrating their awareness that this activity was taking place outside of formal education. It also reinforces the idea that the participants in this study were keenly aware of the different educational setting they were operating in when responding on surveys. The results of thematic network analysis generally confirm key educational differences and orientations existing between formal and informal science education as described by Wellington (1991) and others (Hofstein & Rosenfeld, 1996; Nicolson & Chen, 1994; National Research Council, 2008) discussed in Chapter 1. The significance of participant awareness and its effect on the design and use of mobile science apps as mediating tools within formal and informal science education is discussed in Chapter 6.

While the total number of comments made by teachers was reduced by an absence during the first week, it appears that teachers were nearly divided in comments related to formal (4) and

informal (5) education. This confirmed the cultural effects museum environments and after school programs have on their educational orientation and participation in the mobile design initiative. Comments ranging from, “Fun!-Curriculum connections” to “It’s kind of like how – We don’t always need to have answers to questions – Its [sic] okay not to know.” by teachers suggests strong awareness of the different learning environment and reorientation towards informal education as enrichment (Wellington, 1990; Hofstein & Rosenfeld, 1996). The dynamic nature of educational roles by students and elementary teachers operating differently within informal science settings was also explored within the initial construction and analysis of the research narratives presented later in this chapter.

In addition to participant responses relating to differing roles as students and educators, there were a large number affective comments made by the students in this study. While some affective responses by students such as “I think its [sic] cool!” indicate the possible weakness and implementation of the survey tool itself as it was presented to and understood by younger participants, the large number of affective comments by students also generally affirms Meredith, Fortner, and Mullin’s (1997) views that curiosity, personal interest, and emotion may act as significant motivators to learning for young people within informal science environments like museums and zoos. The higher number of affective comments by students (31) compared to educators (9) also suggests that affective elements motivated students and educators in fundamentally different ways within this study around educational roles. Grade 4 and 5 students were influenced by affective motivations at a much higher level compared to the educators participating in this study. The significance of the students’ affective engagement in this case study affirms Pedretti’s (2004) views on the significance of emotion as a motivating force within

informal science learning. The role of curiosity, emotion and exhibit interactivity function as driving affective forces in mobile app design are discussed in more detail in Chapter 6.

Organizing theme - Participant-based pedagogies: Analysis & findings.

The second organizing theme revolved around participant-based pedagogies. The analysis of the data around this organizing theme examined the possible conflict participants expressed around their informal understanding of Informant Design (ID) versus Participatory Design (PD) as it relates to mobile learning initiatives. Like the first organizing theme, the researcher was interested in analyzing whether the various thematic elements identified and discussed below provided important insights within the apparent dissonance between students and educators' views on the level of their participation in the process of mobile app design observed in the data both thematically and within the construction of research narratives discussed later in this chapter. More specifically, thematic network analysis was conducted to determine if the thematic elements emerging within the data provided additional insights into participants' ideas and views on participant versus informant models of curriculum design.

Figure 5.5 presents sample data collected for the analysis of thematically coded responses on surveys within the organizing theme of participant-based pedagogies. Like the first organizing theme, frequency codes (number of statements) were developed around the thematic elements and concepts that emerged over multiple passes of the participant data. The data confirmed thematic elements existing around participatory design (PD) and informant design (ID) based pedagogies discussed in Chapter 4. In addition to this, other thematic elements emerged around participant views about the design and activities different teams were working on. Like the first organizing theme, there were other comments that either weakly or indirectly connected to participant-based pedagogies within the coded data as well.

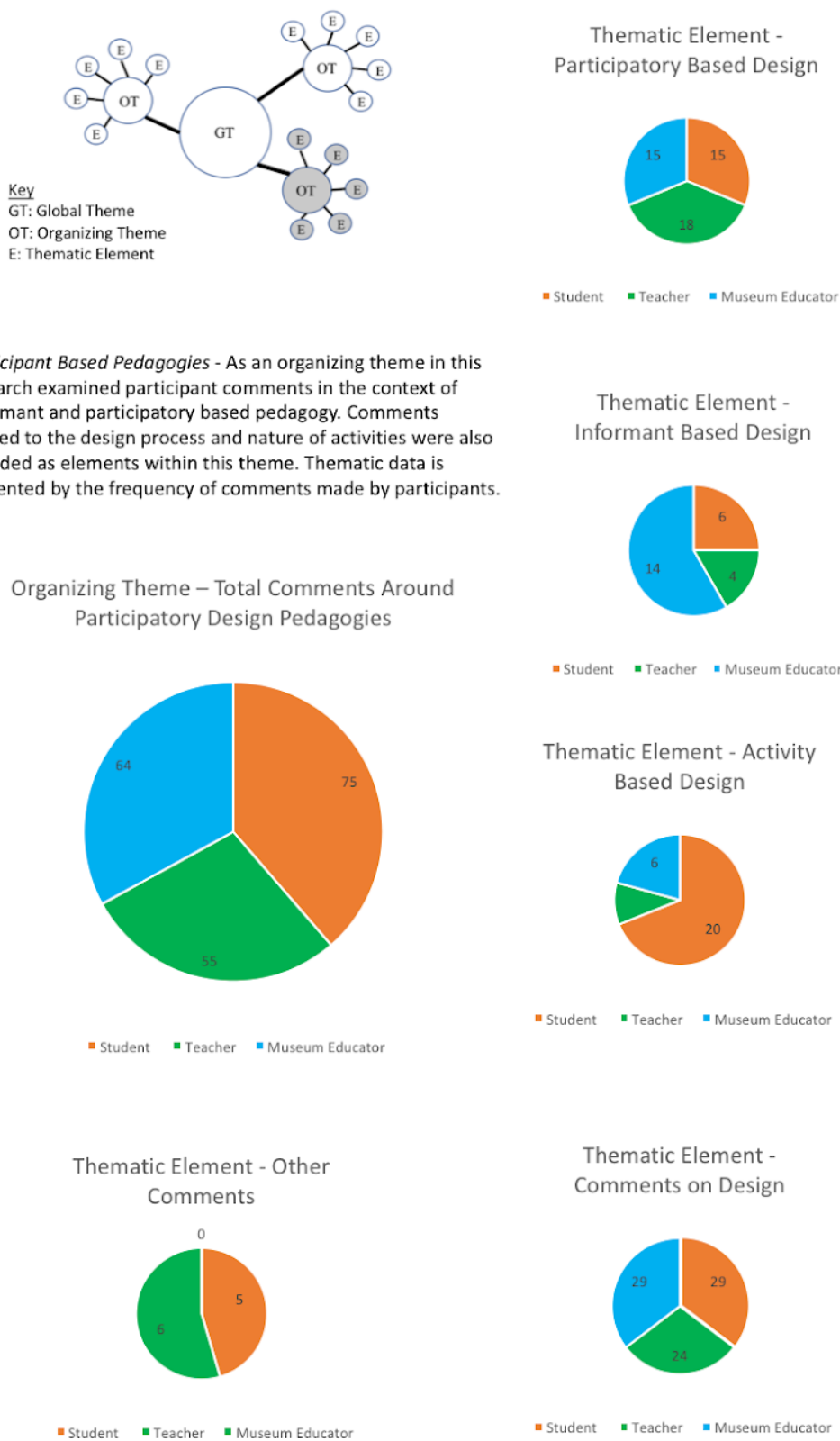


Figure 5.5: Participant data around the organizing theme of participant-based pedagogies.

Similar to the first organizing theme, the frequency data around participant-based pedagogies is varied. There were 75 comments by students and 119 by educators within the organizing theme of participant-based pedagogies. As [Figure 5.5](#) shows, most of the comments made by students were thoughts and ideas related to their team's design (29) and mobile learning activities (20).

When compared to responses by educators, student comments about participating in the project tended to align with more participatory-based (15) statements rather than informant-based design (6) where user roles are much more limited as was the case in this research suggesting a greater sense of participation reported by students than educators. There were two comments identified as other. The greater sense of participation reported by students was also examined through the research narratives presented later in this chapter.

Like the students they worked with, the most common thematic element for elementary teachers within the second organizing theme related to their role within the process of team design (24) with a much smaller number of responses about the specific interpretive activities their teams were creating (3). Teacher comments skewed towards a participatory-based model of design (18) rather than informant-based approach (4). However, a key difference within the responses made by the participating educators was a desire towards greater participation rather than the sense of participation reported by students. Like the results reported by students around participation-based design above, the desire by educators for more participation was examined in the narrative-research process describe later in this chapter.

There were a slightly higher number of comments marked as other made by elementary teachers (6). The most frequent comments by museum educators tended to focus on issues and topics related to design (29) with a slightly higher number of comments about the activities (6) their teams were designing compared to elementary teachers. In examining comments around

participatory (15) and informant based pedagogies (14), museum educators tended to respond equally. In this data set there were no comments made by museum educators classified as other. Participant-based responses and observed use around the tightly based paper framework (see [Appendix D](#)) and complex structure of Design & Learn prototyping app suggested a more pronounced awareness and frustration with the informant model utilized in this case study among the participating elementary and museum educators compared to student designers. This phenomenon was also observed within the process of constructing research narratives explored later in this chapter.

Within each group of participants, the largest percentage of responses tended to associate to issues related to the educational design of their app prototypes and the activities their design teams were creating. However, unlike the educators they worked with, students tended to be more focused on the kinds of activities they were creating compared to the comments received by elementary teachers and museum educators. Student comments in this category tended to explore the different kinds of games and activities they were designing. Within both the process of thematic network analysis presented here and the research narratives examined towards the end of this chapter, it appears that most of the educators were more focused on supporting students in the successful design and building of the activities design teams were working on. Rather than discussing their own ideas and activities, educators were focused on the activities the Grade 4 and 5 students on their design teams wanted to design as represented in comments by one museum educator, “Trying to help students focus on specifics. Gave lots of suggestions to help students concepts ideas/possibilities.” This supports Zhai and Tan’s (2015) model of elementary teachers’ dynamic roles in science education as “... (1) dispenser of knowledge (giver), (2) mentor of learning (advisor), (3) monitor of student’s progress (police), and (4)

partner in inquiry (co-learner)” (p. 907). It also reinforces the educational role and position students play within participant-based pedagogies and design.

In addition to focusing on students’ ideas and activities, the data also illuminated the respondents’ views on their level of participation in this project. While the mobile design project was based on an Informant Design (ID) model described earlier (see page 64), this data around the organizing theme of participant-based pedagogies illuminate an important area of uncertainty as to the specific level of participation students and educators felt involved in. Students and elementary teachers tended to write a larger percentage of comments favouring participatory rather than the informant-based design process utilized in this study (students = 15% versus 6% and teachers 18% versus 4%). Museum educators were equally divided with 22% informant and 23% respectively. Part of the difference in how students and elementary teachers differ with museum educators may be related to the fact that the process of inviting students and teachers to participate in the study may have skewed their responses towards a more participatory belief while museum educators were aware that the experimental software and mobile design process were being facilitated by an outside researcher.

It is also possible that, because the *Design & Learn* app was designed and built before the mobile design project itself commenced, the different digital content and activities each team designed for this project gave participants (particularly elementary students) a greater sense of ownership and participation in the project. The implications of these results and the participants’ focus on interpretive design of mobile apps as more participatory-based curricula is explored in the research narratives presented later in this chapter.

Organizing theme - Mobile learning and design: Analysis & findings.

The third organizing theme revolved around mobile learning and design. In setting up the data for review, the focus of thematic network analysis examined thematic elements identified in the previous sections including: participant views on mobile learning, technological complexity/infrastructure required to support it, and other design elements. As in the case of the previous two organizing themes, multiple passes were required and other thematic elements emerged. Within the realm of mobile learning and design, there was some overlap in participant data related to Informant Design (ID) and the types of activities the mobile technology and software could support.

Like the previous two organizing themes, the researcher was principally interested in exploring participant views around the design and use of mobile technology. [Figure 5.6](#) presents the coded data collected for analysis of mobile learning and design as the organizing theme. Like the previous two themes, frequency codes (number of statements) were developed around the thematic elements and concepts that emerged over multiple passes of the research data. The first review confirmed thematic elements existing around technical issues and participant thoughts related to the specific mobile technologies discussed in the previous chapter including the strengths and weaknesses of the iPad 2 platform and prototyping software *Design & Learn*. Participant responses connected to mobile learning and the technological and institutional infrastructure required to support current and future mobile and museum based interpretive software were also uniquely coded as thematic elements and concepts.

The rarest responses generally included a statement about mobile activities and other single word responses, affirmations (“yes”, “no” or “never” as examples) and one interesting outlier worth discussing in more detail later in this section.

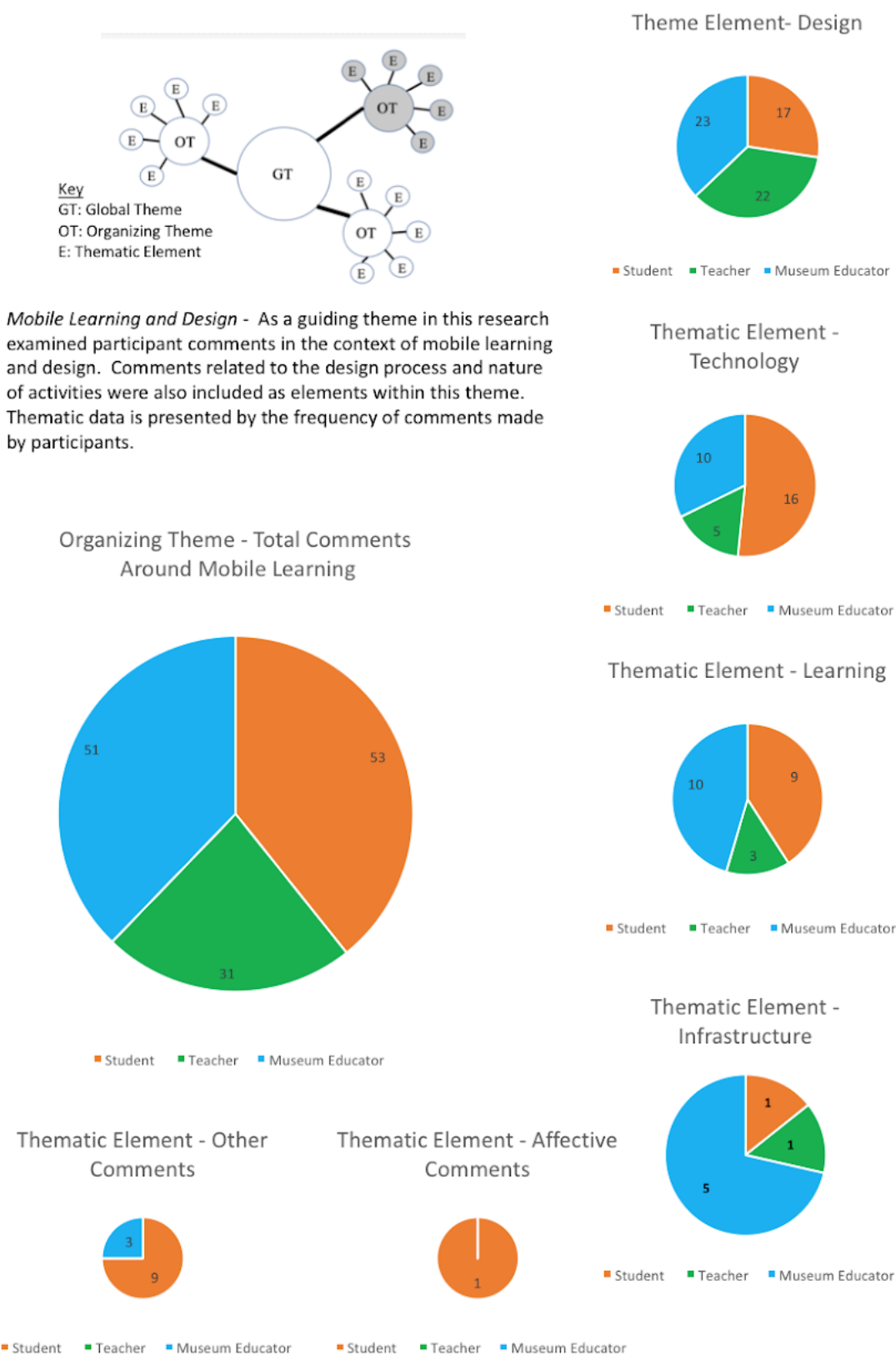


Figure 5.6: Participant data related to the organizing theme of mobile learning and design.

Like earlier organizing themes, the data around mobile learning and design from participants' surveys in this study ranges from simple exclamations to intriguing thoughts and ideas. There were 53 comments by students and 80 by educators within the organizing theme of mobile learning and design. As [Figure 5.6](#) illuminates, most of the comments by students revolved around their thoughts and ideas related to design (17) and frustrations/critiques of the poor recording and cameral capabilities of the iPad 2 systems used in this study (15).

Thoughts and ideas about mobile learning (9) were the third most frequent comments made by students. There were (9) other comments with most being a single word response "No" in response to whether or not individual students would change their team's design. Finally, in terms of student responses, there was one affective comment related to mobile learning and design by students as well as one comment related to student views on the infrastructure required to support mobile learning and design in museums.

Elementary teachers were also overwhelmingly focused on topics and issues around design (22 out of 32 comments by elementary teachers). Issues and frustrations with the iPad 2 platform and prototyping software were the second most common area related to mobile technology (5). There were (3) comments specifically related to mobile learning and one statement focused on the mobile and technological infrastructure required to support current and future mobile learning and design initiatives. No comments by teachers were recorded as either affective or other.

Like their peers from the elementary schools, the most frequent comments, thoughts, and ideas by museum educators revolved around mobile design (23 out of 48 comments). Many of the museum educators reported technical constraints and frustrations (12) with the limited recording capabilities of the older iPad 2 systems and complexity of the prototyping software

Design & Learn utilized in this study echoing many of the frustrations the participating students and teachers reported. Comments by museum educators about mobile learning (10) were nearly as frequent as elementary students and they expressed the strongest interest as a group in the conversations around the technological and institutional infrastructure (5) required to support current and future mobile interpretive design and software initiatives. Three comments were made by museum educators within the category of other and there were no affective comments related to mobile learning and design by museum educators.

Similar to earlier thematic analysis connected to participant-based design, the organizing theme of mobile learning and design illuminated a strong focus by all participating groups around design elements from either a content or technological perspective. Elementary students expressed the strongest interest (as an overall percentage of their total comments) in mobile learning and design. They were also the group most frustrated by the technical limits of the iPad 2 system and the challenge of being dependent on adults to help them with the *Design & Learn* software. Field observations and informal interviews with many of the students and educators participating in this study reinforced the responses participants reported in their surveys and illuminated within both the process of recursive and narrative analysis described in the following sections. Given that this project occurred in an informal museum setting one month after the RBCM announced a major investment in digital and online learning, it is unsurprising that the participating educators from the museum were more actively engaged in responding about the design, technical limitations, programming, and infrastructure required to support mobile learning and design initiatives in the museum. A key comment coded as other made by one museum educator stating, “I think we all started out with pre-conceived ideas about what we

would be doing” (April 21, 2016) was also significant in this study as the research narratives and overall findings of this case study are presented at the end of this chapter.

Triangulated Analysis Section 2: Recursive Analysis and Results

Recursive analysis (Patton, 2002) was also an essential analytical tool utilized in this case study. Merriam (1998) notes that, “the right way to analyze data in a qualitative study is to do it simultaneously with data collection” (p. 162). Within this framework, the dynamic process of recursion influenced both the process of constructing data for thematic network analysis and the evolving nature of research narratives presented later in this chapter. As an important methodological tool of data triangulation, recursive analysis allows the researcher to actively explore and simultaneously reflect upon the processes of data collection, analysis, and experimental modification throughout the research process (Merriam, 1998). For this research, the primary tools utilized for analytic recursion included direct observation, participant conversations and the use of a researcher’s field journal. Angrosino (2004) discusses the value and important use of both reflexive and responsive interaction and communication with participants in educational research. This is particularly essential in smaller qualitative studies like this where individual participants can significantly shape the outcome and findings of the experimental process or topic being examined.

While recursive analysis as an analytical tool was valuable within the process of simultaneously analyzing data throughout the case study, the sheer volume of data generated within the narrow window of the mobile design project required additional triangulation through the processes of thematic and narrative analysis. Given the diversity of data generated in this case study, the construction and use of multimedia/modal database forms a rich medium for analysis from multiple perspectives.

Although they may strive for objectivity in the recording and analysis of data, social researchers who use observational methods are aware of the possibility that bias arising out of the nature of observation itself may compromise their work. It is therefore desirable for researchers to become consciously aware of such possibilities and then to take steps to avoid them. (Angrosino, 2004, p. 758)

The use of triangulation and critical recursive reflection provided important tools for identifying, reflecting upon, and addressing issues of research bias (2004). Within this scenario the simultaneous analysis and experimental modification of participant activities by the researcher vectored the case in ways that illuminated the most significant findings of the theme or topic being studied. Although the recursive process of reactive modification risks omitting discoveries that are either too subtle or muted within earlier phases of research, the use of reactive modifications allow the ability of researchers to focus on areas of interest and enhance a deeper understanding of the educational elements or learning processes being analyzed.

Given the active role the central researcher in this case study played as both the project facilitator and co-designer of the experimental app software utilized in the mobile design project, the process of analytic recursion also acknowledged the inherent conflict around research objectivity discussed in Chapter 3. Most of the recursive analysis within the research process and data presented below involved key modifications of the experiment during the time mobile app prototyping activities that were completed by the design teams. Other modifications were made due to the lack of a scientific advisor for this study. The principle data utilized within the process of analytic recursion included the researcher's field notes, observations and participant feedback/suggestions within the various surveys and interviews conducted during this study. Once the data had been presented and analyzed, two recursive frameworks were identified and

constructed as having significant outcomes related to the design and use of mobile interpretive apps as mediating tools for educators and students in natural history museums and STCs.

Modifications and effects on results.

Within the process of recursive analysis, the most significant modifications to this study revolved around a significant reduction of the total time allotted for participants to complete their mobile app designs and the decision not to include a participating scientific expert or advisor as a resource each design team could access during the project. Each of these modifications to the schedule, activities, and participants involved would have important effects on the data collected and utilized for this project. These areas are explored in detail below.

Modification of schedule & activities – Effect on results.

As noted in the research narratives presented in Chapter 5, many of the elementary teachers and students were exhausted when participating in the first mobile design session for three hours after having completed a full day of school. The mobile design project was originally designed as a weekend activity, but due to scheduling issues with both the museum and school, was changed to an after-school format running on consecutive Thursdays. As both the researcher and facilitator, I had anticipated fatigue from participants from the school but not to the level reported by participants in our conversations and surveys. One museum educator wrote, “The timing of the workshop was challenging as I felt that after an hour or so the kids hit a wall after a long day of school.” Another elementary teacher reported, “They needed a lot of help focusing their topic – they really faded by the end of the day but were excited about what they were doing.” Because recursive design practices allow for a reactive process (Angrosino, 2004), it was an easy decision to trim the sessions from three to two hours which is reflected in a subsequent comment by an

elementary teacher on the second week that, “the shorter time frame today was good for their energy + focus” (April 14, 2016).

However, in my field journal, I was worried about the impact this modification would have on the process and quality of data collected. Despite the condensed schedule, all the data elements were completed for this study with one significant exception around peer review and testing discussed later in this chapter. While it was clear that both the museum and elementary teachers were satisfied with the change, a new stressor emerged in the data around concerns that participants had about completing all the elements of the *Design & Learn* app, which was originally developed to allow teams to create three mobile learning activities in the Natural History Gallery. Given the shortened schedule and intense pace most design teams were on, it was decided to make a second modification to the study around the number of interpretive

Table 5.3

Completed Activities by Each Design Team

Design Team	<i>Number and Activity Description</i>
Design Team #1	<i>2 Stations: The Beach, The Sub</i>
Design Team #2	<i>2 Stations: Bones on the Inside & Bones on the Outside</i>
Design Team #3	<i>2 Stations: Otters of Wonder & Weird and Wonderful</i>
Design Team #4	<i>2 Stations: Land Animals & Water Animals</i>
Design Team #5	<i>2 Stations: Ocean Adventure & Tidal Pool Trip</i>

Note: Number and type of activities completed by each design team.

activities each design team had to complete, instead of completing three different mobile prototyping activities, each design team was encouraged to complete at least one mobile activity

to share with other teams. As evidenced in [Table 5.3](#), every design team was able to complete at least two different mobile activities.

Within the process of recursive analysis, the impact of this modification is moderately significant as it reduced the number of mobile interpretive activities (app station) each design team could complete and share. As [Table 6.4](#) displays, only two of the five design teams were able to complete three different museum activities. The modified schedule also eliminated the opportunity design teams had to revise and update their prototypes based on the peer feedback they received from other teams reviewing their initial app designs. Like the previous issue of peer testing and evaluation, the impacts of modification and its implication are explored in [Chapter 6](#).

Omission of a scientific expert and advisor – Effect on results.

In addition to the effects of modifying the project's schedule and number of interpretive activities completed by each team, the omission of a scientific consultant and participant in this study may be considered important in terms of the its omission on the types of mobile learning activities and quality of data produced by the design teams in this study. In the original proposal, a science expert was included to act an advisor and consultant to each team. While numerous studies have illustrated the importance of accessing scientific expertise in the process of educational design and learning (Briscoe & Peters, 1997; Bybee, 1998, Barab & Hay, 2001; Tanner, Chatman & Allen 2003), it was not possible to secure funding for this position during this research. This omission of a scientific expert or advisor within this case study will be important to address in future research as some responses made by educators noted their concern about the level of participant knowledge (educators and students) and scientific accuracy of the

mobile activities their design teams were creating. The absence of a scientific advisor and/or mentor in this case study and the implications for future research are explored in Chapter 6.

Mobile interpretive apps and issues of research bias.

The use of analytical triangulation and critical recursive reflection provides an important tool for identifying, reflecting upon, and addressing issues of research bias (2004). Within this research related to mobile app design, bias was evident as well. Angrosino writes:

Although they may strive for objectivity in the recording and analysis of data, social researchers who use observational methods are aware of the possibility that bias arising out of the nature of observation itself may compromise their work. It is therefore desirable for researchers to become consciously aware of such possibilities and then to take steps to avoid them. (2004, p. 758)

Because the prototyping app software *Design & Learn* and the mobile design project at the RBCM were designed, organized, and facilitated by the primary researcher in this dissertation, there was a strong motivation on part of the researcher to ensure that the participants (particularly students) were supported and successful at some level in creating their team's interpretive app prototypes. Had the researcher not intervened in the process of guiding design teams through the technical complexities of paper modeling and the *Design & Learn* app, it is quite likely that many of the design teams would not have been able to successfully complete their digital prototypes.

In addition to the topics of objectivity and bias discussed above, within the process of recursive analysis in participant-based educational research, it was important to identify and address issues of bias within this case study. In order to validate educational research, Creswell (2012) notes the importance of acknowledging the level of bias and how educational researchers

address them. In looking at the potential of mobile science apps as educational mediating tools, the most significant issues connected to research biases are related to the three areas of inquiry within this project: educational roles, interpretive design, and the potential use of M-learning within informal science settings. In many ways, the informal observation of elementary students engaged in their own learning within the natural history galleries at the RBCM not only fostered the researcher's interest in this case study, but biased it as well. Prior to this case study, the researcher reasoned that elementary students observed using mobile devices in the natural history galleries were already engaged in some significant (but unknown) process of meaning making with their mobile devices. The researcher also assumed important learning might be occurring as well, as students recorded and shared photos and videos with their peers and other family members. Given the lack of experience all participants reported related to their use of iPads within informal settings like the RBCM discussed below, this turned out to be a significant area of bias by the researcher. Each research bias is summarized and addressed in [Table 5.4](#).

The first area of research bias related to the researcher's perceptions about how young people are using the mobile devices they possess and have access to. Although there is a significant body of research presented in the literature review around children's access and use of mobile technologies (see pages 14-16), it did not match the experiences of the elementary students in this case study. Only three of the thirteen elementary students had their own mobile device compared to 97 percent of their peers in the United States and Canada (Kabali et al., 2016; Steeves, 2014). No elementary students used iPads within informal science settings like the RBCM. However, the low level of experience by the participants in this study also illuminated future possibilities within this area of informal science education and research. As a result of the unique characteristics of the students and teachers participating in this study, accommodations

were made to provide additional tech support to each design team including an extra after school session that was specifically created for students and design teams needing additional support in converting their paper prototypes into completed digital app prototypes.

Table 5.4

Research Bias and Associated Issues

Research Bias & Issues	How Bias was Addressed in Study
<p><i>Mobile Learning Bias:</i> Students are already using their mobile devices to learn.</p> <p><i>Issue:</i> Students may be using their devices for other purposes than mobile learning at the museum such as gaming or other unrelated digital activities.</p>	<ul style="list-style-type: none"> • Peer reviewed research on children’s use of mobile devices in learning (presented in Chapter 1) • Discussion on children’s previous use of iPads in the museum settings for learning.
<p><i>Design Bias:</i> Students are designing their own learning in some significant way.</p> <p><i>Issue:</i> The student design process may not be occurring at all or is so disjointed/unorganized as to lead to misconceptions and incomplete knowledge about the exhibit they are engaged with. Also, the exhibit may not be optimized for augmented use of mobile devices by young people.</p>	<ul style="list-style-type: none"> • Discussion on children’s previous use of iPads in the museum settings for learning. • Researcher separated one level primarily by facilitating and observing students’ participation and inclusion on design teams rather than co-designing activities with them. • Post activity discussions with students and educators around their views/reflections on designing interpretive apps together
<p><i>Educational roles differ in informal settings:</i> Students and educators have different views on use/value of mobile devices for learning.</p> <p><i>Issue:</i> Students and educators have diverse views on the value of M-learning (Sharples</p>	<ul style="list-style-type: none"> • Peer reviewed research on children’s use of mobile devices in learning (presented in Chapter 2) • Discussion on children’s previous use of iPads in the museum settings for

2008; Moore 2009) within informal science settings. The researcher's view on M-learning may not be shared by other educators who see the use of technology in museum settings differently.

learning.

- Post activity discussions with students and educators to understand if and how their views may have changed by participating in the study.
-

Note: Description of the various areas of research biases and issues including how they were addressed in this study.

The second area of research bias included differences students and educators reported around the educational value of M-learning and the design and use of interpretive apps. Studies such as MacCallum, Jeffery and Kinshuk (2014) discussed the diverse views educators have around the value of educational apps. As illuminated in the results from thematic network analysis discussed earlier and the research narratives presented in the final section of triangulated analysis presented in this chapter below, many students and educators participating in this study had preconceptions about mobile technologies and M-learning. In order to minimize research bias in this area, the role of the researcher was primarily limited to acting as facilitator and observer except in the case of one design team where an absence required support as a substitute member for one session. One benefit of using of multiple design teams in this study was the observed phenomenon that each of the five design teams represented micro-case studies providing important insights into the complex dynamics of having different groups of students and educators working together in co-authoring mobile curricula.

In addition to the recursive modifications and areas of research bias addressed above, the researcher's familiarity with many of the museum educators participating in this study due to his experience as a learning team volunteer for the museum made the absolute elimination of research bias impossible. Within the process of recursive analysis discussed here, the influence of the modifications to research activities in combination with how research bias was addressed

exhibited both positive and negative effects on the results of this case study. While the limited applicability of this study was anticipated by the researcher, the results, comments and recommendations made by this group of participants significantly contributes to the future design and use of co-authored mobile apps in natural history museums and STCs discussed in the final chapter.

Triangulated Analysis Section 3: Research Narratives – Analysis and Results

Contrary to other research methodologies and analytical tools that often omit the experiences of the primary researcher, the use of research narratives in this case study intentionally acknowledges the role, experiences and actions of the central researcher. Yin (2009) notes that, “in most existing case studies, explanation building has often occurred in narrative form” (p. 120). Shulman (2004) argues that, “a case is a special kind of story; it is a narrative” (p. 497). Three research narratives were created for analysis and are presented in [Appendix H](#). The development and use of three research narratives as an analytical tool in this case study recognized the value of examining how the process of creating mobile learning software and the curricular process underlying them with participants was analyzed from the researcher’s perspective. Yin (2009) and Shulman (2002) note the value of research narratives in educational research as a process in which the researcher constructs meaning from the observed participant experiences and data. The inclusion of participant experiences, quotes, ideas and suggestions within each research narrative also provides a voice for the elementary students and educators in this study (Errante, 2000). Ollenshaw and Cresswell (2002) note that a central feature of narrative research is that it allows the “inquirer” (p. 2) to learn from their participants within the context of the setting or environment they may be working in. The research narratives were also developed within a socio-cultural context described by Jakobsson & Davidson (2012) by which

the story emerges from the social interactions and experiences of participants constructing meaning from artefacts (as represented and displayed in the natural history galleries) via educational tools and interactive learning. In this case, the research narratives examined whether the design and use of mobile science apps represented important educational mediating tools by which meaning making was socially explored and constructed by students and educators working together. The research narratives provide “raw data for researchers to analyze as they retell or restory the story based on narrative elements such as the problem, characters, setting, actions, and resolution” (p. 3). As noted in [Table 5.1](#) earlier in this chapter, there were a wide variety of collected data utilized for the construction of each research narrative summarized below including direct observations, educational artefacts (both physical and digital), interviews, audio/video recordings, and informal conversations with participants.

The research data listed above was collected into a multimedia database (secure flash drive) and library for direct use to analyze and construct each research narrative discussed in the following sections. Having a macro-view of participant data, particularly with data not easily coded thematically such as informal conversations with participants and many unique digital elements such as video recordings and photos created by the different design teams, was particularly valuable when constructing each research narrative analyzed here. Within these narrative contexts, the story and experiences of different design illuminated the rich ideas, thoughts and views of the participants involved in the mobile app design project at the RBCM. The research narratives also clarified key thematic elements utilized in the process of coding and analyzing data for both thematic network and recursive analysis presented earlier in this chapter. The combined and non-linear nature of triangulated analysis (see [Figure 5.1](#)) would, in turn, affect the analysis of the research narratives summarized below.

Research narrative #1: Changing educational roles in mobile app design.

The first research narrative (see [Appendix H](#)) explored how the inclusion of young people's designs and ideas within the process of mobile app design and learning in the RBCM's natural history galleries transformed the traditional roles students occupied within informal science education as either a student or visitor. The research narrative was constructed from wide variety of data including; survey responses, transcribed pre- and post-interviews with educators, a review of the educational artefacts different design teams created, research observations, and journaling by the primary researcher. Narrative analysis indicated that mobile apps and design did have an effect on the educational roles of elementary students. The research narrative documents how at the start of this research, the majority of participants approached the mobile design project within the educational identity and role they occupied as an elementary student, teacher or museum educator. This trend was exemplified by the following interview response from a participating museum educator discussing the process of working with elementary teachers.

Um...well I think for us...it is really key for us to align with the curriculum and the school system and to work with teachers for sure...uh...but as you know we have different objectives in situations like that so I did find that it was interesting on a couple of occasions where the teacher that I paired with...who was terrific...but she was really interested in making sure the kids understood the content of the gallery that they were in...reading, learning, and memorizing facts about the...and I am sure she is not the kind of teacher who is fact driven...it was just that they were in this environment and here is something the kids could learn about. Whereas I really want

them (as) a museum educator to (be) engaged with the exhibits and I wanted them to be curious and I wanted them to follow their curiosity. (May 28, 2016)

This observation was not surprising to deduce from an examination of participant comments and other collected data analyzed within the research narrative about educational roles. Like the use of thematic networks described earlier in this chapter, the first research narrative confirmed that participants tended to operate within prior educational roles. However, as exemplified in both thematic and narrative analysis, this research illuminated the awareness elementary students and teachers had of the different educational settings they were operating within. The research narrative also reinforced many of the features differentiating formal and informal learning described by Wellington (1991) prior to the widespread availability and use of mobile technologies and apps discussed in Chapter 1. However, within the context of social-constructivist and technologically-mediated learning, one key difference emerged. When examining the influence of mobile technology and design on learning, many of the participants noted the significant potential (and some concerns) of mobile devices and learning within the natural history galleries at the RBCM as it relates to educational roles and learning by students within the RBCM.

There was almost universal hope on the part of students and elementary teachers that the inclusion of elementary students' ideas within the mobile design initiative would empower students as not only as mobile curriculum designers, but active educators capable of teaching others at the museum. Examples of participant responses in the research narrative by students demonstrating their interest and abilities both as mobile designers and co-educators within the research narrative were exemplified in the following survey responses:

Because your [*sic*] making an app to teaching [*sic*] people about the stuff you are working on. (G4 Student, March 31, 2016).

I liked working with the adults. my [*sic*] suggestion is for the adults that want to make apps with kids do (it) more often. (G4 Student, March 31, 2016)

Let the kids do all the work unless they say they need help. (G4 Student, March 31, 2016)

The last comment is particularly insightful within the research narrative as it expressed a strong interest by students wanting more autonomy as a design group to create mobile content and activities. This suggested evidence of authentic role-play and advocacy by the students participating in this research project. McSharry and Jones (2000) examine the importance of authentic role-play within science education as an active pedagogy for “child-centred” (p. 73) inquiry. Craciun (2010) argues that authentic role-play allows students to “recognize and interpret their place in the world” (p. 176). In this case, participant desires for creating mobile activities for learning served as an important catalyst for experimental role play and the ability of elementary students to experiment with different educational roles as both co-teacher and mobile app designer.

In addition to the elementary students’ desires to be involved in the design of mobile learning apps for the museum, many educators expressed hope for student involvement and incorporating the ideas of young people into mobile learning at the museum. Examples of the views elementary teachers and museum educators expressed related to the creation of new educational roles for students included the following survey comments.

Co-design and co-creation is an important value in my learning approach to working with youth. I am trying to build a sharing culture and respectful exchange between kids and adults. (Museum Educator, March 31, 2016)

-[sic]great opportunity to connect technology into the real world – increase the use of technology for learning purposes (not just games) - opportunity for students to become “educators” in some capacity. – [sic] love that it will be interactive for students. (Elementary Teacher, March 31, 2016)

However, in order to achieve this goal for the students they worked with, some educators noted the importance of delineating educational roles of the participants more concretely as expressed in this statement from an interview.

I think at the beginning when I am saying the teacher and I could have different objectives with the kids. Even though we both know in general what each other does, it would be a good idea, I think for the museum educators and teachers, formal teachers...at the beginning of a session like this again to clarify and identify how our roles differ. (Elementary Teacher, May 28, 2016)

The data presented within the first educational narrative point to the significance of mobile technologies in fostering new educational roles as students and educators were cooperative engaged in the design and use of mobile science apps for the natural history gallery. The mobile

technology utilized in this study (though not without problems described in other research narratives discussed in the next few sections) illuminated how the design and use of mobile science apps within informal science settings can act as important precursor for more participatory educational engagement for elementary students experimenting with new roles as an extension of the Museum 2.0 and 3.0 movements described by Simon (2010) in Chapter 2. Within the first narrative, one museum educator noted how the educational technology set the stage for experimentation by students and educators working together.

And it was also interesting I think the playground was also a little bit level because neither of us knew exactly what the project was or how exactly it was going to work. So although I knew the museum and the content. She knew the students. So we were both bringing something to the...and I think that works. That worked well. It wasn't...I wasn't leading it. She wasn't leading it. But together we were finding our way through with the kids. (Museum Educator, April 28, 2016)

The first research narrative concluded by noting that while the participants in this study continued to operate within the educational roles of the formal and informal cultural institutions they are associated with, mobile technologies and digital curriculum design provided a novel way in which elementary students could experiment with educational roles through authentic role-play and participatory design. While other research around the use of authentic role-play and participant-based learning prior to the widespread advent of mobile technologies and learning existed in science museums (see McSharry & Jones, 2000; Rogers, 2003; Attewell & Savill-Smith, 2004), the strong desire reported by elementary students within this case study for an increasing educational role in the design and use of mobile science apps in museum settings is important to consider when developing these educational technologies for science museums in

the future. The use of educational role-play as a precursor towards the authentic participation and digital citizenship of elementary students within informal science settings as a form of participatory mobile design and curricular pedagogy was explored in the second research narrative.

Research narrative #2: Mobile curricular development as a participatory process.

The second research narrative in [Appendix H](#) examined participant-based pedagogies of curricular design. While there is a significant body of research on socially-mediated participant design within science museums and informal education (e.g., Jakobsson & Davidson, 2014; Rogers, 2005; Simon, 2010), the influence of mobile technologies, learning and design through participatory and social-constructivist frameworks within informal science settings is still emerging. The research narrative traced the dissonance some participants experienced around the differences existing between informant and participatory-based design. Most importantly, the research narrative illuminated contrasting perceptions between how students and educators reported about the level of involvement they experienced within the process of mobile app design. According to the participant data used to construct the research narrative (thematic network data, participant interviews, the researcher's field journal), in general the students reported much higher rates of participation and satisfaction when compared to the comments and responses made by elementary teachers and museum educators. Examples of survey and video responses made by students about their participation and satisfaction with the mobile activities their design teams created included:

I liked working with them (museum educators and teachers) because they let us choose everything. (G4 Student, April 28, 2016)

It was good working with museum educators and teachers. (G5 Student, April 28, 2016)

I enjoyed it a lot and it was fun to spend time with new people. (G5 Student, April 28, 2016)

I do because I think we did a good job designing, and because, we are the (Team Name)! (G5 Student April 28)

I think it was a little different with the teachers but I think it was a little better. (G5 Student, April 28, 2016)

Within the second research narrative about participant-based curricular design, it was also evident that many of the educators involved in this study expressed an even stronger desire for more participatory-based models of curricular design rather than the informant-based model utilized in this case study.

I would not consider the project 'designing educational software', rather it is co-designing content. This distinction was a major point of confusion at the beginning of the process. Yes, of course designing software and content with target group involvement is important, but the question is what is being tested/developed.

(Museum Educator, April 28, 2016)

I would like to think for museums to work with young people. I think it is quite amazing that you look at the end product that they created considering this was cumbersome software...So imagine if you did know the program and you (snaps finger) had a quick lickity splitz you know...up to date software...there's a couple of hurdles there...and more time...you time limited because it was after school...but what if it was a Saturday morning...or a summer half day camp or day camp...so I think there is real potential for it. (Elementary Teacher, May 28, 2016)

Overall, the second research narrative reinforced existing trends in participatory-based museums by researchers discussed in Chapter 2 such as Simon (2010) and Clinton et al. (2009). However, while many elementary students would be content to have their real names and other personal identifiable information included within the authorship of the educational apps their teams designed, several educators expressed concerns about the public nature and porous boundaries existing within the use of mobile apps that include capabilities such as social media sharing features (but not used in this study) within the *Design & Learn* app. Social media sharing capabilities within mobile science apps may act as a significant challenge for the full participation of elementary students in mobile learning and app design. This is particularly true in areas of science and education where the public discourse exists in contended space for students interested in designing mobile science activities on topics considered culturally sensitive or other controversial topics in Canada or the United States. Mobile learning activities created by students on topics such as: gender identity, sex education, climate change and evolution (in the United States) would likely be considered highly controversial and potentially dangerous for young authors if published within the public domain in app stores or iTunes.

The research narrative suggests that the accelerating capabilities of the mobile technologies in combination with the evolving nature of online communities and discourse requires significant additional research as it relates to the application and extension of mobile science apps beyond the immediate use by students, classrooms and the science museums students may be creating individually, in groups or in partnerships with educators as was the case here. The second research narrative also illuminated many important questions around the nature of public participation by elementary students within the larger public discourse of natural history museums and STCs for future research as well. This includes an examination of whether the design and development of mobile technologies as a mediating tool shapes the nature of education by its designers/users or is itself shaping the nature of education of its designers/users. While the research narratives presented so far illustrated the capabilities of mobile apps as important mediating tools for experimenting with different educational roles and levels of participation by elementary students within digitally-based informal science education, anxieties about the porous nature and possibly abusive situations elementary students might be exposed to within public forums emerged as significant challenges related to the authentic participation of elementary students within informal science communities and museums like the RBCM. The final research narrative examined the influence and impact of the mobile technology and educational software utilized in this case study.

Research narrative #3: Mobile learning & technology.

The final research narrative in [Appendix H](#) explored how participants on the five design teams utilized mobile technologies and the app prototyping software to create different mobile science activities at the RBCM. In utilizing thematic and other participant data such the digital prototypes and other educational artefacts to construct the research narrative on mobile

technologies and learning, it was evident that many of the participants had preconceptions about the design and use of mobile apps that evolved over time during this research project. This deduction was reinforced in one particularly astute survey response made by one of the participating museum educators.

I think we all started out with pre-conceived ideas about what we would be doing. It took a week or two to really get us all on the same page. BUT [sic] once we did decide on the who? what? why? how? etc., we were off to the races! It was a very satisfying + fun activity for all of us. (Museum Educator, April 28, 2016)

Key topics and events in the third research narrative include a discussion on how participants overcame their near universal frustration with poor multimedia capabilities of older iPad 2s and complexity of the *Design & Learn* software, the types of mobile learning activities each design teams created, and a discussion on how participant concepts about the design and use of mobile science apps evolved over the course of mobile design project. Each of these events and topics within the research narrative influenced how elementary students, teachers, and museum educators thought about the future inclusion of these mobile technologies for students at the RBCM. Survey responses by the participating students and educators during the first session of the mobile design project illuminated their excitement about participating in the mobile design project. Representative statements in the research narrative by students and educators included:

I love Tech and this I though was AMAZING! [sic] (G4 Student, April 7, 2016)

I am excited to make an app that makes the museum display more interactive. The students respond well to apps and they are more engaged.” (Elementary Teacher, March 31, 2016)

Despite initial optimism, once participants were engaged in the design process, the third research narrative showed near universal dissatisfaction with the multimedia recording capabilities of the older iPad 2s and the complexity of the prototyping software utilized in this research as expressed in comments by students and educators alike.

The camera quality because it was hard to work with the quality. (G5 Student, April 21, 2016)

It was the adults challenge with the iPad software that was a challenge. Challenging that the field labels are not descriptive enough. We were quite lost as to “where” we were in software design. (Museum Educator, April 21, 2016)

The second comment by a museum educator was echoed by other museum educators and elementary teachers who discussed the complexity and lack of time they had to learn how to use the software. Many of the participating educators made numerous suggestions for improving future versions of the experimental software utilized in this study. As noted in other research narratives, the participating educators were aware of the possible pitfalls of using mobile apps capable of recording and sharing user data through publicly accessible social-media platforms. This mirrors other research by Milner-Bolotin (2017) about the challenge of assisting educators

and students with the technical support required to utilize novel technologies and apps for scientific inquiry and design as was the case in this study.

Despite participant frustrations with the older tablets and the complexity of the mobile design software, there was a significant amount of experimentation and diversity in the types and content and mobile activities each design team created. While most other mobile learning research within informal science settings focused on highly specialized mobile devices and software developed without student input (see Katz, Goldman, Foutz, 2011; Roschelle & Pea, 2002; Zimmerman, 2011), this research examined what kind of educational content and activities design teams would create with the iPad. Although the *Design & Learn* software was an overly complex prototyping tool as reported by participants, it was also open-ended in the sense that the experimental software allowed participants to design mobile activities and content about a wide range of topics. Despite the app's complexity and limited capability of the iPad 2s, students were able to create a wide range of science topics related to the natural history exhibits summarized in [Table 5.5](#).

In reviewing the types of learning activities and content as it related to the NRC's (2009) learning strands for students within informal science settings, a consistent pattern emerged with participants as designers and users. The categorization of the mobile learning activities and content demonstrated that all five design teams primarily created activities within the first two strands of the NRC learning strands (see [Appendix G](#)). Results from both the thematic and narrative analysis of participant responses on surveys and interviews would suggest the novelty of the software, in combination with the limited experience participants reported in using iPads within museum environments most likely affected the types and levels of science curricula that each design team created.

Table 5.5

Types of Mobile Activities Design Teams Created

<i>Design Team</i>	<i>Description of Mobile Activities by Each Team</i>	<i>Type of Learning Activity for Students as Designer or User based on the NRC's Learning Strands (LS)* for informal science education.</i>
<i>Design Team #1</i>	<i>The Beach</i> - activity based on BC coast and tide pool exhibits asking users to find and photograph different animals in the exhibit. Video element asks users to record moving animal in the tide pool.	<i>Students as Designers</i> LS – Strand 1, 2 & 6 <i>Students as Users</i> – LS – Strand 1, 2 & 3
	<i>The Sub</i> - activity based on submarine exhibit asking users to find and photograph different animals in the exhibit. Video element asks users to record living fish in the aquarium.	<i>Students as Designers</i> LS – Strand 1, 2 & 6 <i>Students as Users</i> – LS – Strand 1, 2 & 3
<i>Design Team #2</i>	<i>Bones on the Inside</i> – activity that encouraged students to find and photograph specific animals. Video asked users to think about whether beak was a bone or not.	<i>Students as Designers</i> LS – Strand 1, 2 & 6 <i>Students as Users</i> – LS – Strand 1 & 2
	<i>Bones on the Outside</i> – activity that directed students to take pictures of specific bone and fossil elements. Video asked users what they learned about the Harbour Porpoise skeleton	<i>Students as Designers</i> LS – Strand 1, 2 & 6 <i>Students as Users</i> – LS – Strand 1, 2 & 4
	<i>Otters of Wonder</i> – this learning activity focused on asking users to think about the differences between river and sea otters (diet, fur & ecology). The video asked the users what they learned about river and sea otters.	<i>Students as Designers</i> LS – Strand 1, 2 & 6 <i>Students as Users</i> – LS – Strand 1 & 2
<i>Design Team #3</i>	<i>Otters of Wonder</i> – this learning activity focused on asking users to think about the differences between river and sea otters (diet, fur & ecology). The video asked the users what they learned about river and sea otters.	<i>Students as Designers</i> LS – Strand 1, 2 & 6 <i>Students as Users</i> – LS – Strand 1 & 2
<i>Design Team #4</i>	<i>Weird and Wonderful</i> – this activity encouraged users to explore marine and the giant surgeon exhibits. The vide	<i>Students as Designers</i> LS – Strand 1, 2 & 6 <i>Students as Users</i> – LS – Strand 1, 2 & 4

<i>Design Team #5</i>	asked users to record all the living animals in the aquarium.	<i>Students as Designers</i> LS – Strand 1, 2 & 6
	<i>Land Animals</i> – activity encouraged users to learn about and photograph forest animals using clues. Video element asks students to think about what these animals eat.	<i>Students as Users</i> – LS – Strand 1, 2 & 3
	<i>Water Animals</i> – activity encouraged users to learn about and photograph wildlife living in freshwater and marine environments. The video asked users to think about how animals stay warm	<i>Students as Designers</i> LS – Strand 1, 2 & 6 <i>Students as Users</i> – LS – Strand 1 & 2
	<i>Ocean Adventure</i> - activity based on submarine exhibit asking users to find and photograph different crab, coral species, and the water temperature gauge in the exhibit. Video element asks users to record three fish in the aquarium.	<i>Students as Designers</i> LS – Strand 1, 2 & 6 <i>Students as Users</i> – LS – Strand 1 & 2
	<i>Tidal Pool Trip</i> - activity based on Coastal BC exhibit asking users to find and photograph different birds, seals, and starfish in the exhibit. Video element asks users to record living animals in the tide pool.	

*Note: This table summarizes learning activities each design team created including general learning outcomes published by the NRC (2008) learning strands for students within informal science settings (see [Appendix G](#)).

For example, as exemplified in screenshots of the multimedia e-Books created by Design Teams #1 and #3 (see [Figure 5.7](#)), the design teams' text is combined with user generated photography.

As a result, the design and use of the mobile learning activities would be described as completion activities based on the interest and content of the mobile designer in combination with the interactive response and possible sharing by visiting students as mobile users.

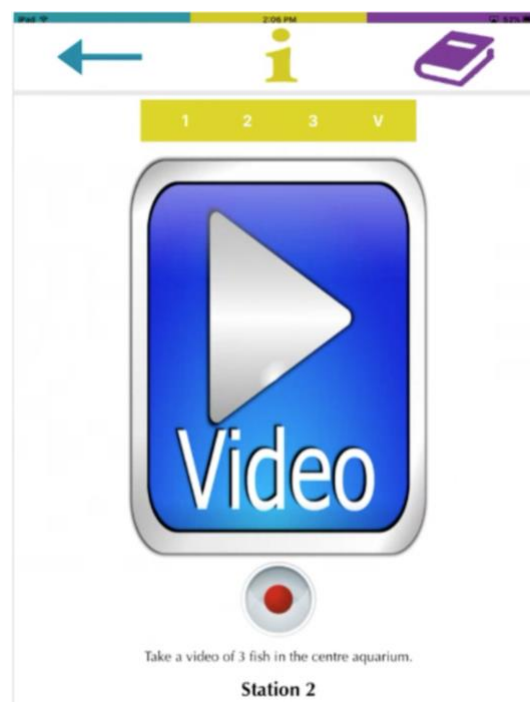
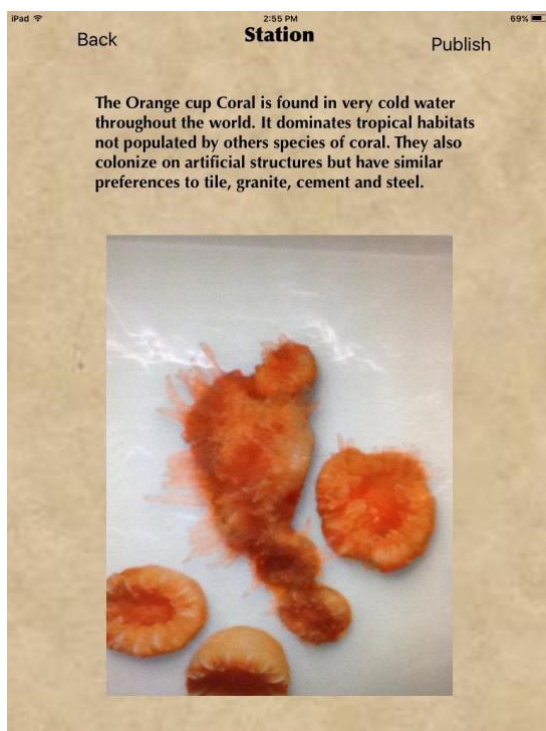


Figure 5.7: Screenshots of digital e-books by Design Team #3 (on top) and Design Team #1 (bottom). The left screen shows text by the designers with photos by the user. The right screen shows the video recording activity for users created by each design team.

Completion of exhibit-based mobile activities could be assessed based on the relationship between the designers' text and the users' photographic response and accuracy to it. The participant use of video recordings illustrated how different design teams approached the use of video elements within the mobile activities each team was creating. In Design Team #3's video activity about otters, the video response is directly related to the other content and photography the design team created for the user to interact with and complete. Design Team #3's plan to have user create a video response by the user could be utilized to assess student understanding of the difference existing between river and sea otters.

In another example by Design Team #1, the video prompt encouraged users to freely record living fish in the ocean submarine exhibit's aquarium allowing users the option of constructing a non-verbal video response of the scientific topic or phenomenon (in this case marine life) directly observed and recorded by the user. This mobile learning activity contrasted with video prompts created by other designers as illustrated by Design Team #3's more explicit question asking users to talk about the differences between river and sea otters. The video prompt by Design Team #1 utilized the recording capabilities of the iPad to record living fish in the exhibit which could be interpreted and assessed in a variety of ways by the both the users and app designers.

This exemplified the ability of the mobile software to facilitate learning not only in the user's interpretation of the artefacts and exhibits the mobile activity was designed for, but also showed how the mobile technology mediated interactivity with the exhibits, themes and topics created by the mobile designers. The participant nature of the app design tool utilized in this case study also included the potential exchange of completed mobile content (as videos, e-book or printable PDF file) by the user with family members, a school, or the museum itself.

The results of this case study support other research findings on the role physicality (Kubicek, 2005), sensory aesthetics (Hein, 2012), and the emotional responses (Falk & Gillespie, 2009) function as essential drivers within the selection of topics and mobile learning activities completed by the elementary students participating in this study. However, absolute findings are blurred by the novelty of software, the limited experience participants reported in mobile design and use of mobile apps in museums, and the short nature of this study. Despite these issues, it was evident from the third research narrative about mobile technologies and learning that the elementary students' concepts of mobile-app design evolved over the course of the mobile design project at the RBCM. In the third research narrative, students and educators reported that they had not considered the design of a place-based learning app that could be designed and used by elementary students and other young visitors to the museum.

I have not used an iPad at the museum before. I do not know what to do with it. (G4 Student, April 7, 2016)

I've used an iPad but not in a museum. I actually have one. I watch take pictures and play on it [sic]. (G5 Student April 7, 2016)

Some educators were concerned that mobile technologies and apps might distract or restrict students from the dynamic and open nature of informal inquiry.

It will be challenging at first to think of the iPad as a tool + not a distraction. I worry I won't know enough about the technology to be helpful. But I anticipate that the

students will know more + be able to answer each other's questions. In a museum setting, I value having students engage with real objects. I am curious to observe how students will behave/react to artefacts vs. technology. Where will most of their excitement come from? Will the technology enhance the learning around the object or will it distract? (Museum Educator, March 31, 2016)

When asked about what they wanted to design during the first week, many students wrote that they wanted to code and design mobile games and other virtual activities. The combination of thematic data and narrative analysis of video recordings by the elementary students suggested that student views on the idea of mobile design expanded beyond coding and the creation of games and activities in virtual environments expanded to include ideas about place-based and peer-mediated learning. When asked whether they thought their team's app design could teach other students about the natural history of British Columbia, the majority of students felt that the mobile app their design team created provided important and fun learning activities for peers.

Yes. Because your [*sic*] making an app to teaching [*sic*] people about the stuff you are working on. (G4 Student, April 28, 2016)

Yes, because it shows you all about every different place in BC. (G5 Student, April 28, 2016)

Yes. It offers something new to do for people who have been to the museum lots and it encourages people to spend more time here." (G5 Student, April 28, 2016)

Like the participating students, the third research narrative also described how educators' views shifted over time as exemplified by these sample comments by elementary teachers and museum educators.

Applying it to the real world...applying it to a museum where they go on spring break They go in the summer. They can go and see...oh...this app we created applies outside of the classroom and presentations that we do in the classroom and I think that was a really valuable piece. (Elementary Teacher, May 29, 2016)

I think it is quite amazing when you look at the end product that they created considering that this was cumbersome software. I found it cumbersome and we didn't have a lot of knowledge going in. So imagine if you did know the program and you (snaps finger) had a quick lickity splitz you know...It would be even better if they created it under those circumstances. So, I think there is some real potential for it. (Museum Educator, May 28, 2016)

The students enjoyed creating the content for this app and felt like they did a good job. It was a good experience for them. I also feel like it gave the students some ownership over the museum which is really neat. (Elementary Teacher, April 28, 2016)

As illuminated in the sample comments and observations of the participants including the design and use of the mobile app prototypes created by each team, the third research narrative confirmed that students were capable of creating mobile learning activities and content relevant to their interests. The variety of topics and activities created by each design team illuminated how student interests and inquiry transcends the current educational programming of the RBCM and the BC Science Curriculum for Grades 4 and 5 suggesting new possibilities for participant-based inquiry with elementary students at the museum. The significance of mobile content and activity design by elementary students existing as an important form of mobile meaning making and digital inquiry remains an important topic of future research discussed in the final chapter.

Chapter Summary

The triangulated analysis presented in this chapter examined the idea of mobile apps as educational mediating tools within three central research narratives including: educational roles, participant-based pedagogies, and the design/use of mobile technologies. Each of these narratives were developed and analyzed around the central research questions presented in Chapter 1.

In the first part of triangulated analysis the process of thematic network analysis of data within three central organizing themes (and research topics/questions) was examined. The process of experimental design and authentic role-play served as an important precursor to the authentic participation of elementary students as co-designers of mobile curricula within informal science settings and emerged as a key finding in this case study. The participants were oriented towards more participatory models of curricular design and frustrated by the limited capabilities and structure of the older iPad 2 systems and mobile design software used for this project. This study also illuminated how participants' views on mobile technologies and learning might shape the design, use, and construction of more inclusive participant-based interpretive

apps including the complex interpretive infrastructure necessary to support participant-based design and co-authorship. The process of recursive modification and adaptation illuminated both positive and negative effects on the mobile design project as a whole. Recursive analysis was also valuable in identifying and addressing issues of research bias and objectivity.

In addition to thematic networks and recursive analysis, three research narratives were developed and analyzed within this chapter. The first research narrative examined how mobile technologies can foster authentic role-play and potentially shift the traditional educational roles of students from that of learner and visitor to mobile designer and co-teacher. The second research narrative explored the design of mobile apps existing as a form of participatory-curriculum development and digital citizenship. Participant desires, frustrations and hopes for the future development of mobile science apps for young people were presented in the final research narrative documenting how the views of elementary students and educators about mobile design and learning changed by their participation in the mobile design project at the RBCM.

When the analysis of all three research narratives described above is combined it was evident that design and use of mobile science apps within informal science settings of the natural history galleries of the RBCM had important effects on how participants view their role within educational processes and mobile curriculum design. As important but imperfect mediating tools, the design and use of mobile interpretive apps provided elementary students with the opportunity to transcend traditional roles as student visitor to more participatory roles of co-teacher and mobile designer. Within these new educational roles, the participating students actively explored science education as it related to the shared interests of the members on their design team and the students they were designing digital content and activities for. The physicality of the exhibits

within the natural history gallery influenced the selection of topics and activities by the design teams participating in this project.

Elementary teachers and museum educators favoured a more participatory-based model of mobile app design than the informant-based process utilized in this case study. New forms of mobile meaning-making emerged as well with young designers inspired by the physicality and sensory aesthetics of informal science exhibits acting as sources of direct inspiration for creating new ways for other young visitors to both interact with and respond to the natural history exhibits at the RBCM. The process of triangulated analysis summarized in this chapter led to important new discoveries around the design and use of mobile interpretive apps as educational mediating tools within informal science education. The expressed desire by both the participating teachers and students in educational design reported in this case study is an exciting opportunity for natural history museums and STCs interested in participant-based design and augmented mobile learning. The implications and future applications of place-based mobile content created in partnership with young people within informal science settings are discussed in the final chapter.

Chapter 6

Discussion, Research Implications & Future Directions

Chapter Overview: Starting with an overview of the primary research questions that formed the foundation of this research project, the final chapter summarizes key findings and implications within mobile-interpretive app design processes involving elementary students. In discussing current and future research efforts, emphasis is focused on the design and use of mobile interpretive apps as imperfect educational mediating tools within the process of co-authoring mobile science apps and digitally-based curricula that include the participation of elementary students and other young visitors within educational discourses occurring at natural history museums and STCs. The chapter concludes with recommendations for incorporating the ideas and voices of young people within mobile and digitally augmented forms of participatory-based science education.

It offers something new to do for people who have been to the museum lots and it encourages people to spend more time here. (Grade 5 Participant, 2016)

It was neat when we were nearing the end. It had got quite stressful and I am like, ‘Oh no! Am I going to be able to finish this on time?’ But in the end, it worked out. (Grade 5 Participant, 2016)

Co-creative projects progress very similarly to collaborative projects, but they confer more power to participants. Staff members and community partners work closely to achieve their shared goals. The project development process is often co-determined by the preferences and working styles of participants. The result is a project that is truly co-owned by institutional and community partners. (Simon, 2010, p. 264)

Discussion on Participant-based Interpretive Design

This research explored participant-based models of mobile interpretive app design for young people within socio-constructive research frameworks connected to educational roles,

participant-based pedagogies, and mobile design/learning through the process of *triangulated analysis*. As presented in the preceding chapter, triangulated analysis and research allowed for a more in-depth and critical examination of the participant experiences, collected data, artefacts, and observations made during this study.

Given the small population and use of the experimental software in this research, the process of triangulation was particularly valuable as it allowed multiple passes over the participant data using three different analytic tools selected for this research including: thematic networks (pages 123-141), recursive analysis (pages 141-150), and research narratives (pages 150-171). When combined, each analytic tool illuminated new areas of inquiry, challenged pre-existing research biases about elementary students' involvement in M-learning, and generated excitement around the future use of co-authored mobile apps with children. Key analytic crossroads and discoveries are explored in more detail in the following sections.

Thematic Elements and Patterns Within Research Narratives

When combining the analytic processes of thematic networks and research narratives, a complex interplay emerges where coded elements and themes illuminated within the data also formed important aspects of the constructed research narratives and vice versa. As an analytical research tool, the dynamic significance of thematic network analysis as it relates to narrative and recursive processes cannot be understated. Attride-Stirling (2001) notes that thematic networks are effective tools when exploring the structure and patterns around the central global theme. Within the context of analytic triangulation, thematic network analysis extended the overall understanding of the initial findings and organizing themes examined during narrative analysis. If recursion is the process of critically evaluating and/or reviewing each research narrative as embodied by the experiences of participants over the course of the research project, thematic

network analysis illuminated patterns that potentially challenged, supported, or directed the narratives emerging from this research in new directions. For example, within the thematic network analysis and discussion presented in Chapter 5 as it relates to educational roles, it was evident that students and museum educators tended to respond from the cultural identities and roles they occupied as students or museum educators respectively. Elementary teachers were aware of the informal nature of the museum learning environment and shifted towards more balanced responses with roughly an equal number of comments related to formal and informal learning.

Participant comments around design were also refined throughout the process of coding and thematic analysis. The frequent use of affective statements by elementary students in their responses to the survey questions illuminated how emotion, interactivity and the visual aesthetics of the museum exhibits influenced student interest and the topics and activities they decided to work on with their design team. In this study the elementary students tended to exhibit a greater sense of optimism about the level of participation they experienced in the mobile design project. Responses by museum educators and elementary teachers voiced a strong preference for more participatory models of digital curricular design rather than the informant model utilized in the mobile design initiative at the RBCM. In the area of mobile learning, students expressed more satisfaction with the content and activities their teams created with surprisingly few young designers wanting to revise their design team's mobile app prototypes. Instead, they saw the potential of the mobile technology and discussed other topics and mobile learning activities they would like to design for their friends and peers. The majority of educators wanted the student activities their design teams created to go beyond basic levels of content knowledge towards deeper levels of digital and science inquiry that extended beyond the physical exhibits of the

museum and include applications in nature and the larger community. The patterns emerging within thematic network analysis reinforced how powerful a tool analytic triangulation can be when examining the global theme of this case study as many of the thematic patterns and elements were incorporated into the final research narratives discussed in the next section.

Research Narratives and Recursion: An Evolving Story

In many fields of educational research, the story of the primary researcher is often omitted and/or de-emphasized in the discussion and results of published studies. Yet as Yin (2009) notes, "...explanation building often exists in narrative form" (p. 214). Moen (2006) writes that one of the most meaningful units in research is the narrative as it weaves diverse elements within the context of a story. As such, this research acknowledges the central role and orientation the primary researcher fulfills within the process of proposing the project, designing the experimental software utilized in this study, and facilitating the research activities with educators and students at the RBCM. This is important to keep in mind when examining the value of the research narratives presented in Chapter 5. Guba & Lincoln (1994) and Lagemann (2000) note the challenge of maintaining objectivity within this form of research. It is at this point where the value of including recursive analysis is most valuable in triangulating data. Recursion allowed the research to be critically examined and revised as new data and discoveries were being made.

One important example discussed in Chapter 5 examined how the researcher's assumption about the existing use of mobile technologies by students for meaning making was challenged by the inexperience and lack of access many of the participating elementary students had with the use of iPads in informal settings like RBCM. While many of the students reported that they had used an iPad at school and some responded about their use at home, none had used an iPad in a museum setting. When asked how many of our participants had cell phones or other mobile

devices, only three of the thirteen students had access to a mobile device and one student had to share with a sibling. In investigating this further, the participating teachers who also worked at the same school reported that many of the students came from families with limited income, coinciding with research on the digital divide and its persistence in many communities as presented in Chapter 1. The lack of access and experience students reported in this study with mobile technologies and learning echoes challenges researchers have noted in other areas of museum and science education (Dawson, 2014; Livingstone & Helsper, 2007; Norris, 2001; Warschaur, 2003) within socioeconomic and multicultural contexts. The inclusive development of participant-based mobile technology to address issues of equity and access within informal science education will continue to represent a significant area of future research.

As evidenced in this study, the process of recursive analysis and simultaneous modification allowed the researcher to address the lack of experience participants reported by providing additional technical support and an extra afterschool design session for elementary students and educators novel to the use of iPads in museum settings. While just a moment in the research narrative itself, the initial participant responses when combined with the process of dynamic recursion and modification resulted in a more positive outcome for the younger participants in this study as reported by their overall success and sense of satisfaction with the mobile designs and activities their teams created. The process of recursive analysis and experimental modification also influenced how the research narratives unfolded and were analyzed as well as it reinforced awareness about the important socio-economic and cultural factors related to the access, design and use of mobile interpretive apps in this particular case study. New questions around mobile and participant-based curriculum design emerged from the constructed narratives

in this study that will inspire future research. Could mobile apps be utilized as mediating tools if they were not accessible to young people to use and experiment with?

Mobile Interpretive Apps as Educational Mediating Tools

As illuminated in the participant data and triangulated analysis presented in Chapter Five, each analytic tool discussed above contributed towards a greater understanding of the global theme within this study: mobile interpretive apps as educational mediating tools. [Table 6.1](#) presents key research findings and topics of interest for further study. This case study examined how the educational roles and participant conceptions of mobile curriculum design and learning shifted when elementary students were invited to participate in the design of mobile science apps for the natural history galleries at the RBCM. As participants, the elementary students in this study enjoyed designing mobile activities in partnership with educators at the museum and expressed a strong desire for the RBCM to continue developing programs for young people in the area of mobile app design and participant-based learning at the museum.

The research narratives analyzed in Chapter 5 documented a schism that emerged where many of the elementary students reported higher levels of satisfaction with the mobile content and activities their teams had completed compared to responses by many of the educators the students worked with. While this may revolve around the developmental nature of Grade 4 and 5 students, the dominant perception by these young designers that they felt empowered as authentic co-designers is significant when considering the inclusion of young people into the design of mobile science apps for natural history museums and STCs. This case study demonstrated that, over the course of four weeks, students' initial orientation and conceptions (expressed via comments and survey responses) about the use of mobile technologies for playing video games and completing other activities in virtual environments shifted. Despite the lack of experience of

using iPads in museums settings, at the end of the mobile design workshop, elementary students expressed a strong interest in place-based design and digitally-mediated learning activities at museums like the RBCM. The process of designing mobile science activities by groups of students and educators working together allowed elementary students to experiment with different educational roles as mobile content designers and peer users. This illuminated how authentic role-play can serve as an important pre-cursor to more inclusive participant-based design and digital citizenship within natural history museums and STCs.

For educators, curriculum designers, and researchers interested in more participatory-based models than the Informant Design process utilized in this case study, an understanding of Arnstein's Continuum of Power (1969) presented on pages 85 and 86 describes the inherent challenges of fostering the inclusion of young people as authentic and equal partners within the process of curriculum design. While the clear majority of elementary students in this research felt empowered as participants and designers as exemplified in the data analysis and participant responses presented in Chapters 5, the same was not true for educators. Many of the responses and suggestions made by educators expressed a desire to push the boundaries of student participation farther. It was evident that educators participating as informants in this case study wanted to shift future participation and design from a consultative model within Arnstein's Continuum of Participation toward more collective models that allow children to initiate and share educational decision making as equal co-learners. The participating educators were more aware of the porous nature of mobile technologies and using social media elements that potentially included risks of cyberbullying and trolling of students wanting to share and publish content in public domains.

Table 6.1

Research Findings from Triangulated Analysis

Research Question 1: *What effects do mobile technologies and app designs have on the educational roles of students and educators working together to create informal science education content and activities at natural history museums and STCs like the RBCM?*

Research Results**Findings Related to Students & Educators**

Educational Roles: The design and use of mobile science apps allowed students to experiment with new educational roles.

Students allowed to experiment with new roles of *co-designer & educator*

Connection to Educational Research: Authentic Role-play and User-Centred Learning

Educators ceded authority over content and supported students as mobile curriculum designers

Research Question 2: *How might the interpretive pedagogies and the participation of young people and educators in mobile design initiatives contribute toward a co-authored interpretive design process that fosters more socially-engaged and self-directed learning within natural history museums and STCs?*

Research Results**Findings Related to Students & Educators**

Participant-based Curriculum Design: The design of mobile curricula based on the informed participation of students and educators.

Students felt empowered as participants and want to continue partnering with educators to create M-learning activities in the museum.

Connections to Educational Research: Participant Design & Place-based learning, Digital Citizenship

Educators wanted more participation and deeper inquiries created by students and are concerned about porous nature of mobile technologies and their possible misuse within the museum.

Research Question 3: *What opportunities and challenges exist in the development and use of mobile interpretive apps for facilitating social and self-regulated learning among young people in the natural*

history galleries at the RBCM?

Research Results

Findings Related to Students & Educators

Mobile Technology and Learning: The design and use of mobile activities was influenced by the physicality of the exhibits and tended to focus on knowledge based content and activities.

Connections to Educational Research: Mobile learning as a form of meaning making, technical and social challenges associated with M-technologies and public sharing

Use of mobile technologies for place-based mobile learning that was novel for both students and educators in this study.

Educators and students have pre-conceptions about the design and use of mobile apps within informal settings like museums.

Students wanted to acknowledge personal authorship over the mobile content and activities their design teams created.

All participants were frustrated with the poor multimedia recording capabilities of the iPad 2 system and complexity of the prototyping software used in this case study.

Note: Description of the various research findings and connections to educational research. For educators, curriculum designers, and researchers interested in more participatory-based

The challenge to the full inclusion of children's ideas, activities and participation within public discourses is an important area for natural history museums and STCs to consider. The perceptual differences observed between the students' sense of participation and desire for authorship of mobile content in contrast with the participating educators' recommendations for greater levels of student participation in combination with the above concerns about mobile technologies is a subject of future research discussed later in this chapter.

The design and use of mobile interpretive apps by students and educators in this case study indicated that the mobile app prototyping software such as the experimental *Design & Learn* app operated as an important, but imperfect, educational mediating tool. When the discussion of

Wellington's (1990) features of formal and informal science education from Chapter 1 is projected forward within the context of M-learning and digital curriculum design described in [Table 6.2](#), mobile technologies and science apps act as an educational bridge supporting many of the central features of both formal and informal science education. As educational tools, the ubiquitous and spontaneous nature of mobile technologies allows them to be leveraged in both formal and informal science settings (Crompton et al., 2016). Mobile apps and learning can be personalized for individuals or used collaboratively by groups of students to explore different science topics and activities (Cahill et al., 2011; Zimmerman, 2011).

In designing mobile activities alongside the students they were working with, the participating educators were impressed with the variety of topics and activities elementary students created. Many of the examples described on [Table 5.5](#) illustrate to what extent these five design teams created mobile learning curricula that exceeded the number of existing educational programs and topics currently available for students to participate in at the RBCM. As educational tools, participatory-base mobile curricula initiatives like the one described in this research allow for more personalized learning as teams engaged with the exhibits differently while constructing mobile learning activities. However, as imperfect mediating tools, it is likely that institutional concerns by natural history museums and STCs connected to student authorship, user privacy, and the accuracy of mobile apps and content developed by elementary students will likely remain significant issues as educators and students begin creating mobile and digital content in science education. As an area of future research, institutional concerns about authorship, privacy, and content accuracy are discussed in the following section.

Interestingly, mobile learning and literacy is not specifically mandated within the BC curriculum for elementary students' suggesting it has many parallels with informal education at the time of

this writing. However, many mobile apps do contain specific user agreements and licenses that will likely play a significant role as to how mobile science curricula are utilized in both formal and informal settings. The RBCM master plan for education presented on the bottom row contrasts with Wellington (1990), echoing the increasing level of cooperation between formal and informal science education since the article was published (see discussion about Wellington’s article in Chapter 1).

Table 6.2

Features of Informal, M-Learning and Formal Science Learning

Informal Learning (Wellington, 1990)	M-Learning & Children	Formal Learning (Wellington, 1990)
<i>Features</i>	<i>Features</i>	<i>Features</i>
Voluntary	Ubiquitous/Spontaneous	Compulsory
Open-ended	Blended & Interactive	More closed
Learner-led	User/s-led	Teacher-led
Learner-centred	User/s-centred	Teacher-centred
Social aspect central, e.g. social interactions between visitors	Private or Collaborative Virtual or Place-Based	Social aspects less central
Undirected	Undirected or Directed	Directed
Not Legislated	Terms of Service & Use	Legislated (controlled)
RBCM Master Plan (2016-2017)	M-learning as a Mediating Tool	BC Science Curriculum (2017)
This enhanced learning program, with its web portal and revamped tours, will provide students and teachers province wide a stronger and more comprehensive BC perspective, learning	M-learning and technology allows learners to access information based on personal interests, level, and learning style. Learners can create, share and evaluate content individually or in	The Science K–9 curriculum supports a place-based approach to science learning and ensures that environmental learning is present throughout the subject area. (BC Ministry of Education, 2017)

<p>opportunities directly linked to the curriculum, and greater and more equitable access to the collections at the museum. (RBCM, 2016)</p>	<p>groups.</p> <p>M-learning and technology allows proficient educators to act as facilitators and guides for individual or groups of students. Educators can use mobile technologies and apps to personalize and differentiate learning around different topics. Groups can interact, collaborate and discuss shared work. M-content and activities can be assessed using different tools. Educators often learn alongside their students.</p>	<p>BC Curricular Goals Include:</p> <ul style="list-style-type: none"> • Understanding of Nature of Science • Develop place-based knowledge • Develop conceptual and procedural knowledge of science • Develop habits of mind • Become scientifically literate citizens (BC Ministry of Education, 2017)
<p><u>Grade 4 & Grade 5 Programs:</u> Multiple onsite and broadcast science programs for K-12 classes which can also be designed around needs of teachers and their classes. The natural history gallery exhibits biomes and multicellular organisms for study.</p>	<p><u>M-Learning:</u> Multiple third party science apps that could be utilized for learning/interaction and peer sharing. <i>No science museum apps discovered that allow students to create their own learning content and activities.</i></p>	<p><u>Grade 4 & Grade 5 Science Curricula:</u> G4 Science – senses, biomes, matter, lunar cycles G5 Science – multicellular organisms, chemical solutions, simple machines, types of rocks & rock cycle</p> <p><u>M-Learning:</u> Multiple third party science apps that could be utilized for learning/interaction</p>

Note: This table identifies features of formal and informal science education from Wellington (1990) and compares these features with M-learning from examples by the RBCM and BC's science curriculum.

As illustrated in [Table 6.2](#), the RBCM has a wide variety of educational programs designed to meet the needs of K-12 educators and their students including both onsite and offsite learning opportunities. In addition to their educational programming, the RBCM does have one app for young visitors at the primary and pre-school level and a second app for the general public on exotic and non-native species in British Columbia. In addition to online and onsite educational

programming, the exhibits at the RBCM show connections to the formal BC science curriculum for Grade 4 and 5 students as it relates to natural biomes and multicellular organisms. The natural history galleries can also be described as representing place-based learning within both the formal and informal science curricula of BC.

However, before discussing the potential and future use of mobile design software by students and educators, it is important to discuss the technology associated with M-learning utilized in this research in more detail. The evolving capabilities of mobile devices to run interactive apps and create mobile content and activities create new opportunities for independent learning by students and other young visitors. In fact, one museum educator questioned if educators would even need to be involved in the design and sharing of mobile interpretive apps by students and visitors once the technical complexity and ease of use by students was more effectively worked out. She stated:

Maybe their own circle of culture? That their own experiences and what they want to do and how to do it and go from there. But I don't know how...Is it required that we would have to be involved with that? I don't think so. Is it a better product? I don't know maybe it is maybe it is not. (29, November 2016)

This participant's comment is intriguing in its acknowledgement of the unique educational spaces elementary students and other young visitors occupy within formal and informal science settings and how they learn. There was some hesitancy to add an additional structured layer of digital interpretation even if it was content co-created with the students. Another museum educator wrote:

I think the way the 'co-design' was structured replicated [a] visit where the chaperone is asked to get out of the way and only take part when the student needs

help. I am more interested in embracing us all as learners, and going deeper into intergenerational learning and design. (29, November 2016)

Although there were some initial fears that students might become bored or disinterested in the natural history gallery by spending so much time there, several educators noted that the process of designing M-learning activities around the different physical exhibits in the natural history gallery engaged students even more deeply. One museum educator wrote:

Yes. The group using the app found out new info about the creatures in their mission. They looked forward to watching/reading their book + exclaimed “Wow” about the fact regarding the sea cucumber. Even though they had spent time in the museum, they were looking more closely and finding new things. (28, April 2016)

These comments recognize the unique space elementary students occupy as visitors and learners within informal environments. As mobile technologies and apps become more ubiquitous, it is quite likely that students, like the adult visitors around them, will use their devices to construct meaning and capture memories of their experiences and interactions within science museums in novel and diverse ways. Adult concerns about the high levels of screen time students are exhibiting with their mobile devices (Common Sense Media, 2013 & 2017; Kabali, 2016) will also likely drive strong interest on the part of some natural history museums and STCs to create physically active “screen free” exhibits as well.

This research on mobile science apps that are co-created by students and educators working together does not advocate for the replacement of other key forms of physical inquiry and interactivity students engage in at science museums. However, key findings in this research indicated that participatory-based mobile design initiatives with young people provide new forms of science exhibit interactivity and learning by students acting as mobile curricula designers and

users. This research also demonstrated that mobile apps co-designed with elementary students provide a more accessible digital tool for participatory-based learning and civic engagement compared to other adult social media sites such as twitter or Facebook.

Although the *Design & Learn* app could design and prototype three different interpretive activities, the lack of experience participants and educators had with prototyping software combined with the limited time (four sessions) students and their teams were allocated to complete designs were major obstacles for each team. Based on participant experiences and suggestions, future iterations of the *Design & Learn* app would be greatly simplified and reduced to one interpretive prototyping activity. Subsequent versions of the experimental app would be limited to creating one mobile activity that design teams could complete. In order to create multiple activities, additional iPads or resetting their team's iPad's prototyping software would allow students and educators to create additional M-learning content and activities. Further development of the software utilized in this study would also focus on newer iPads with better multimedia recording capabilities as well.

While this study focused on the use of Swift-based app design and the iPad system, it should be noted that the underlying educational and curricular processes could be replicated using other mobile operating systems and tablets using Android, Python or other equivalent software. Despite the technical challenges and complexities of the prototyping software, nearly every participant in this study (young and less young) wanted to push the technology further in designing and sharing the interpretive knowledge and activities they created for the RBCM's natural history gallery. Many of the participants' comments and suggestions served as inspiration for both the future development of educational software and more authentic co-authoring activities discussed later in this chapter.

Implications of Co-authored Interpretive Apps as Educational Mediating Tools

In considering the present and future use of mobile interpretive apps as educational mediating tools, it is important to consider what implications this research might have in other educational contexts, settings, and research. During the mobile design project, the majority of responses by participating educators focused on technical aspects of inputting students' ideas and designs within the software itself. Once the apps were designed and shared with other teams, many educators began to reflect and discuss the potential use of mobile digital apps and the infrastructure required to support its use in museum settings like the natural history gallery at the RBCM. For example, while not used in this study, the *Design & Learn* app was capable of sharing students' projects through social media sites and email. In thinking about the social and technological possibilities one elementary teacher said:

The one thing that I do like about being able to send yourself from the app that you made is that you take ownership over what you are doing. It is not just...I am going to take a picture and be silly and make some videos. You are actually creating something that you get to share. Versus...if you know that is not going to go anywhere or do anything then I will just fuss around and be silly. You know. SO [sic] it gives them that element. (May 11, 2016)

As noted earlier in this chapter, natural history museums and STCs have to be cautious as well with student-generated content and activities as shared by her colleague:

The other thing you have to think about too is if it is going out to the universe (laughter) is making sure that the content they are putting on there...I can see someone picking this up and doing something that is not appropriate and then is

shared on social media where everyone can see it and...you have to be really careful.

(May 11, 2016)

This research looked at constructivist model for interpretive design as discussed in Chapters 1-3. Within Vygotsky's theory of social constructivism, language is one of the most important cultural tools mediating learning (1978, 2004). Given the extensive capabilities of mobile devices to capture thematic and discursive data related to the co-creation and use of mobile interpretive apps by educators and students, the potential examination of interactive and participant-designed science apps as digitally-mediated conversations echoes Jakobsson and Davidson's rich sociocultural and digital matrix of social constructivism (2012). In this case, the process of social interaction and the emotional appeal of the various artefacts and exhibits displayed within the natural history galleries inspired further digital inquiry and exploration by the members of each design team. The mobile technology was leveraged for the social mediation of artefacts (Vygotsky, 1978; Wertsch, 1991) in a complex process of digital meaning making. As mediating tools within social-constructivist contexts above, interactive and participant-based mobile science apps were effective in fostering digitally-constructed and technologically-mediated conversations between educators and students operating as both designers and users. This research also illuminated the potential co-created apps might play as a form of digital inclusion and civic engagement as young people create and share their ideas and designs within exhibition spaces and the science museums' social media platforms. The analysis and comments made by educators about student learning in Chapter 5 also described how students' perceived ownership about the mobile content and activities they were creating and sharing with other teams enhanced student learning about specific exhibits or artefacts within the natural history galleries of the RBCM. The examination of secondary conversations between the designers and

users of the digital interpretive tools as educational responses to the M-learning content and learning activities created by designers exists as a future area of research.

In addition to the role mobile apps can play as educational mediating tools, this study illuminated how participant-based mobile apps signified new forms of digital meaning making within informal science education and learning. In this case, the mobile prototyping software not only facilitated important conversations between educators and students as they created mobile learning content and activities, but also represented the product of inspiration and interactivity as student designers socially-constructed meaning through the physical interaction with science exhibits, artefacts, and mobile content the science app was designed for. Once completed by designers, as mobile curricula, participant-based science apps functioned as a secondary source of digital meaning making by visiting students as users interacting with science exhibits and constructing their digital responses individually or with peers. Digital responses to participant-based science apps could then be shared with peers, family members, schools, and the science museum itself. Student designs and responses to the mobile content elementary students co-create with educators can also be evaluated and corrected as a learning tool for both students as designers and students as users. As discussed in the previous section, it should be noted that the design and use participant-based science apps would exist as one of many educational options for learning and exhibit interaction students and other young visitors could choose from and explore at the RBCM and other STCs. Student and participant-based learning may be of particular interest for students already familiar with the museum or wanting to design mobile learning activities and content around specific exhibits, topics or other scientific artefacts in more detail as exemplified by many of the mobile topics and learning activities created by the design teams in

this case study. A key issue for future research, identified earlier in this chapter, would be the challenge of evaluating student-designed content for scientific accuracy and learning.

This desire to be involved in mobile curricula development by young people in combination with expressed preference by the participating educators for more participatory models of app design uncovered many of the challenges associated with informant-based models within natural history museums and STCs. The inclusion of students' voices and ideas is particularly important within the evolving Museum 2.0 and 3.0 movements underway in Natural History Museums and STCs in Canada and the United States. Participant-based mobile design represents a rapidly evolving form of authentic inquiry and public engagement with science and museum educators that young participants are keen to participate in with science with. This research also demonstrated how the design and use of mobile science apps such as the experimental software utilized in this research like represents a wave of mobile educational research and activities designed by young people and other informal app developers for natural history museums and STCs. A key challenge within Informal Science 3.0 lies in an understanding of the complexity of possibilities of participation by young people as demonstrated in this research; these possibilities include being involved in authentic role play, mobile learning design, and as a user. Underlying all these roles for elementary students are larger issues within science education and informational technologies including orientations related to citizen-based science and digital citizenship.

Despite the potential use of mobile interpretive apps as mediating tools for the inclusion of elementary students' ideas and activities for their peers, the structure of the mobile design project and complexity of the educational software partially reinforced older models of interpretive education where elementary students are following a digitally structured path that is both

facilitated and guided by the educators they worked with. The resolution to this problem is addressed in future research discussed in the next few sections including the presentation of a model for participatory-based mobile design by students and educators working together within informal science and museum settings.

The participant data also illuminated the trend of younger designers' tendency to focus on activities and content while the participating educators primarily supported students and discussed the nature of mobile learning and app design. Although the process of Informant Design was useful within the context of the limited funding and time available for research, ultimately it cannot be considered as a fully inclusive model of participant design for either the students or educators involved in this study. This is due to several factors. First, the prototyping software was designed in advance of the mobile design initiative without participant input, which would have made its design and use much simpler for students and educators new to the technology and process of mobile design. Another key factor revolved around the format and structure of the Informant Design process itself, which, due to time constraints and institutional requirements, was designed without the input of the participating students. Despite these caveats, the results presented in Chapter 5 would suggest that the mobile design project met the goals of Informant Design of including elementary students' ideas and activities within the process of creating M-learning activities for the RBCM's natural history galleries. Research findings, in combination with participant recommendations for even more participatory-based design and input by elementary students, inspired several ideas around the future inclusion of interpretive voices and activities created by elementary students and other young visitors in natural history museums and STCs.

As an educational mediating tool that is increasingly capable of designing place-based science activities by students operating as both designers and users, mobile technologies and science apps can facilitate personalized and differentiated learning within both formal and informal science settings at the RBCM and other science museums at multiple levels including individuals, groups, and possibly the community at large if student prototypes are fully developed and published within different app stores such as iTunes or Google Play. In this case study, the mobile interpretive apps operated as important but imperfect mediating tools between the elementary students and educators at the RBCM. The triangulated analysis illuminated the ability of participant-based mobile app design to allow elementary students to experiment with different educational roles as mobile learning designers and users. The elementary students in this study expressed a strong desire to both co-author digital content and M-learning activities with educators and independently. The elementary teachers echoed their students' interest in developing mobile content and learning activities in partnership with educators at the RBCM, suggesting its potential in future professional development and education programs for educators within informal science education as the Science and Museum 3.0 trends are concurrently emerging within formal education. Many of the participating teachers, as exemplified in their responses quoted earlier in this section, noted the value and future use of these technologies by students and teachers for informal science learning in the future once many of the design and technical complexities of mobile design software such as the experimental app utilized in this research have been simplified and made more user friendly. Educator responses and recommendations received in this case study are in line with other reported trends in near future use of mobile software and learning in formal and informal settings (Crompton, 2016; Druin, 2009). Just as pre-service teachers are taught how to create classroom blogs and other websites

today in the vast majority of teacher education programs, primary and secondary teachers will likely be constructing mobile learning activities including app development at the primary and secondary levels within the near future.

The desire by students and teachers to be more involved in the design and use of mobile digital content in this study conforms to continued influence of participatory museum design (Rogers, 2003) and the Museum 3.0 movements (Simon, 2010) explored in Chapter 2. In this case the design of mobile content and learning activities, in combination with the increased capabilities of mobile devices/software and increased perception by students and teachers about their value in engaging with museum exhibits, illuminated the potential of these technologies to foster a more inclusive and participatory learning environment for natural history museums and STCs interested in fostering increased public participation. Given the definition of informal science education as the voluntary and lifelong engagement and learning by visitors including students (Griffin, 2012; Friedman, 2008; Wellington, 1990), the design and use of participatory-based mobile science apps allow natural history museums an additional mediating tool to meet the diverse educational requirements of their visitors, including young students, as was the case in this research. This is particularly true for visitors, students, and formal educators interested in designing their own learning experiences for their peers or students.

It should also be noted that the mobile software utilized in this study was dependent on the exhibit, topic or artefact the designer created it for. While the exhibits and artefacts contained within the natural history museum were created for visitor interaction and learning independent of any mobile technology or app, in this case the M-learning activities completed in this study invited users to explore topics in novel ways based upon the design by each team (see discussion pages 162-170). The app was not designed to replace physical interactivity and learning by

visitors, but as a supplement, allowing for new ways to engage with and interact with the museum's exhibits and artefacts. This is particularly important within science education where many scientific phenomena and artefacts are difficult to observe and replicate (see discussion on pages 38-41) in classroom settings such as reconstructed models/dioramas of extinct species and environments. This result was confirmed by participant responses related to exhibit engagement and design as a source of personal ownership of design and learning by students as they created mobile activities for their peers.

Perhaps most importantly, as mediating tools, the participant-based mobile science apps utilized in this study illuminated how students and elementary teachers can increase their level of participation in educational design and also, through the production and sharing of co-authored activities and mobile content, foster new forms of social discourse within the science museums' physical and online forums. This is particularly true as it relates to social discourses and how they might interact with and influence the nature of informal science education when co-authored mobile content and activities explore issues related to STS-E (Aikenhead, 2006; Pedretti & Nazir, 2011) and problem-based learning (Cahill et al., 2011). As educational designers capable of co-authoring a more diverse range of mobile science content, elementary students can create a wider range of interactive and socially mediated mobile activities for their peers than what currently exists within natural history museums and STCs. It is quite likely that issues of scientific accuracy and misconceptions would arise within the body of mobile learning content and activities students would create. In addition to meeting the educational requirements of the participating museum or school, the inclusion of a peer review process on student content provides additional user practice and experience critically evaluating the designs of their peers for scientific accuracy and applicability with the exhibits or artefacts the mobile learning activity

is designed around. When combined with peer users operating as active respondents to the diverse mobile experiences co-authored by peers, and socially mediated by the natural history museums and STCs, new forms of public engagement and discourse emerge for young people now positioned, by the production and use of mobile science apps operating as mediating tools, to participate in the larger social discourses related to science, education and society.

Although many of the issues and challenges associated with the use of interpretive apps revolved around technical issues with the iPad 2 systems and complexity of the software discussed previously, it is important to be aware of the porous nature of mobile technologies as it relates to the inclusion of student ideas and activities in public domain such as app stores and other social media sites like the science museum's Facebook or Twitter feeds. Student access to mobile technologies and their application within different educational settings pointed to larger sociocultural and economic barriers (in this case the digital divide discussed earlier) associated with the inclusion and support of students within informal science education and M-learning. Despite the widespread use and the increased technical capabilities in the area of learning design and content production with mobile devices, no examples of participant-based mobile design within informal science settings for young people associated with natural history museums and STCs could be found prior to this case study. The absence of educational research in this area also represents a significant opportunity for future educational research and engagement with place-based mobile science curricula development and design in natural history museums, STCs and other informal educational settings including outdoor studies. Based on the results of the triangulated analysis conducted for this research in combination with participant comments and recommendations, a model of more participatory involvement by elementary students as co-designers was developed and is presented below.

Recommendations for Future Research

The next logical step for educational researchers would include the further refinement and study of including young people within the process of mobile app prototyping and development of educational software in science education. This case study successfully demonstrated how elementary students, working in partnership with educators, were capable of co-creating a wide variety of mobile learning activities in informal science settings that also extended beyond the existing educational programming of the museum and the provincial science curriculum for Grades 4 and 5 in BC. Based on the research and participant feedback analyzed in this case study, a future model of participant-based learning and design was developed. [Figure 6.1](#) demonstrates the relationships between software designers, museum educators, and participants in creating educational apps for the museum (please note that each section will be magnified and discussed in detail below). While this research demonstrated that elementary students were both capable and highly motivated to co-design mobile learning activities with educators using the experimental software Design & Learn, the next step would be to develop a process by which participant ideas were developed for community sharing and co-authoring M-learning ideas for the museum that also extended the application of informal science education in real world settings. A key omission in this study was the absence of pre- and post interviews, which would be important in understanding the complex curricular and thought processes involved as young people shared their ideas with researchers. The following model creates a process and structure where participant ideas are developed, shared, evaluated and incorporated within the interpretive library of the host museum or STC. history museums and STCs. Multiple points of research are identified within each of the phase italicized above starting with participant ideas.

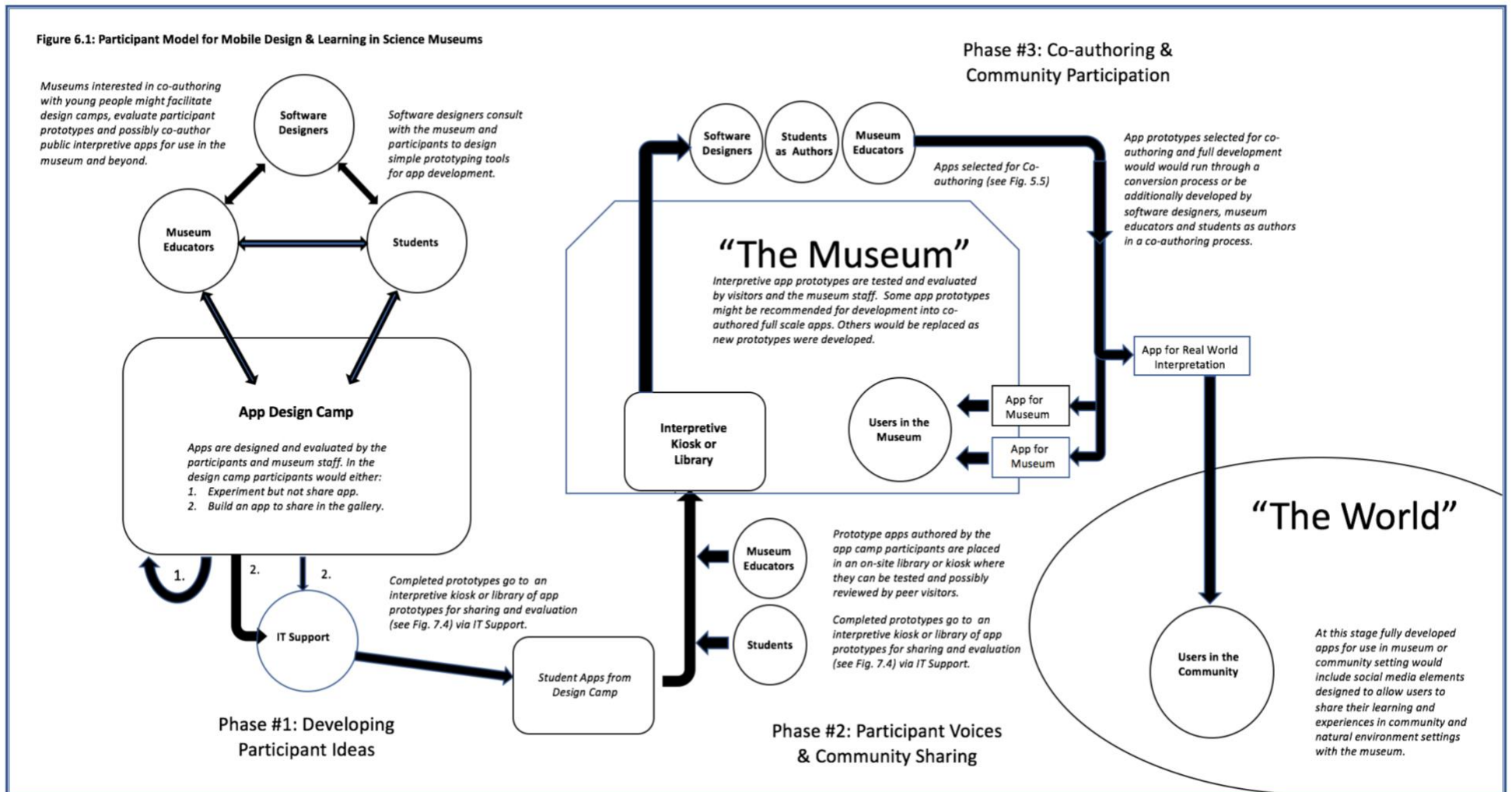


Figure 6.1: Participatory model of mobile interpretive development utilizing participant ideas, voices, sharing, and co-authoring that expands participating by young people within interpretive discourses at museums and STCs. This model is magnified with different sections presented in additional Figures 6.2-6.4.

Phase #1: Participant Ideas

The left side of participant-based design model presented in [Figure 6.1](#) explores participant ideas. Magnified in [Figure 6.2](#) below it is possible to see the major actors and relationships around supporting the development of participant ideas within informal science education at museums. The key actors within this model are software developers, museum educators, and students or other young people participating in app design camps. Although this dissertation explored the inclusion of elementary students' interpretive ideas and activities for M-learning within an Informant Design (ID) model, based on the results and interest expressed by the participants at the end of this mobile design project, the next phase of research would be to move towards an even more Participatory Design (PD) model of curricular development that includes participant ideas within the design of the mobile prototyping software itself. Then next phase of research would focus on how elementary students and museum educators would partner with software developers to create a prototyping tool and interpretive apps that younger participants can more independently use to create their own M-based learning activities and content within the museum galleries and exhibits.

Key recommendations by the participating educators and elementary teachers in this study include simplifying the prototyping app software so that individual and small groups (2-3) of students could more independently use the app as a design tool. Rather than the more intensive design teams composed of five members (2-3 students, 1 elementary teacher, and 1 museum educator) utilized in this experimental project, the participating educators wanted educational software that could be used by an entire class with the support of a single teacher and museum educator for the entire class.

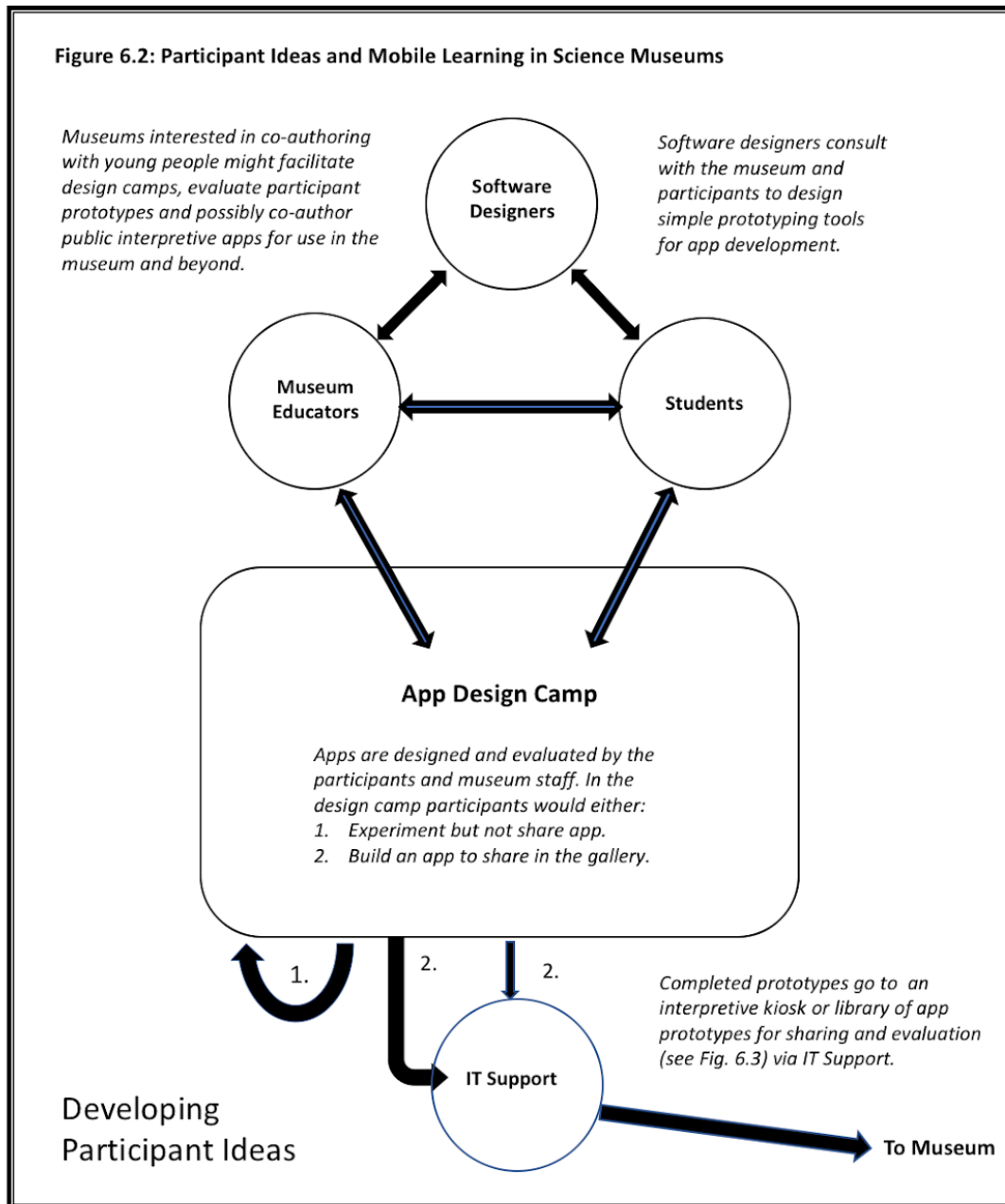


Figure 6.2: Within the first section of the participatory model presented in Fig 6.1, students would share their ideas on educational software designs with museum educators and software programmers that they wanted to create for M-learning activities and extensions designed by and for students visiting the natural history museum or STC.

Once app prototypes are created they would be prepared for an optional phase of peer evaluation within the natural history or science exhibits. The next phase of future educational research revolves around participant voices and community sharing.

Phase #2: Participant Voices and Community Sharing

Another important area of future educational research related to mobile learning and design with young people revolves around participant voices and community sharing. While the topic of participant voices and community sharing was partially addressed in this research, much more work is needed. [Figure 6.3](#) illustrates the process of developing participant voices and community sharing. In addition to having participants' M-learning ideas and activities they develop within the museum's app development camps (scaled up from the single experimental design camp utilized in this study), the young designers would have the option of testing, revising and submitting their M-learning designs into an interpretive kiosk or prototyping library situated in the museum's natural history or science gallery the activities were designed for. Other elementary students and young visitors from the public could then test the interpretive app prototypes developed by the young designers through an informal peer review process where apps could be tested, evaluated and reviewed by visitors and educators within the natural history museum or STC.

Potential research in this area might examine how participant voices are expressed and shared, as represented in [Figure 6.4](#). Some designers might limit community sharing to the app design camp itself while others might choose to submit work to the museum's public design interpretive kiosk or library. Other future research, capable of being either quantifiably or qualitatively analyzed, might explore how young visitors and educators outside the designer's app camp select and evaluate the mobile interpretive activities and designs created

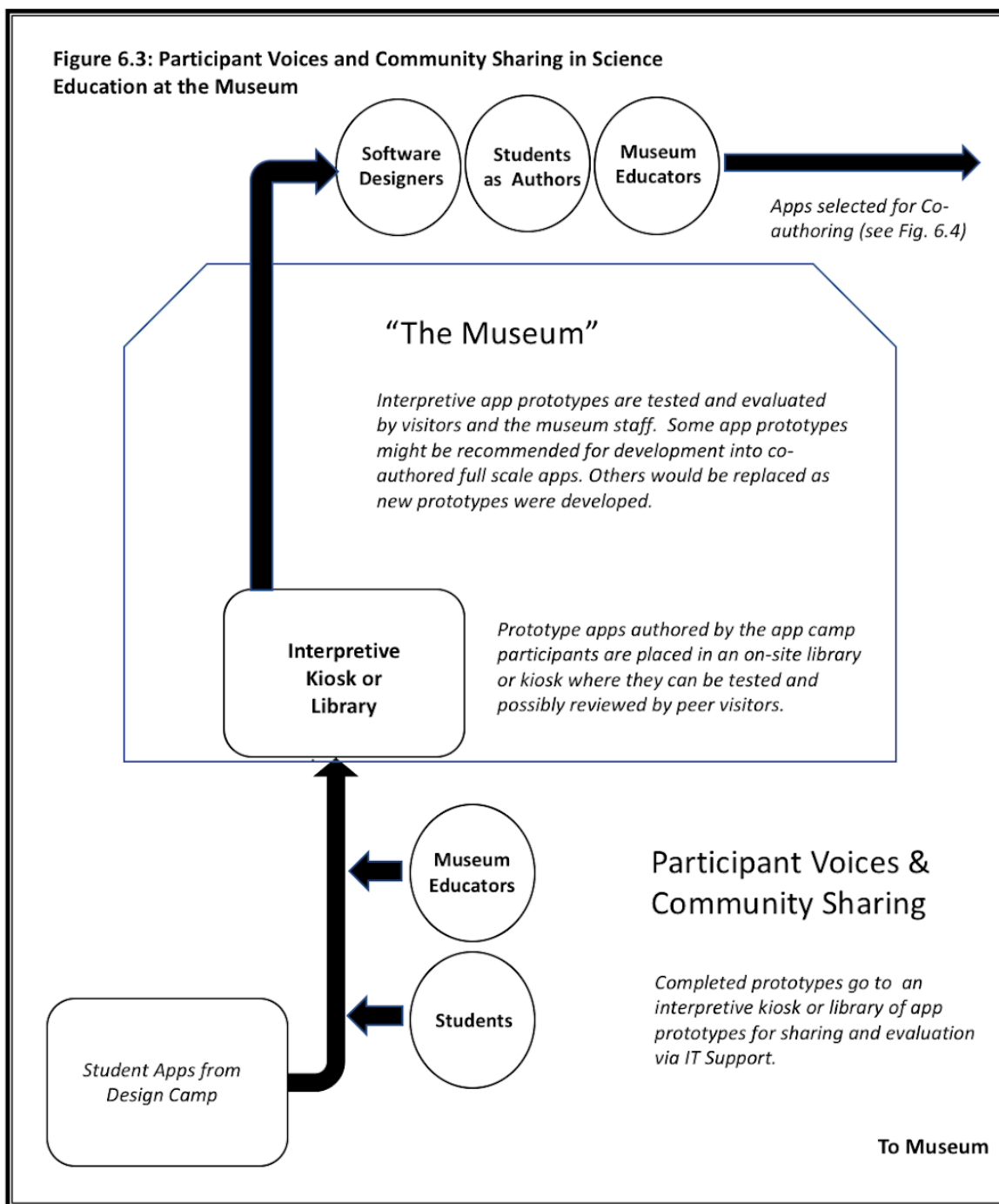


Figure 6.3: Within the second section of the participatory model presented in Fig 6.1, students use interpretive design apps developed in Fig. 6.2 to create interpretive activities and designs for sharing with peers and the museum. Young designers wanting to test their interpretive designs with the community would share their ideas and activities within an in interpretive kiosk or library located in the museum galleries where the activities were created.

by elementary students in the app design camps. The next section explores how interpretive app prototypes might be selected by natural history museum and STCs for co-authoring and including young peoples' ideas and activities as an essential interpretive voice within larger public conversation about the topics and themes explored within a museum's exhibits and galleries that also including real-world applications.

Phase #3: Co-authoring and Community Participation

The final area on the right of [Figure 6.1](#) above and magnified in [Figure 6.4](#) below explores co-authoring and community participation. This stage of participant design explores how natural history museums and STCs might, through a co-authoring process, select onsite app prototypes submitted by young designers and develop them into fully functioning and publically available interpretive apps (via iTunes, Google Play, or other app stores) for the museum visitors and the general public. As co-authored apps, these fully developed interpretive apps would represent different interpretive voices and possibilities for more specialized inquiry by and for visitors interested in looking at natural history museum artefacts and galleries from the perspectives of different authors and inquiry-based activities. One significant area of future research in the area of participant-based design and interpretive co-authoring would be to discover whether or not the inclusion of more interpretive voices and options for designers and visitors fosters a different relationship between natural history museums and STCs and the public. Other studies would look at the efficacy of using the app to learn informal science.

Other Areas of Significant Research Within M-learning in Museums for Young People

In addition to the major areas discussed above, other significant areas for future research include future studies around the diversity of mobile interpretive apps and activities young designers might create for their peers and other visitors within informal science settings.

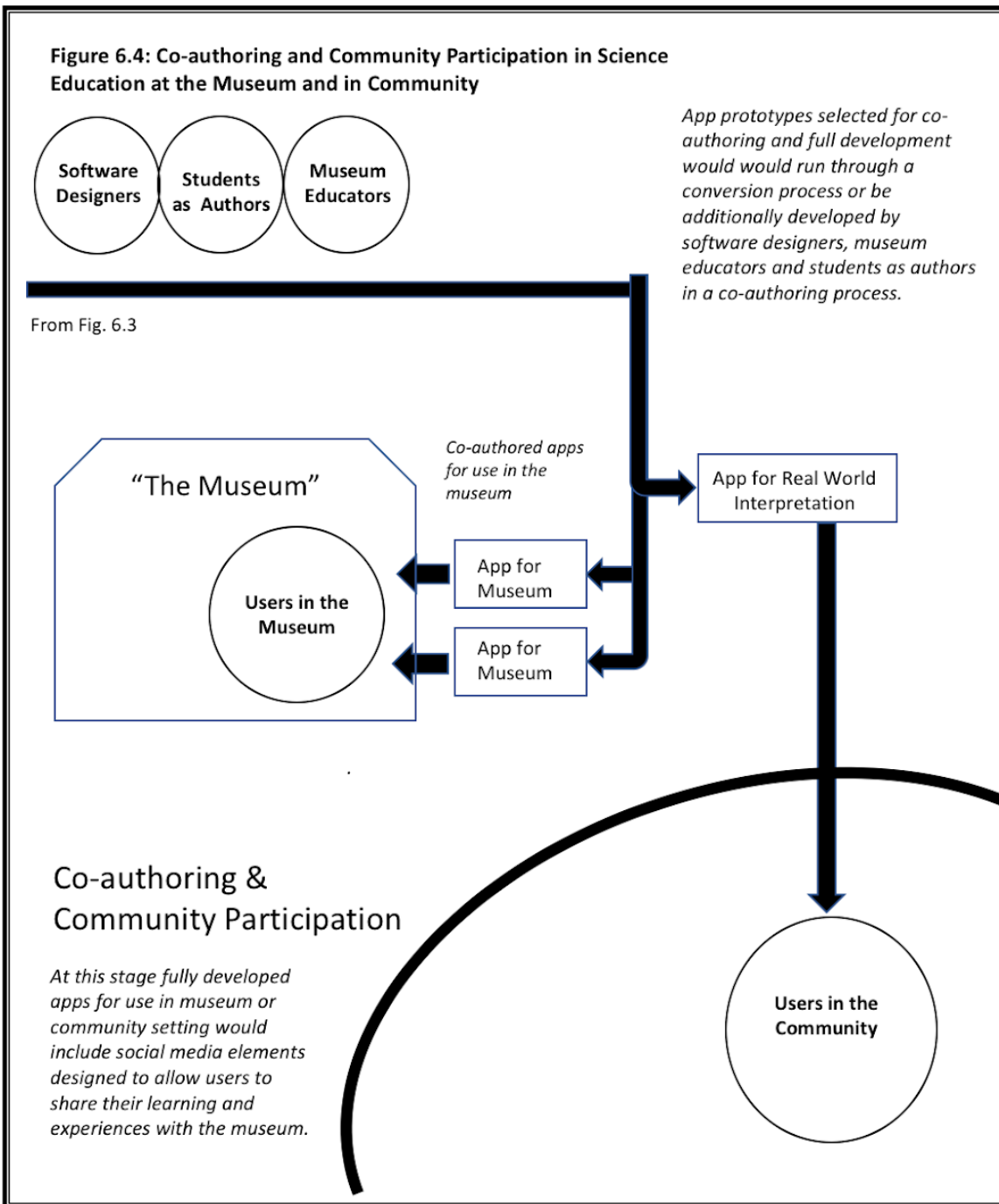


Figure 6.4: In the final area of the participatory design, student and other participants based designs successfully tested and evaluated by the public in the community sharing kiosk (see Fig. 6.3) might be selected by the museum for further co-authoring and formal development as publically available museum apps that offer M-learning opportunities within the museum or other real world environments. As co-authors, students and other participants would add to the interpretive voices available to engage in within natural history museums and STCs.

A deeper understanding of how student agency operates within the process of participant-based mobile app development and use in informal science education in relationship to the curricular development of other software and digital medias reported by Code, Clarke-Midura, Zap & Dede (2013) would also contribute to our understanding on student-centred inquiry.

Additional research into the kinds of interpretive activities and inquiries young designers are creating to engage peers and other visiting users of the software within the physical environment of the museum's natural history galleries and science artefacts are needed as well. Burden and Kearney's (2016) framework around the future use of mobile science curricula to explore scientific phenomena either virtually or in other physical contexts would also be an important area of future educational research. More specifically, research into whether young people are either re-creating the same interpretive activities and knowledge adult interpretive app designers publish, or something more specific to students' interests and connected to the unique lived experiences and perspectives of young people, would need to be examined as well. Understanding if the design and use of mobile interpretive apps by students as co-designers and users develops scientific knowledge or might lead to scientific misconceptions about science as described by Driver, et al. (1994) and Thompson & Logue (2006) would have to be examined within the context new forms of digital meaning making discussed earlier in this chapter.

In addition to future studies about the types of mobile science apps students as participants and designers might construct and how it supports the development of scientific understanding and knowledge by other visiting students as users, the role of science experts and scientific organizations is another important area of future research. The original research proposal for this case study included the participation of a science expert acting as an advisor and mentor for the design teams reported in this study. However, as described in Chapter 5, due to funding and

scheduling constraints, it was not possible to include a scientific advisor and expert in this research. Given the important role scientific experts can serve within science education and learning documented within other research (Barab & Hay, 2001; Briscoe & Peters, 1997; Bybee, 1998; Tanner, Chatman & Allen 2003), future research related to how students as designers and users digitally construct, interact, and share their learning with experts will likely play a significant area of future research as well. This is particularly true in the use of mobile science apps capable of social media sharing and interaction where co-authored and publicly available science apps created by students exist in the public domain.

The porous nature of mobile technology, including the potential for a negative public backlash, trolling, and anti-science spamming by bots would need to be examined as it relates to design, the selection and publication of student generated apps around scientifically and culturally sensitive topics in either Canada or the United States, such as evolution, climate change or gender identity. Finally, future research around participant-based app design in natural history museums and STCs would also have to examine the nature of knowledge students are creating as mobile designers as it relates to scientific literacy and digital application of participant-based science apps beyond the museum.

Conclusion: Facilitating a Cosmic Conversation with Young People

The relationship between children and museum exhibits has undergone a tremendous metamorphosis since the founding of the National Museum of Canada and the Smithsonian in the United States. The New Museum movement of the early twentieth century saw the cabinets of curios transformed into elaborate and idealized natural dioramas that included touchable biofacts (bones, tracks, trees, etc.) children could use to explore the diversity of nature. Early curators at the time were concerned that an increasingly urban population of young people were losing

touch with nature as industry, overfishing and large scale farming visibly degraded local forests, fish stocks, and prairie ecosystems in many parts of Canada and the United States during the “Dirty Thirties” (Radar & Cain, 2014, p. 86). *Sputnik* and the Big Science Era supersized many older natural history museums including the RBCM and gave birth to modern science and technology centres such as Science World in British Columbia and the Exploratorium in San Francisco. Older progressive ideals of the early New Museum movement were complemented by developmental and constructivist pedagogies that emphasized the use of model experiments and increasing interactivity and hands-on exploration by young people in engaged with the elaborate and commercialized blockbuster exhibits as the twenty first century approached. The Museum 2.0 and 3.0 movements signified the infusion of digital and increasingly portable information that promised a transformation in the role of children from active observers and consumers within natural history museums and STCs to participants capable of participating in interpretive conversations around science and society.

More than five million people tour the diverse galleries of the American Museum of Natural History every year including the Hayden Planetarium where nine year olds can hear the museum’s new exhibit *Dark Universe* narrated by none other than Dr. Neil deGrasse Tyson, who himself was inspired by the planetarium’s cosmic voice so many years ago (American Museum of Natural History, 2015). While the new generation of children wandering through the science exhibits and activities may appear, in many respects, very similar to those of deGrasse Tyson’s generation in the past, as presented in this dissertation there are significant differences in both the museum and how young visitors engage with museums. Exhibits within natural history and science museums like the Hayden Planetarium have benefitted from the explosion of scientific advances about the cosmos, decades of research around the design of interactive exhibits for

multiple generations of visitors to their galleries, and an infusion of complex multi-media and other digitally immersive technologies capable of fostering more hands on and interactive displays. As illuminated in the first chapter, the young visitors to natural history and science museums are more immersed within digital technologies and environments than Neil deGrasse Tyson's generation was as children. While much of the diversity can be attributed to sociological and demographic changes within the current generation of young people visiting museums (Farrell & Mededeva, 2010; MacGee-Banks, 2010), economic and other forms of cultural and linguistic exclusions still exist as a significant challenge for many natural history museums and STCs (Coffee, 2008; NEMO Science Museum, 2016) including the Hayden Planetarium.

Also, as illuminated in Chapter 1, many young visitors today carry sophisticated smart phones and other devices which did not exist at the time deGrasse Tyson explored the planetarium as a 9-year-old. While it is still possible for young people to hear and experience the voices and interpretive narratives that influenced scientists like Neil deGrasse Tyson in 1967, that may not be enough in the digital age where the boundaries between science education and entertainment can either obscure or enhance a more meaningful scientific understanding by visitors. Elementary students today are already documenting and sharing their experiences at natural history museums and STCs. However, as presented in Chapter 2, most of the existing research around the design and use of mobile apps revolves around young people's use of these technologies for scientific entertainment, digital modeling of natural phenomenon, as a reference, or as a basic search tool for scientific facts or terms related to exhibits (Clark et al., 2013; Trindade, Fiohais & Alameida, 2002; Santos-Gree et al., 2014). This is unfortunate as research into the area of place-based learning applications and socially mediated sharing by adult visitors to museums through programs such as the *Chicago Field Museum App* and *Smithsonian Under*

your Thumb would likely benefit younger students as well if scaffolded and redesigned in a manner that included the ideas and interests of younger visitors. As a result, the participation and voices of young people are largely absent within educational discourses occurring at natural history museums and STCs. Like the existence of dark matter within the cosmos itself, for museum educators and researchers alike, the absence of young people's voices within interpretive design and larger social discourses should be of interest as a matter of social inclusion. While research is still emerging (Lange, 2015), in an age where eleven year olds like Mya (*FullTimeKid* with more than 487,000 subscribers) and seven and nine-year-old brothers Gabe and Garrett (*Gabe and Garrett* with more than 810,000 subscribers) are publishing videos on YouTube that are seen by tens of millions of viewers, much more work by educational researchers is needed around how young people might engage within science education communities. However, as exemplified in this study and the discussion on digital meaning making presented earlier, elementary students are both excited by and motivated to creating M-learning activities and content when invited to participate.

Hopefully, the research on the diverse ideas and capabilities of Grade 4 and 5 students working together with educators to create mobile interpretive apps will encourage museum and science educators to consider exploring including students within the design and use of place-based learning within informal science settings. While the Museum 2.0 and 3.0 movements are encouraging new forms of interactivity, engagement and participation by adult members of the public, significant gaps remain in the area of including young peoples' ideas and learning activities like the elementary students involved in this case study. The cosmic voice that inspired a young scientist in the Hayden Planetarium decades ago appears to be shifting towards more participatory and informal frameworks, perhaps a cosmic conversation, between informal science

educators and the young people they work and interact with. While Neil deGrasse Tyson's story in Chapter One was referring to an astronomical understanding of the cosmos, his childhood experience serves as an eloquent metaphor for educators and researchers in this largely unknown field of informal and mobile based interpretive design, learning and sharing with young people.

Tyson states:

So often an exhibit or a show, particularly at a museum, celebrates what we know. And you expect that, "HERE'S WHAT WE KNOW!" But what about the stuff we don't know? That excites me. (Oct. 2, 2013)

This research demonstrated the capabilities of young people of working with educators to create digital forms of knowing and learning that extended beyond the interpretive programs currently available to elementary students at the RBCM. The experimental software utilized in this study also illuminated the increasing ease students and educators will likely have in the near future in designing mobile science content and activities for their peers within both formal and informal science settings. The findings in this research also pose the idea that informal science education within diverse natural history museums and STCs in Canada and the United States should consider including the collected ideas and voices of young people within interpretive libraries or kiosks as an inclusive form of participatory mobile curricula design and learning for children. Mobile learning apps and technologies will continue to be important tools for mediating interpretive conversations among generations of designers and users within informal science education as presented in natural history museums and STCs.

Libraries serve as concrete cultural symbols of society's collective knowledge. The books, databases, and digital media we search for represent the collected voices and thoughts of those who created them. Within participatory movements and increasingly digitally-linked communities, the interpretation of the science collections and artefacts contained in natural history museums and STCs invites the more diverse public interpretation and authorship within the public discourses surrounding the exhibits and their meaning to the larger world. This includes the voices and ideas of nine and ten year olds everywhere in Canada and the United States carrying mobile technologies and apps like the software utilized in this case study. The inclusion of children's ideas and activities within the mobile interpretive libraries and kiosks in natural history museums and STCs ignites a re-imagination of what natural history and science exhibits might accomplish in the future. The design and use of the mobile interpretive software created in partnership with students and educators for other young people visiting museums adds new interpretive possibilities and voices to the cosmic conversations orbiting science and education.

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Glossary

active informant: A person within the field of user design theory who makes suggestions or provides feedback to software designers in the process of designing and evaluating new software.

active participant: A person within the field of user design theory who participates in the process of software design as a co-author of software that is being developed.

activity theory: An educational theory where socio-cultural educational processes describe object and/or process based learning is understood through the socio-cultural analysis by individual and groups of actors and the educational knowledge, tools, objects, and artefacts they create.

analyst triangulation: A qualitative methodology that utilizes research narratives, thematic analysis and recursion as a way for researchers to triangulate complex data to make meaning.

biofacts: Biofacts are educational artefacts that come from nature such as bones, fossils, parts of plants, or naturally occurring objects from living organisms.

Big Science Museums: Big science museums refers to the development of large and specialized museums specifically for learning about science and technology that emerged after the launch of *Sputnik*.

case study: A record or collection of research based around a particular person, group, or situation overtime.

coding: Coding, in the field of computer science, refers to the language and process of creating software. In educational research coding refers to the classification of data for study.

collective case study: Educational studies or research that critically aggregates, analyses and reflects on multiple cases in order to illuminate important insights or issues within complex educational systems.

cooperative design: A method of educational and/or software design where users and designers work together to complete educational products and/or software.

cooperative inquiry: An educational process based on social or group based inquiry rather than individual learning. Learning, or inquiry, is organized around collective or group questions and/or interests.

contextual design: A method of software design that focuses on development around specific areas, topics, or problems.

cultural-historical: Elements of a particular person, organization, institution or larger community that are culturally and historically bound.

cultural tools: Elements within Vygotsky's theory on socially based learning that describe linguistic and technical based tools that utilize socially mediated language and discourse for cognitive development and learning.

dispersed data collection: Data that is collected over a wide physical or geographic location.

formal science education: A field of educational research that focuses on the educational history and process of science education within K-12 and post-secondary contexts.

informal science education: A field of educational research occurring outside formal science classrooms that focuses on the educational history and process of informal science education related to museums, parks, and science centers.

informant design: Existing as a subfield of user design theory that focuses on involving participants primarily as informants to the design and use of software.

instrumental case study: An area of case studies that examine the use of specific tool (e.g.: curricula, tests, software, etc.) or intervention (specialized and/or adapted/differentiated

resources or other educational support) and their influence on single learner, group or other educational setting.

interpretive app: An educational app for use in informal settings such as museums and science and technology centers.

interpretive design: An important component of informal education where informal educators and institutions create interactive and educational displays for visitors or the public.

interpretive discourse: The educational conversation existing between and among visitors and educators around how educational artefacts and exhibits are understood or interpreted.

Interpretive library: Similar to actual libraries, interpretive libraries are a selection of educational title and activities by different authors that can be used to provide additional opportunities for learning and exhibit interaction for visitors based on the diverse topical interest of authors who created them.

interpretive voice: The narrative message existing as text, audio, video or other multimedia information which conveys information from informal institutions such as museums to the public.

intrinsic case study: Case studies that focus on unique or distinct educational elements or characteristics of a particular educational setting or group.

IOS – Swift: A software and app programming language utilized for Apple devices.

learner-centered design: A method of educational and software design where the learner and/or user drives the development of educational products, processes and/or software.

learning artefacts: Artefacts students create existing as a physical or digital record of learning.

linguistic model: In education linguistic models are used to foster learning through a deeper understanding language through studies and representations of the structural characteristics of language (listening, speaking, reading& writing).

M-learning: A shortened term that refers to the field of mobile learning.

micro-case: A small case study that revolves around sub groups within a larger case study of a single population of research participants.

native informants: People who embody or have significant lived experience and are capable of reporting, sharing, and commenting from their perspective within educational research (individual traits or characteristics such as childhood, gender, race, etc.).

participant pedagogy: A method of education and teaching that emphasizes the process of educators and learners of working together within educational processes.

participant voices: In science and museum education participant voices refers to the inclusion of visitors with educational discourses and participant-based models of learning and exhibit design.

participatory design: A method of educational and software design where the learner and/or user work in partnership with curriculum and/or software developers along a spectrum to create educational products, processes and/or software.

power-over: Within educational research the term power-over refers to the unequal balance of power existing in educational systems between researcher, administrators, educators, and students.

pragmatic perspective: A method of educational design based upon Dewey and the pragmatic school of thought where design and learning is based upon practical design.

problem based learning: A method of educational design where learning is built around having students identify and solve problems related to the curriculum or educational topics being studied.

proto-science museums: Proto-science museums are early nature, technology and industry museums existing prior to Sputnik and the development of *Big Science Museums*.

qualitative research: A research methodology that describes and explores personal, social, and cultural: ideas, opinions, and motivations in ways that are complex and not always quantifiable.

quantitative research: A research methodology that explores and describes social and natural problems through the process of capturing numerical data that can both be characterized and analyzed through statistical analysis.

recursion: A dynamic process of experimental modification and reflection in educational research that allows researchers to explore topics and issues in more depth based responses, feedback, problem solving and observations throughout the research process.

recursive analysis: Within qualitative research methodologies, recursive analysis is the process where the researcher simultaneously modifies, reflects, and collects data based upon the dynamic feedback of participants and continuous data generated through experimental processes in order to gain deeper insight into what is being studied.

research narrative: A story-telling component of triangulated analysis by which the researcher illuminates the rich ideas, thoughts and views of the participants within a study.

semiotic model: Semiotic models in education are culturally based representations, symbols or other signs utilized for learning or interpretation. Depending on their construction semiotic models may represent simple or complex ideas.

socio-cultural: Within educational research these describe elements of people, places, and institutions based upon social and cultural frameworks or models.

Tabula Rasa: Tabula Rasa or its English translation “blank slate” in the context of this dissertation refers to John Locke’s educational philosophy that individuals are born in a blank cognitive state whereby knowledge and thinking is explicitly taught to the student.

thematic analysis: The process of analyzing participant data through the classification and coding of statements and ideas in order to illuminate and identify central themes or ideas.

triangulated analysis: A qualitative research methodology that incorporates research narratives, thematic analysis and recursion in the analysis and interpretation of complex data.

user-centered design: A method of software design within computer science that revolve around the identification and production around a specific task or problem. Once developed the software is evaluated by users and either completes the task successfully or is updated by developers until it meets the requirements of the task or problem.

user design theory: A field of software design and theoretical research that explores how software users utilize, are impacted by, or are involved in the design and creation of mobile and computer based software.

Appendix A: Certificate of Approval for Research



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of Victoria

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T 250-472-4545 | F 250-721-8960 | uvic.ca/research | ethics@uvic.ca

Certificate of Approval

<p>PRINCIPAL INVESTIGATOR: Michael Hammond-Todd</p> <p>UVic STATUS: Ph.D. Student</p> <p>UVic DEPARTMENT: EDCI</p> <p>SUPERVISOR: Dr. David Blades</p>	<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td style="text-align: right;">ETHICS PROTOCOL NUMBER</td> <td style="text-align: left;">15-356</td> </tr> <tr> <td colspan="2" style="text-align: center; font-size: small;">Minimal Risk Review - Delegated</td> </tr> <tr> <td style="text-align: right;">ORIGINAL APPROVAL DATE:</td> <td style="text-align: left;">19-Nov-15</td> </tr> <tr> <td style="text-align: right;">APPROVED ON:</td> <td style="text-align: left;">19-Nov-15</td> </tr> <tr> <td style="text-align: right;">APPROVAL EXPIRY DATE:</td> <td style="text-align: left;">18-Nov-16</td> </tr> </table>	ETHICS PROTOCOL NUMBER	15-356	Minimal Risk Review - Delegated		ORIGINAL APPROVAL DATE:	19-Nov-15	APPROVED ON:	19-Nov-15	APPROVAL EXPIRY DATE:	18-Nov-16
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<p>PROJECT TITLE Factors Influencing the Development of Mobile Learning Initiatives for Children in Natural History Museums</p> <p>RESEARCH TEAM MEMBER None</p> <p>DECLARED PROJECT FUNDING: None</p>											
CONDITIONS OF APPROVAL											
<p>This Certificate of Approval is valid for the above term provided there is no change in the protocol.</p> <p>Modifications To make any changes to the approved research procedures in your study, please submit a "Request for Modification" form. You must receive ethics approval before proceeding with your modified protocol.</p> <p>Renewals Your ethics approval must be current for the period during which you are recruiting participants or collecting data. To renew your protocol, please submit a "Request for Renewal" form before the expiry date on your certificate. You will be sent an emailed reminder prompting you to renew your protocol about six weeks before your expiry date.</p> <p>Project Closures When you have completed all data collection activities and will have no further contact with participants, please notify the Human Research Ethics Board by submitting a "Notice of Project Completion" form.</p>											
Certification											
<p>This certifies that the UVic Human Research Ethics Board has examined this research protocol and concluded that, in all respects, the proposed research meets the appropriate standards of ethics as outlined by the University of Victoria Research Regulations Involving Human Participants.</p> <p>_____ Dr. Rachael Scarth Associate Vice-President Research Operations</p>											

Certificate Issued On: 19-Nov-15

15-356 Hammond-Todd, Michael

Appendix B: Recruitment Letters**University
of Victoria*****Participant Consent Form
Elementary teachers***

Factors Influencing the Development of Mobile Learning Initiatives for Children in***Natural History and Science Museums***

You are invited to participate in a study entitled *Factors Influencing the Development of Mobile Learning Initiatives for Children in Natural History and Science Museums* that is being conducted by Michael Hammond-Todd.

Michael Hammond--Todd is a doctoral candidate in the department of Department of Curriculum and Instruction at the University of Victoria and you may contact him if you have further questions by email: ecostudy@uvic.ca.

As a doctoral candidate, I am required to conduct research as part of the requirements for a degree in Curriculum and Instruction. It is being conducted under the supervision of Dr. David Blades. You may contact my supervisor at 1-250-721-7775.

Purpose and Objectives

The purpose of this research project is better understand how museum educators might work with young people to design new learning opportunities in the form of mobile interpretive apps. Students occupy a unique position as it relates to the kinds of learning opportunities available to them in museum settings. This research explores how students might contribute to the process of interpretive design as it relates to the creation of a model interpretive app for young visitors to the natural history gallery in Grades 3-5. In addition to the process of designing an app, the participants will be able to share their work with their peers in this project and officials from the museum. Participants will also have the opportunity to make

suggestions and recommendations that may benefit other institutions considering the development of interpretive apps for young people in museums and science centers.

Importance of this Research

This research is important because it will add to our understanding of how to better involve young people (Grades 3-5) within the interpretive design process in a museum setting. It also contributes to the development of more activity-based interpretive software specifically designed for elementary aged visitors. This research also contributes to our understanding of possibilities and pitfalls related to the inclusion of mobile interpretive apps for young people within informal education.

Participants Selection

You are being asked to participate in this study because of your position, role, and knowledge as an elementary educator working directly with young people in Grades 3-5. Your ideas and thoughts as to how museums can incorporate student's ideas into interpretive design forms an important aspect of this research.

What is involved

This research is scheduled to take place in the winter. Most of the activities will be completed during ~~four~~ THREE hour sessions on Saturdays over the course of a four-week period. The activities include interest surveys, focus groups, software prototyping using paper and other student friendly materials, media design, evaluating app prototypes, project reflections, and suggestions for further research. Individual and group discussions/interviews form an important part of this research as well.

Proposed Timetable

- *January:* Recruitment of participants (15 Grades 3-5 students, 5 elementary teachers & 3-5 museum educators).
- *February:* Elementary teachers, museum educators, and a science advisor would meet for two hours to discuss the project and plan a “software design camp” for elementary students.
- *March:* the software design camp would take place. Working in teams (3 students, 1 educator & 1 interpreter) through the process of informant design, each team would develop an interpretive prototype in 3 hour sessions over the course of four Saturdays. The process would follow “informant design” described above in two cohorts.

Throughout this research video, audio recordings, written notes, observations, and an analysis of educational/project artefacts (your designs and final projects) will be utilized in this research. Transcripts and other printed testimonies will be developed based upon your work, ideas, and observations on this project. Because videos, Photos and other identifying images will be used in this research, an additional section granting Michael Hammond-Todd the permission has been included below.

Inconvenience

Participation in this study may cause some inconvenience to you such as missing other weekend school, community or family based activities because of the scheduled time for this project.

Risks

There are no known or anticipated risks to you by participating in this research except the possibility of fatigue during the 3 hour software design camp sessions. you have the right to both request and take breaks at any time during this research.

Benefits

Your participation in this research project has many potential benefits as well including your contribution and ideas on how to involve young people in the design of mobile interpretive apps within museum and other informal settings. It is also an opportunity to co-design educational/interpretive software with young people and museum educators who share your interests. This project will also culminate with a mobile app you can share with your family and friends.

Voluntary Participation

Your participation in this research must be completely voluntary. If you do decide to participate, you may withdraw at any time without any consequences or any explanation. If you do withdraw from the study your individual data will not be used. Michael will separately seek permission on the use of group work that has already been completed. For the purpose of sharing all of your individual and group work will be anonymized with pseudonyms.

On-going Consent

To make sure that you continue to consent to participate in this research, I will provide opportunities to withdraw from the research at the beginning of each weekly session or by email/phone.

Anonymity

Unless individually agreed upon below, this research will protect your anonymity through the use of pseudonyms for research purposes. This includes the use of character names by young people in the development and presentation of any multimedia software using the video, images or voices of young people. Records of your work, ideas, participation (including video, photography, audio, and software), and suggestions will be stored securely by the researcher for a period of no more than four years after the research has been completed. After four years, all the data associated with this project will be destroyed unless permission is sought by the researcher to continue storing the data from this research project.

Confidentiality

Your confidentiality and the confidentiality of the data will be protected by remote storage either in locked file cabinets located in the researcher's office or, for educational software, tablets or iPads securely stored and locked as well. Except for the relevant data shared through the production of Michael's doctoral thesis, all data and records will be kept confidential unless individual permission has been granted by you.

Dissemination of Results

The results of this study will be shared with members of the public primarily through the production and dissemination of Michael's doctoral thesis. Two to three research article may be developed and shared/presented at scholarly meetings as well including conferences for museum and/or educators. An additional permission from you will be requested for articles and presentations developed outside of the doctoral dissertation.

Disposal of Data

Three years after this research has been completed the data from this study will be disposed of in the following ways. Unless your permission has been sought to continue storing the data, all paper based activities and educational artefacts will be shredded. Any electronic data such as video, audio, Photographs, and software prototypes will be erased.

Contacts

Individuals that may be contacted regarding this study include Michael Hammond-Todd (email: ecostudy@uvic.ca or 1-250-514-5917) and/or his supervisor David Blades (dblades@uvic.ca or 1-250-721-7775).

In addition, you may verify the ethical approval of this study, or raise any concerns you might have, by contacting the Human Research Ethics Office at the University of Victoria (250-472-4545 or ethics@uvic.ca).

Your signature below indicates that you understand the above conditions of participation in this study, that you have had the opportunity to have your questions answered by the researchers, and that you consent to participate in this research project.

<i>Name of Participant</i>	<i>Signature</i>	<i>Date</i>
----------------------------	------------------	-------------

Visually Recorded Images/Data Participant or parent/guardian to provide initials, *only if you consent*:

- Figures may be taken of me for: Analysis _____ Dissemination* _____
- Videos may be taken of me for: Analysis _____ Dissemination* _____

*Even if no names are used, you may be recognizable if visual images are shown in the results.

THE PROTECTION OF YOUR IDENTITY: For the purpose of this research your names will be anonymized with the use of a professional title unless specifically requested to do so below.

Please select statement only if you consent:

I consent to be identified by name / credited in the results of the study: _____ (Participant to provide initials)

I consent to have my responses attributed to me by name in the results: _____ (Participant to provide initials)

A copy of this consent will be left with you, and a copy will be taken by the researcher.



Participant Consent Form Science Consultant

Factors Influencing the Development of Mobile Learning Initiatives for Children in

Natural History and Science Museums

You are invited to participate in a study entitled *Factors Influencing the Development of Mobile Learning Initiatives for Children in Natural History and Science Museums* that is being conducted by Michael Hammond-Todd.

Michael Hammond--Todd is a doctoral candidate in the department of Department of Curriculum and Instruction at the University of Victoria and you may contact him if you have further questions by email: ecostudy@uvic.ca.

As a doctoral candidate, I am required to conduct research as part of the requirements for a degree in Curriculum and Instruction. It is being conducted under the supervision of Dr. David Blades. You may contact my supervisor at 1-250-721-7775.

Purpose and Objectives

The purpose of this research project is better understand how museum educators might work with young people to design new learning opportunities in the form of mobile interpretive apps. Students occupy a unique position as it relates to the kinds of learning opportunities available to them in museum settings. This research explores how students might contribute to the process of interpretive design as it relates to the creation of a model interpretive app for young visitors to the natural history gallery in Grades 3-5. In addition to the process of designing an app, the participants will be able to share their work with their peers in this project and officials from the museum. Participants will also have the opportunity to make suggestions and recommendations that may benefit other institutions considering the development of interpretive apps for young people in museums and science centers.

Importance of this Research

This research is important because it will add to our understanding of how to better involve young people (Grades 3-5) within the interpretive design process in a museum setting. It also contributes to the development of more activity-based interpretive software specifically designed for elementary aged visitors. This research also contributes to our understanding of possibilities and pitfalls related to the inclusion of mobile interpretive apps for young people within informal education.

Participants Selection

You are being asked to participate in this study because of your position, role, and knowledge of the natural history and ecology of British Columbia and your experience of working directly with young people at the elementary grade levels. Your ideas and thoughts as to how museums can incorporate scientific inquiry and knowledge into student's ideas about interpretive design forms an important aspect of this research.

What is involved

This research is scheduled to take place in the winter. Most of the activities will be completed during four hours session on Saturdays over the course of a four-week period. The activities include interest surveys, focus groups, software prototyping using paper and other student friendly materials, media design, evaluating app prototypes, project reflections, and suggestions for further research. Individual and group discussions/interviews form an important part of this research as well.

Proposed Timetable

- *January*: Recruitment of participants (15 Grades 3-5 students, 5 elementary teachers & 3-5 museum educators).
- *February*: Elementary teachers, museum educators, and a science advisor would meet for two hours to discuss the project and plan a “software design camp” for elementary students.
- *March*: The software design camp would take place. Working in teams (3 students, 1 educator & 1 interpreter) through the process of informant design, each team would develop an interpretive prototype in 3 hour sessions over the course of four Saturdays. The process would follow “informant design” described above in two cohorts.

Throughout this research video, audio recordings, written notes, observations, and an analysis of educational/project artefacts (team designs and final projects) will be utilized in this research. Transcripts and other printed testimonies will be developed based upon your work, ideas, and observations on this project. Because videos, Photos and other identifying images will be used in this research, an additional section granting Michael Hammond-Todd the permission has been included below.

Inconvenience

Participation in this study may cause some inconvenience to you such as missing other scientific, community and family based activities because of the scheduled time for this project.

Risks

There are no known or anticipated risks to you by participating in this research except the possibility of fatigue during the 3 hour software design camp sessions. you have the right to both request and take breaks at any time during this research.

Benefits

Your participation in this research project has many potential benefits as well including your contribution and ideas on how to involve young people in the design of mobile interpretive apps within museum and other informal settings. It is also an opportunity to co-design educational/interpretive software with young people and elementary teachers who share your interests in natural history and science. This project will also culminate with a mobile app you can share with other science educators.

Voluntary Participation

Your participation in this research must be completely voluntary. If you do decide to participate, you may withdraw at any time without any consequences or any explanation. If you do withdraw from the study your individual data will not be used. Michael will separately seek permission on the use of group work that has already been completed. For the purpose of sharing all of your individual and group work will be anonymized with pseudonyms.

On-going Consent

To make sure that you continue to consent to participate in this research, I will provide opportunities to withdraw from the research at the beginning of each weekly session or by email/phone.

Anonymity

Unless individually agreed upon below, this research will protect your anonymity through the use of pseudonyms for research purposes. This includes the use of character names by young people in the development and presentation of any multimedia software using the video, images or voices of young

people. Records of your work, ideas, participation (including video, Photography, audio, and software), and suggestions will be stored securely by the researcher for a period of no more than four years after the research has been completed. After four years all the data associated with this project will be destroyed unless permission is sought by the researcher to continue storing the data from this research project.

Confidentiality

Your confidentiality and the confidentiality of the data will be protected by remote storage either in locked file cabinets located in the researcher's office or, for educational software, tablets or iPads securely stored and locked as well. Except for the relevant data shared through the production of Michael's doctoral thesis, all data and records will be kept confidential unless individual permission has been granted by you.

Dissemination of Results

The results of this study will be shared with members of the public primarily through the production and dissemination of Michael's doctoral thesis. Two to three research article may be developed and shared/presented at scholarly meetings as well including conferences for museum and/or educators. An additional permission from you will be requested for articles and presentations developed outside of the doctoral dissertation.

Disposal of Data

Four years after this research has been completed the data from this study will be disposed of in the following ways. Unless your permission has been sought to continue storing the data, all paper based activities and educational artefacts will be shredded. Any electronic data such as video, audio, Photographs, and software prototypes will be erased.

Contacts

Individuals that may be contacted regarding this study include Michael Hammond-Todd (email: ecostudy@uvic.ca or 1-250-514-5917) and/or his supervisor David Blades (dblades@uvic.ca or 1-250-721-7775).

In addition, you may verify the ethical approval of this study, or raise any concerns you might have, by contacting the Human Research Ethics Office at the University of Victoria (250-472-4545 or ethics@uvic.ca).

Your signature below indicates that you understand the above conditions of participation in this study, that you have had the opportunity to have your questions answered by the researchers, and that you consent to participate in this research project.

Name of Participant *Signature* *Date*

Visually Recorded Images/Data Participant or parent/guardian to provide initials, *only if you consent*:

- Photos may be taken of me for: Analysis _____ Dissemination* _____
- Videos may be taken of me for: Analysis _____ Dissemination* _____

*Even if no names are used, you may be recognizable if visual images are shown in the results.

THE PROTECTION OF YOUR IDENTITY: For the purpose of this research your names will be anonymized with the use of a professional title unless specifically requested to do so below.

Please select statement only if you consent:

I consent to be identified by name / credited in the results of the study: _____ (Participant to provide initials)

I consent to have my responses attributed to me by name in the results: _____ (Participant to provide initials)

A copy of this consent will be left with you, and a copy will be taken by the researcher.



**University
of Victoria**

***Participant Consent Form
Grade 3-5 Students***

A Study About Designing an Mobile App with Young People at the Royal BC Museum

Dear Student:

Hello. My name is Michael Hammond-Todd and I am a doctoral candidate at the University of Victoria. I am writing to invite you to participate in a study about how museums and can involve young people like you in the process of designing a mobile interpretive app for young people visiting the natural history gallery of the Royal BC Museum. You can help with this project if you would like to. You do not have to help if you do not want to. This project will take place on Thursdays during the month of March and involve many different activities where you can share your ideas and designs with educators and me. Each session of the museum's software design camp will last 3 hours. These activities include group discussions, visual mapping, paper based prototyping, the creation of media elements, and sharing/evaluating the mobile software your team develops. You will also have the opportunity and in groups to share your ideas and suggestions for helping the museum involve Grade 3-5 students in creating interpretive programs for other young people in elementary schools.

Your real name will not be put on any papers written about this project unless you specifically request it with your parent or guardian's approval. Your name will not be put on the video recordings, Photographs, or the mobile apps you create and they will be erased three years after the study is done.

If you decide to help with this project but then change your mind you can stop helping at any time.

If you do not understand what the researcher Michael would like you to do, please ask me questions.

If you want to help with this project, please write your name on the line at the bottom of this page.

Student's Name _____

Student's Signature _____

Privacy is important to us and we want to protect your identity. your real name will not be used unless you want us to. Would you like us to use your name when sharing your work and ideas with other educators and organizations such as the museum or university?

___ Yes, it is okay to use my real name

___ No, it is not okay to use my real name

Parent/Guardian signature: In my judgment, my child understands the information in this consent form and agrees to be in the study.

Witness Signature _____ Date _____

A copy of this consent will be left with you, and a copy will be taken by the researcher.



**University
of Victoria**

***Participant Consent Form
Parent Permission***

Factors Influencing the Development of Mobile Learning Initiatives for Children in

Natural History and Science Museums

Your child has been invited to participate in a study entitled *Factors Influencing the Development of Mobile Learning Initiatives for Children in Natural History and Science Museums* that is being conducted by Michael Hammond-Todd.

Michael Hammond--Todd is a doctoral candidate in the department of Department of Curriculum and Instruction at the University of Victoria and you may contact him if you have further questions by email: ecostudy@uvic.ca.

As a doctoral candidate, I am required to conduct research as part of the requirements for a degree in Curriculum and Instruction. It is being conducted under the supervision of Dr. David Blades. You may contact my supervisor at 1-250-721-7775.

Purpose and Objectives

The purpose of this research project is better understand how museum educators might work with young people to design new learning opportunities in the form of mobile interpretive apps. Students occupy a unique position as it relates to the kinds of learning opportunities available to them in museum settings. This research explores how students might contribute to the process of interpretive design as it relates to the creation of a model interpretive app for young visitors to the natural history gallery in Grades 3-5. In addition to the process of designing an app, the participants will be able to share their work with their peers in this project and officials from the museum. Participants will also have the opportunity to make suggestions and recommendations that may benefit other institutions considering the development of interpretive apps for young people in museums and science centers.

Importance of this Research

This research is important because it will add to our understanding of how to better involve young people (Grades 3-5) within the interpretive design process in a museum setting. It also contributes to the development of more activity-based interpretive software specifically designed for elementary aged visitors. This research also contributes to our understanding of possibilities and pitfalls related to the inclusion of mobile interpretive apps for young people within informal education.

Participants Selection

Your child is being asked to participate in this study because he/she expressed an interest in working with peers and educators to design and build a model interpretive app at the Royal BC Museum in Victoria. As a part of this research your child's ideas and thoughts as to how museums can incorporate young people's ideas about interpretive design forms a central aspect of this research.

What is involved

This research is scheduled to take place in the winter. Most of the activities will be completed during three hour sessions on Thursdays in March over the course of a four-week period. The activities include interest surveys, focus groups, software prototyping using paper and other student friendly materials, media design, evaluating app prototypes, project reflections, and suggestions for further research. Individual and group discussions/interviews form an important part of this research as well.

Throughout this research video, audio recordings, written notes, observations, and an analysis of educational/project artefacts (your child's designs and final projects) will be utilized in this research. Transcripts and other printed testimonies will be developed based upon your child's work, ideas, and observations on this project. Because videos, Photos and other identifying images will be used in this research, an additional section granting Michael Hammond-Todd the permission to use video or Photography of your child has been included below. Photos of your child may be used (with your permission) in the production of dissertation. screenshots of the software your child constructed with other elementary students, educators (elementary & museum) and a science advisor maybe used as well.

Inconvenience

Participation in this study may cause some inconvenience to you child such as missing other Saturday school, community and family based activities because of the scheduled time for this project. The software design camp for this research will take place outside of regular school hours.

Risks

There are no known or anticipated risks to your child by participating in this research other than the possibility of fatigue. There will be regular 10 supervised breaks during the software design camp, depending on the time (this information will be forwarded to HERB), a twenty-minute snack or lunch break will also be provided to all participants.

Benefits

Your child's participation in this research project has many potential benefits as well including his/her contribution and ideas on how to involve young people in the design of mobile interpretive apps within museum and other informal settings. It is also an opportunity for your child to co-design educational/interpretive software with young people and elementary teachers who share your child's interest in natural history and science. This project will also culminate with a mobile app your child can share with you his/her family.

Voluntary Participation

Your child's participation in this research is completely voluntary. If you do decide to have your child participate, you may withdraw him/her at any time without any consequences or any explanation. If you do withdraw your child from the study his/her individual data will not be used. Michael will separately seek permission on the use of group work that has already been completed. For the purpose of sharing all of your child's individual and group work will be anonymized with pseudonyms.

On-going Consent

To make sure that you continue to consent to the participation of your child in this research, I will provide opportunities to withdraw from the research at the beginning of each weekly session through a museum contact or by email/phone.

Anonymity

Unless individually agreed upon below, this research will protect your child's anonymity through the use of pseudonyms for research purposes unless your child specifically requests it and there decision is approved by each of his/her parents or guardians. This includes the use of character names by young people in the development and presentation of any multimedia software that uses video, images or voices of young people. Records of your child's work, ideas, participation (including video, Photography, audio, and software), and suggestions will be stored securely by the researcher for a period of no more than three years after the research has been completed. After three years, all the data associated with this project will

be destroyed unless permission is sought by the researcher to continue storing the data from this research project.

Confidentiality

Your child's confidentiality and the confidentiality of the data will be protected by remote storage either in locked file cabinets located in the researcher's office or, for educational software, tablets or iPads securely stored and locked as well. Except for the relevant data shared through the production of Michael's doctoral thesis, all data and records will be kept confidential unless individual permission has been granted by you.

Dissemination of Results

The results of this study will be shared with members of the public primarily through the production and dissemination of Michael's doctoral thesis. Two to three research article may be developed and shared/presented at scholarly meetings as well including conferences for museum and/or educators. An additional permission from you will be requested for articles and presentations developed with this data outside of the doctoral dissertation.

Disposal of Data

Three years after this research has been completed the data from this study will be disposed of in the following ways. Unless your permission has been sought to continue storing the data, all paper based activities and educational artefacts will be shredded. Any electronic data such as video, audio, Photographs, and software prototypes will be erased.

Contacts

Individuals that may be contacted regarding this study include Michael Hammond-Todd (email: ecostudy@uvic.ca or 1-250-514-5917) and/or his supervisor David Blades ([dblades@uvic.ca](mailto:d blades@uvic.ca) or 1-250-721-7775).

In addition, you may verify the ethical approval of this study, or raise any concerns you might have, by contacting the Human Research Ethics Office at the University of Victoria (250-472-4545 or ethics@uvic.ca).

Appendix C: Participant Surveys for Educators and Students



Mobile Design Camp March 31st Educator Meeting



Thank you for participating in the Mobile Design Camp for students and educators at the RBCM. Before getting into the project itself, this research would like to learn more about your views and ideas about interpretive (educational) design for elementary students. There is also a short section that explores your views and experiences on using mobile technologies in museum environments.

Question #1: Check one: Elementary Educator Museum Educator

Question #2: Why are you interested in participating in a project where young people and educators co-design a mobile interpretive app?

Question #3: What are your views and goals when designing educational experiences for elementary students in museums?

Question #4: Have you used an iPad or tablet in a museum setting either by yourself or with young elementary aged visitors? If so, briefly describe your experience.

Question #5: What are your thoughts and opinions on having elementary students use iPads and other mobile devices to learn in the natural history gallery at the RBCM?





Check-in for Students

Mobile Design Camp April 7th



Thank you for participating in this mobile design camp for students at the RBCM. Before beginning the design camp, Let's learn more about why you are interested in designing apps at the museum.

Question #1: Check one: Grade 3 Student Grade 4 Student Grade 5 Student

Question #2: Why did you sign up for the mobile design camp?

Question #3: Have you used an iPad or tablet in a museum? If so, what did you do with it?

|



Check-out for Students

Mobile Design Camp April 7th



Thank you for participating in the Mobile Design Camp today. Before you go, we would like to hear your ideas and thoughts.

Question #1: Check one: Grade 3 Grade 4 Grade 5

Question #2: What would you like to design for other elementary students visiting the museum?





Mobile Design Camp April 14th



Check-in for Students

Welcome to the second week of our mobile design camp! Before starting today, let's check in with the following question:

Question #1: Check one: ___ Grade ___ Grade 4 ___ Grade 5

Question #2: What are your ideas or thoughts about working in teams?



Mobile Design Camp April 14th




Check-out for Students

Thank you for all your hard work in the mobile design camp today. Before you go, we would like to hear your ideas and thoughts.


Question #1: Check one: ___ Grade 3 ___ Grade 4 ___ Grade 5

Question #2: What was your role in designing your team's paper app prototype?





Mobile Design Camp April 21st




Check-in for Students

Thank you for participating in this interpretive design camp for students. Before beginning today, I would like to learn more about why you are interested in designing apps at the museum.

Question #1: Check one: Grade 3 Grade 4 Grade 5

Question #2: Should elementary school students use their real names and photos for educational apps like the ones you are designing? Why or why not?





Mobile Design Camp April 21st



Check-out for Students

Thank you for participating in the Mobile Design Camp today. Before you go, we would like to hear your ideas and thoughts.

Question #1: check one: Grade 3 Grade 4 Grade 5

Question #2: What recommendations do you have for other students who are creating videos, photos, or voice tracks for their apps?





Mobile Design Camp April 28th



Thank you for participating in this Mobile Design Camp for students at this month. Before heading home, please give us your final thoughts and ideas to make design camps like this even better.

Question #1: Check one: Grade 3 Grade 4 Grade 5

Question #2: Now that you have had the opportunity to test your design share it with other groups, what do you think about the process of creating mobile apps like these for other students?

Question #3: Do you think your mobile app can teach other students about the natural history of BC? Why or why not?

Final Check-out for Students

Question #4: What do you like most about your app? What would you change if you could design it again?

Question #5: What was it like working with teachers and museum educators on this project? What recommendations do you have for adults who want to work with students to design mobile apps?

Thank you for participating in the Mobile Design Camp!





Mobile Design Camp April 7th Educator survey

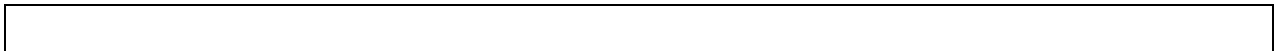


Thank you for participating in the Mobile Design Camp today. Before you go, we would like to hear your suggestions, ideas and recommendations for the next session.

Question #1: Check one: Elementary Educator Museum Educator

Question #2: How can you support the design ideas and elements the young people are proposing this week while meeting the science and educational goals of BC and/or the museum?

Question #3: Please feel free to share any thoughts, ideas or opinions you have regarding your work with the elementary students today as they began the process of interpretive app design.





Mobile Design Camp April 14th Educator Survey



Thank you for participating in the Mobile Design Camp's second session. Before you go, we would like to hear your suggestions, ideas and recommendations for the third session.

Question #1: Check one: Elementary Educator Museum Educator

Question #2: As the elementary students began designing their paper prototypes, what was your role in the process?

Question #3: Please feel free to share any thoughts, ideas or opinions you have regarding your work with the elementary students today as they constructed their paper prototypes of the interpretive app.





Mobile Design Camp April 21st Educator Survey



Thank you for participating in this interpretive design camp today. Before you go, we would like to hear your suggestions, ideas and recommendations for the next session.

Question #1: Check one: Elementary Educator Museum Educator

Question #2: In thinking about your group's use of multimedia cues (video, photography, and audio), what challenges and opportunities do you think these multi-media elements present when used by other visiting elementary students in the gallery?

Question #3: Please feel free to share any thoughts, ideas or opinions you have regarding your work with the elementary students today as they created the multimedia elements for their app.





Mobile Design Camp April 28th Final Survey for Educators



Thank you for participating in this interpretive design camp today. Before you go, we would like to hear your suggestions, ideas and recommendations for the next session.

Question #1: Check one: Elementary Educator Museum Educator

Question #2: Now that you have had the opportunity to test the design your group created and share it with other groups, what are your overall thoughts on the process of working with young people to create mobile apps like these for other students?

Question #3: Do you think the app can teach other students about the natural history of BC? Why or why not?

Question #4: What do you like most about app this group designed? What would you change if you could design it again?

Question #5: Do you think co-designing educational software with young people is worth the time, effort, and resources required to support the development of learning initiatives like these? If so, why? If not, why not? What recommendations do you have for adults who want to work with students to design mobile apps?

Thank you so much for participating in this project!



Post May Interview Questions with Teachers and Museum Educators

Elementary/museum staff

focus group/planning

Group responses #1

interpretive design camp

Thank you for participating in the Mobile Design Camp. The purpose for today is to discuss how iPads and other tablets might be used by students in the museum and set goals for the Mobile Design Camp starting in April:

Discussion questions for elementary and museum educators:

- *Q#1:* Have your ideas and views on designing educational activities with elementary students changed since participating in the RBCM Mobile Design Camp?
- *Q # 2:* What are your thoughts and views around partnering with formal or informal educators on learning initiatives like this?
- *Q#3:* The software in this app is designed to share through different social media platforms. What are your thoughts on having young people designing and using educational apps that include social media sharing?
- *Q#4:* What recommendations do you have for other museums and school districts exploring digital learning through the use of interpretive apps designed and used by young people?

Audio recordings of the discussion and planning of the interpretive design camp would be collected for later analysis. Key elements for analysis in the discussion include descriptions as to how the adult participants in this phase described the role of elementary students in the proposed interpretive design camp. The participation of all participant names would be anonymized according to generic roles (i.e.: elementary educator, museum educator, or museum scientist).

Appendix D: App Template for Mobile Design Camp



Mobile Design Camp April

Team Name: _____ Station: _____

Video Introduction: Write what you want to say in your video introduction here. You should welcome the visitor to your station. Tell them what they are learning about and why it is important. Also, you may want to let them know what they will be doing (taking photos and making a movie).

Practice: Try presenting your introduction. When you are ready, record it in the Design App (we can help show you where to record your video).

Photo #1: Write in one clear and detailed sentence what kind of photo you would like the visitor to take:

Photo #2: Write in one clear and detailed sentence what kind of photo you would like the visitor to take:

Photo #3: Write in one clear and detailed sentence what kind of photo you would like the visitor to take:

Video: Write in one clear and detailed sentence what kind of video you would like the visitor to make:

Text for Multimedia Museum eBook



Appendix E: Thematic Network Analysis Data

The following tables show the raw coded thematic data by frequency and as a percentage of the comments for each thematic element.

Table 1

Distribution of Comments by Students and Educators Within Educational roles

Participant	Category	# of Comments	% of Total Comments
Student	Role as Student	21	36%
	Affective	31	53%
	Formal Education	0	0%
	Informal Education	4	7%
	Other	2	4%
	Total Comments	58	
Elementary Educator	Role as Student	3	16%
	Affective	5	26%
	Formal Education	4	21%
	Informal Education	5	26%
	Other	2	11%
	Total Comments	19	

Museum Educator	Role as Student	1	3%
	Affective	4	11%
	Formal Education	4	11%
	Informal Education	24	69%
	Other	2	6%
	Total Comments	35	

Note: Number and percentage of comments made by students and educators within the organizing theme of educational roles. Each category represents different thematic elements within the process of thematic network analysis.

Table 2

Distribution of Comments by Students and Educators Within Participant-based Pedagogies

Participant	Category	# of Comments	% of Total Comments
Student	Informant	6	8%
	Participatory	15	20%
	Design	29	39%
	Activity	20	27%
	Student	3	4%
	Other	2	2%
	Total Comments	75	

Elementary Educator	Informant	4	7%
	Participatory	18	33%
	Design	24	45%
	Activity	3	5%
	Student	0	0%
	Other	6	10%
	Total Comments	55	
Museum Educator	Informant	14	22%
	Participatory	15	23%
	Design	29	45%
	Activity	0	0%
	Student	0	0%
	Other	6	10%
	Total Comments	64	

Note: Number and percentage of comments made by students and educators within the organizing theme of participant-based pedagogies. Each category represents different thematic elements within the process of thematic network analysis.

Table 3

Distribution of Comments by Students and Educators Within Mobile Design & Learning

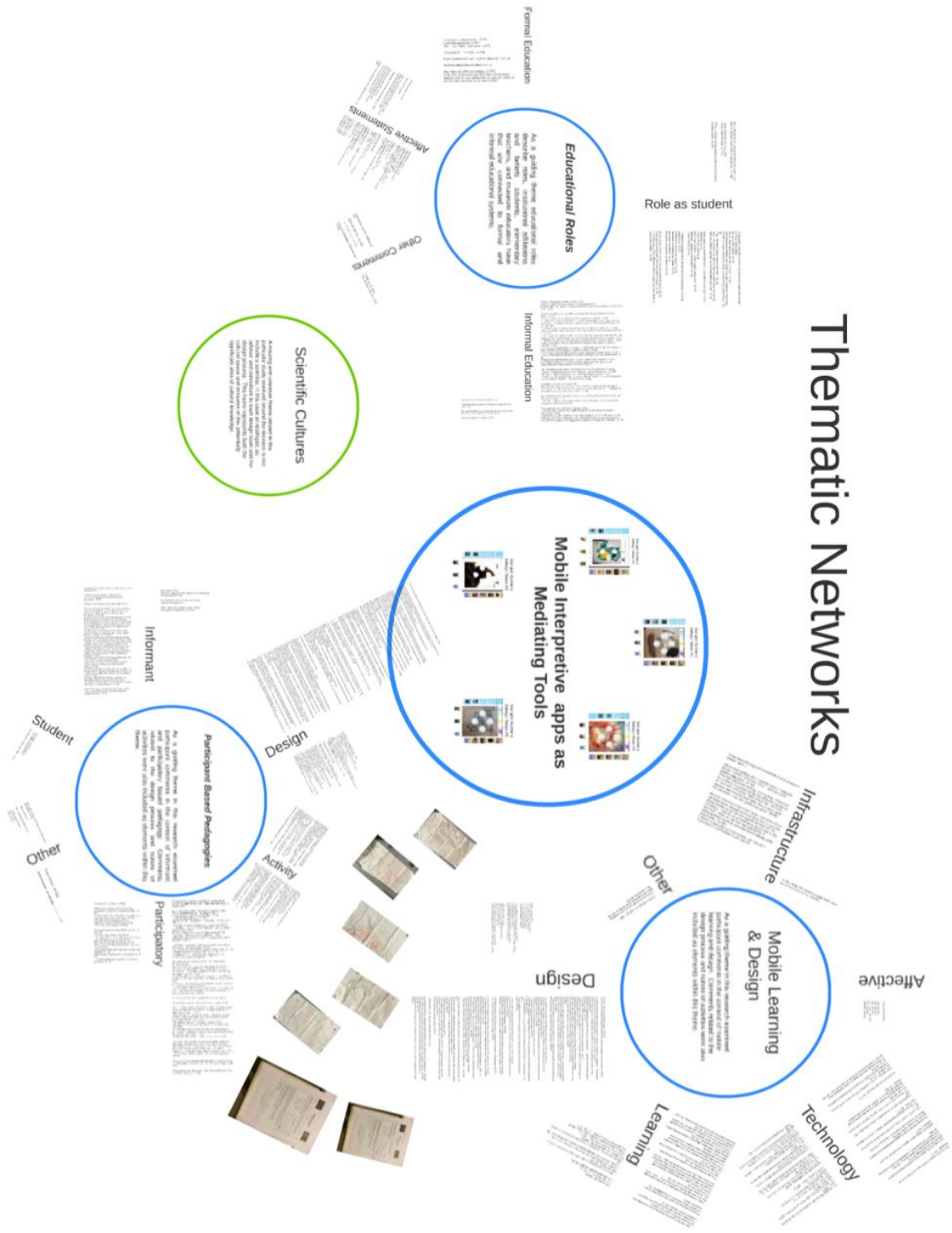
Participant	Category	# of Comments	% of Total Comments
Student	Design	17	32%
	Technology	16	30%
	Learning	9	17%
	Infrastructure	1	2%
	Affective	1	2%
	Other	9	17%
	Total Comments	53	
Elementary Educator	Design	22	71%
	Technology	5	16%
	Learning	3	10%
	Infrastructure	1	3%
	Affective	0	0%
	Other	0	0%
	Total Comments	31	
Museum Educator	Design	23	45%

Technology	10	20%
Learning	10	20%
Infrastructure	5	10%
Affective	0	0%
Other	3	6%
Total Comments	51	

Note: Number and percentage of comments made by students and educators within the organizing theme of M-learning and design. Each category represents different thematic elements within the process of thematic network analysis.

Appendix F: Screenshots from Thematic Network Analysis

The following pages show screenshots from the process of thematic network analysis (see Chapter 5). The first figure shows the complete thematic network with the global (center) and organizing themes. The following pages magnify each section of the thematic network.



Formal Education

“professional development – (C-FT)
leadership opportunity (C-FT)
“-funt! – curriculum connections (C-FT)
To participate in research. (C-FM)
In end, teacher took over + work fro students.” (C-FM)
Teachers always show samples.”(C-FT)
See where they differ and overlap. (C-FIM)
Quite often the teachers objectives were clearly purely
cognitive and she was getting them to read and include as
much natural history info as possible.(C-FM)

As
des
anc
tea
tha
info

Figure 3: Educational role and participant comments related to formal education.

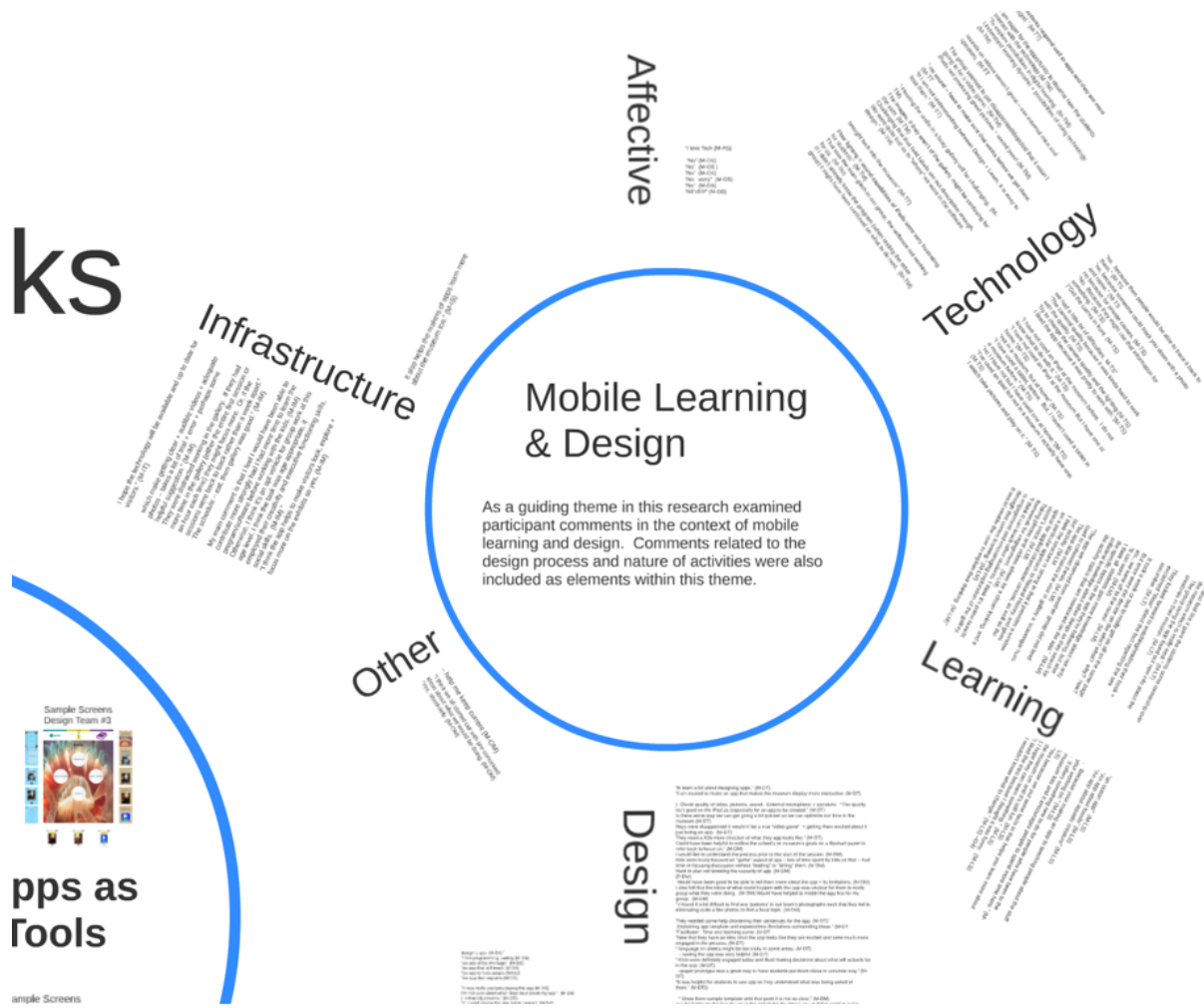


Figure 4: Mobile learning & Design as an organizing theme.

ks

Infrastructure

I hope the technology will be available and up to date for photos - make getting clear + audio videos + adequate helpful suggestions - of real + error + perhaps some more time in the gallery (either the entire first session or an hour each time they're back to back rather than sessions were back to back rather than a week apart. The schedule - eat, then gallery was good." (M-M)

My main comment is that I feel I would have been able to contribute more strongly had I had more time to explore the program/software before working with the kids. (M-M)

Otherwise, I think it's an apt vehicle for group social skills. (M-M)

I think the app helps to make visitors look explore + focus more on the exhibits so yes. (M-M)

It also helps the markers of apps learn more about the museum too. (M-S)

Mc & |

As a guiding participant c learning and design proc included as

...technology will b which make getting clear + audio photos - takes a lot of that + auc more time in the gallery (either the e sessions were back to back rather than The schedule - eat, then gallery was go

My main comment is that I feel I would hav contribute more strongly had I had more time to explore the program/software before working with the kids. (M-M)

Otherwise, I think it's an apt vehicle for group social skills. (M-M)

I think the app helps to make visitors look explore + focus more on the exhibits so yes. (M-M)

& De

As a guiding their participant comm learning and design process ar included as eleme

Other

- help me keep current (M-OM)
I think we all learned a lot with pre-received ideas about what we would be doing. (M-OM)
Yes, absolutely. (M-OM)

Figure 6: Participant comments related to infrastructure or coded as other.

video
(M-DM)

Design

design a app. (M-DS)

"I like programming, coding (M-DS)

"an app video montage" (M-DS)

"an app that will teach (M-DS)

"an app to help people (M-DS)

"An app that explains (M-DS)

"It was really cool processing this app (M-DS)

"I'm not sure about what I like best about my app." (M-DS)

"minor adjustments." (M-DS)

"If I could design the app again I would! (M-DS)

What I change is the video's I did." (M-DS)

in the app section." (M-DS)

what you will need to photograph." (M-DS)

camera recording." (M-DS)

clues for my app." (M-DS)

"I was watching actor in introduction video." (M-DS)

"Have a good background (refers to screen of app). (M-DS)

To learn a bit about designing apps." (M-DT)

"I am excited to make an app that makes the museum display more interactive. (M-DT)

} Check quality of video, pictures, sound. External microphone + speakers. "The quality

isn't good on the iPad 2s (especially for an app to be created." (M-DT)

Is there some way we can get going a bit quicker so we can optimize our time in the

museum (M-DT)

Boys were disappointed it wouldn't be a true "video game" + getting them excited about it

just being an app. (M-DT)

They need a little more direction of what they app looks like." (M-DT)

Could have been helpful to outline the school's or museum's goals on a flipchart paper to

refer back to/focus on." (M-DM)

I would like to understand the process prior to the start of the session. (M-DM)

Kids were really focused on "game" aspect of app + lots of time spent by kids on that + had

time re-focusing discussion without "leading" or "telling" them. (M-DM)

Hard to plan not knowing the capacity of app. (M-DM)

(P-DM)

Would have been good to be able to tell them more about the app + its limitations. (M-DM)

I also felt that the ideas of what could happen with the app was unclear for them to really

grasp what they were doing. (M-DM) Would have helped to model the app first for my

group. (M-DM)

"I found it a bit difficult to find any 'patterns' in our team's photographs such that they led to

eliminating quite a few photos to find a focal topic. (M-DM)

They needed some help shortening their sentences for the app. (M-DT)

Explaining app template and expectations /limitations surrounding ideas." (M-DT)

"Facilitator: Time and learning curve. (M-DT)

"Now that they have an idea what the app looks like they are excited and were much more

engaged in the process. (M-DT)

"language on sheets might be too tricky in some areas. (M-DT)

– seeing the app was very helpful. (M-DT)

"Kids were definitely engaged today and liked making decisions about what will actually be

in the app. (M-DT)

–paper prototype was a great way to have students put down ideas in concrete way." (M-

DT)

"It was helpful for students to see app so they understood what was being asked of

them." (M-DT)

* Show them sample template until that point it is not so clear." (M-DM)

maybe better on the first day or at the end of the day because we didn't need to make

videos today. (M-DM)

Guide idea to paper prototype. (M-DM)

Explanation of app + instructions at beginning helped, but my team was not paying

attention. Possibly having teams repeat what is required would be helpful." (M-DM)

"Still think students should have seen complete run through of sample app. (M-DT)

"we ran out of time to input info in app." (M-DT)

A photo of the gallery, will help them understand they are in the right place." (M-DM)

"a challenge would be the different range of skills using the iPad, and the more skilled

students taking over. (M-DM)

Would be helpful to have some skill building components of taking photos + video. an

opportunity is the way photos + videos allow for students to express their own

understanding of a place + the objects within it. (M-DM)

"The limited 'clues' – due to lack of recording space – may be a bit confusing for users to

identify the items they're meant to. (M-DM)

"It was the adults challenge with the iPad software that was a challenge. (M-DM)

"Research time is as important as the design elements." (M-DM) -ME

"I was able to better support the kids, when I understood the software better." (M-DM)

"The students enjoyed creating the content for this app and felt like they did a good job. (M-

DT).

Once the students understood exactly, what they needed to do they got right into the project

and it was great to see how excited they got about it." (M-DT)

"I sometimes wished we could upload photos from the internet as well as pics from the

museum." (M-DT)

"I liked the variety and enthusiasm. (M-DT)

"-Fun aspects such as videos for each section. (M-DT) – Would have spent more time

looking for specific facts to add to the book – Would probably try to make the videos more

entertaining" (M-DT)

I liked that they could do a video. (M-DT)

– hard to pick it up + go from the design side (M-DM)."

So it might need more prompting, but definitely on the right track for engagement." (M-DM)

This activity then allowed them to determine their focus on their station + photos. (M-DM)

This seemed to be backwards to way we were thinking of developing app, but it

worked!" (M-DM)

I would add more images (to the station) to help the user know where to go/where to look.

(M-DM)



Figure 7: Participant comments about design in category of mobile learning.

opportunity for students to become "educators" in some capacity. (P-IT)

how they meet the design challenge (P-IM)
 be able to communicate with other (younger) generations. (P-IM)

Perhaps a little misunderstood "app design" (P-IT)

Though because the window of design was relatively narrow (only 4 weeks), and the structure of the app was so set, I didn't feel like the students really designed much. (P-IM)

It was more that we were following instructions. (P-IM)
 And there was a lot of value to this, the kids in my group definitely took it and ran. But I don't feel like their voices really shaped what the end product was. It was more filling in blocks of content, than imagining what the box might be. (P-IM)

So while I see a lot of benefit in this method, I also want to find ways to have more open ended inquiry/ design/ co-design/ etc." (P-IM)

I don't know how much of that they really got. (P-IM)
 But that is OK, that's why the adults were there. (P-IM)

"I would not consider the project 'designing educational software', rather it is co-designing content. (P-IM)

This distinction was a major point of confusion at the beginning of the process. Yes, of course designing software and content with target group involvement is important, but the question is what is being tested/ developed. (P-IM)

"Definitely worth our time- that being said though, I felt like it wasn't so much co-design. (P-IM)

The teacher and I were more holding the students hands to further the generation made by those students. (P-IM)

This didn't seem like co-design. I think for genuine co-design between students and adults, there needs to be a space for the adults to be actively involved making choices. (P-IM)

Meaning, I think that the way the 'co-design' was structured replicated museum visits where the chaperone is asked to get out of the way and only take part when the student needs help. (P-IM)

There were some glitches with the framework. (P-IT)

"Yes it is beneficial as their perspective allows for engaging products. (P-IT)

just helping" (P-IS)

"Because I wanted to learn about how we would put the app together (P-IS)

more thoughts are better than one!" (P-IS)

"helping with ideas (P-IS)

I didn't have a lot of ideas in mind." (P-IS)

They were very helpful to us. (P-IS)

Informant



Figure 10: Participant comments coded as informant-based design, student, and other in category of participant-based pedagogies.



Figure 11: Global theme with screenshots of each design team. In the analysis, each team's screen could be magnified and analyzed for content related to different categories of informal science learning.

Appendix G: Analysis of the Type of Learning Activities by Design Team

Learning Science in Informal Environments: Strands Approach

Outcomes of science education should reflect the core values and unique characteristics of learning and teaching in informal settings. Beyond many shared content and practice goals for science education, informal environments often value - and specifically strive to foster - capabilities and affective outcomes that are unlikely to register on school-based assessments of learning.

Several reports from the National Research Council, particularly [Taking Science to School \(2007\)](#) and [Learning Science in Informal Environments \(2009\)](#), attempted to consolidate the outcomes of learning in informal science settings by synthesizing the current body of research and evaluation studies from out-of-school and in-school learning. Learning Science in Informal Environments (2009) categorizes the following six strands as a set of goals and practices for science learning in ISE:

Strand 1: Sparking and Developing Interest and Excitement

Often characterized by people's excitement, interest and motivation to engage in activities that promote learning about the natural and physical world, this strand focuses on motivation to learn science, and the emotional engagement, curiosity, and willingness to persevere through complicated scientific ideas and procedures over time. People with an interest in science are likely to be motivated learners, seeking out challenges and difficulty, use effective learning strategies, and make use of feedback to develop their knowledge. Individuals are empowered to make their own choices to become involved in science-based experiences or choices about what subject matter to pursue.

Strand 2: Understanding Science Knowledge

Encompassing content knowledge, science learning includes the use and interpretation of scientific explanations of the natural world. More than discrete facts, learners must understand interrelations between concepts and use them to build and critique scientific arguments.

Strand 3: Engaging in Scientific Reasoning

People learn the knowledge and skills to build and refine models and explanations, design and analyze investigations, and construct and defend arguments with evidence. This also includes recognizing when there is insufficient or inappropriate evidence to draw a conclusion, and determining what kind of additional data are needed.

Strand 4: Reflecting on Science

Understanding that science is a way of knowing, and related to understanding how knowledge is constructed and how ideas change. Scientific knowledge is dynamic as new evidence emerges and theories are reevaluated through a process of social engagement in scientific discourse. For laypeople and scientists alike, this provides a critical stance for an informed citizenry in political debate and public policy.

Strand 5: Engaging in Scientific Practice

Despite the stereotype of the lone scientist, science is largely a social endeavor. Participation in the scientific community requires knowledge of language, tools and core values as scientists come together to achieve a greater understanding of a scientific problem. By participating in opportunities for doing science that allow for exploration, learners in informal settings can develop an appreciation for how scientific progress is made, as well as gain greater facility with the language of science, such as “hypothesis,” “experiment,” and “control.”

Strand 6: Identifying with the Scientific Enterprise

Through experiences in informal environments, people may come to see themselves as capable of doing science, and for young people, considering careers in the STEM fields. For those who do not become professional scientists, it is important that they identify themselves as being comfortable with, knowledgeable about, or interested in science, in order to pursue hobbies, take informed policy positions, or draw on science when it seems to be appropriate. Identity develops over a lifetime, and may fluctuate as more or less salient according to the encounters and environments in which an individual lives.

Source:

Friedman, A. J. (Ed.). (2008). *Framework for evaluating impacts of informal science education projects*. Washington, DC: National Science Foundation. Retrieved from <http://www.informalscience.org/news-views/types-learning>

Appendix H: Research Narratives

In each of these three research narratives the data collected including the timelines, experiences and stories of the various students and educators on each design team were explored within each narrative framework noted above with the goal of illuminating important areas of study and initial findings that could be further investigated in the second and third phases of triangulated analysis presented in Chapter 5: thematic analysis and recursion. The summary the research narrative analysis around cultural space, participant-based pedagogies and m-learning is presented below.

Research Narrative on Educational Roles

Research Question 1: *What effects do mobile technologies and app design have on the educational roles of students and educators working together to create informal science education content and activities at natural history museums and STCs like the RBCM?*

“I like having the kids as video guides, and getting to know them and their interests, and letting that guide my own interests. There was a kind of fun finding element when prompted to take photos, and doing that in our group provided for some good group work.”

-Museum Educator, 2016

What would elementary students do? It was a question on the tips of many of the participating educators' minds as the participating museum educators and elementary teachers sat down in preparation for the mobile design project that was scheduled to take place with elementary students the following week. This project was an attempt to disrupt the educational roles discussed above by inviting students into the process of designing educational apps. Survey

responses about their interest in the project illuminated many of the educators' thoughts about the importance of engaging with young people. "Co-design and co-creation is an important value in my learning approach to working with youth. I am trying to build a sharing culture and respectful exchange between kids and adults." In expressing her interest in participating, a Grade 3 and 4 educator wrote that she wanted, "To learn more about museum exhibits. To support student taking ownership of learning." Other museum educators and elementary teachers were "curious" about designing mobile apps with students and/or wanted "To explore possibilities in digital learning."

While noting the potential for engagement and learning by elementary students, several educators expressed concerns about the use of mobile technologies in museum settings and students' abilities to participate. This was particularly true among museum educators. One noted that, "It will be challenging at first to think of the iPad as a tool and not a distraction. I worry I won't know enough about the technology to be helpful." Another commented, "I 'fear' that the info on (the) iPad will override the experience of exploring 'things' and ideas in the museum." The elementary teachers in this group differed with their colleagues at the museum. One specialist educator noted that "Technology is a bright shiny toy to 'draw' kids towards immersion in the task." Another intermediate teacher wrote that this project was a, "-great opportunity to connect technology into the real world – increase the use of technology for learning purposes (not just games) -..." and most importantly an, "...opportunity for students to become 'educators' in some capacity." As the meeting progressed, there were lots of questions about what students might create and "How can this experience be part of a greater learning program?" The answers to those questions would begin to emerge the following week during our first session with the students.

The informal nature of museum and informal science education as it related to the design of mobile apps was evident early in the first session with the students as they selected other members of their design teams and completed the check-in surveys. Nine of the thirteen responses contained the word “fun” in some context. One Grade 4 student wrote, “I signed up because I thought it would be fun and I would learn new things.” Several students were interested in the design process in stating why she joined, “Because I wanted to learn about how we would put the app together also I wanted to see the museum again.”

As presented in the preceding chapter, five design teams formed in this mobile design initiative. Because of the small size and short timeframe of this study, students could self-select the peers and educators they wanted to work with. While a few educators were initially disappointed in not being able to work with the students they preferred, everyone quickly began working on the first task of mobile design: idea generation. The students on Design Team #1 and Design Team #4 expressed disappointment that they would not be designing video games or coding which is described within the context of the third research question on the design and use of technology in the third research narrative presented later in this Appendix illuminating their role as digital consumers of entertainment (Němec, J. & Terna, 2007). Elementary student interest in the technical and coding aspect of mobile apps may also reflect their participation in technology education at home or school as well. The process of designing new interpretive and digital content for peers was new for the participating students. Despite this, all design teams were able to come up with different ideas after the first session as evidenced in each team’s design poster and final prototype (see Chapter 5) and the responses elementary designers wrote at the end of the first session on their “Check-out” surveys provided important insights into some of the key areas explored around their roles as producers of scientific content rather than

recipients or consumers. A Grade 5 designer with Design Team #5 wrote that his team wanted to design, “An app that explains what lives in tidal pools and shows the ocean and learn about life.” Another Grade 5 member of Design Team #2 wanted to create, “An app about fossils.” Design Team #1 decided to focus on “an ocean app” based upon an “underwater scavenger hunt.” Terrestrial and aquatic wildlife, both past and present, were the dominant themes for activities during the first session as illustrated in some of the sample design posters and screenshots below in Photo 5.1. From the moment each design team formed, it was evident that students and educators assumed different roles which is discussed below.

While one elementary educator wrote, when asked about how they supported students in their design ideas and elements, “Not sure”, most museum and elementary teachers on the different design teams focused on supporting facilitation and helping students “keep on track.” Both museum and elementary teachers wanted students to go further and in more depth in the topics and level of knowledge the students were designing. For example, one intermediate teacher with Design Team #1 wrote that she was, “Prompting about Ocean Stewardship (of) our local environment...” and “Bringing in an Aboriginal Piece to our focus (ocean animals and creatures).” This illuminates the different goals and expectations students and educators had as co-designers. At this early stage of research, an interesting observation in the difference between museum educators and elementary teachers was observed as well. A museum educator wrote, “Encouraging the students to imagine what they’d be interested in seeing, learning and finding out more about the aspects/things that interest them.” Another interpreter mentioned her role as supporting students in noting that “By being enthusiastic about our activities together and enjoying our time and work as we develop our ideas.” While the participating teachers tended to focus on content knowledge, museum educators tended to oriented towards discovery models of

learning and support. Within the context about the different cultural spaces students and formal/informal educators occupy, this was an important initial finding needing further verification in the next phase of *triangulated analysis* discussed in the Chapter 5.

Early on it was observed how quickly the members of each design team slipped into different roles. In four of the five teams, the elementary students focused on topics and activities while the educators provided support in the area of technical assistance and structure. One team followed a model where students might pick the topic but generally were encouraged to fill in content and activities as directed by the educators they were working with. In both of these approaches, the educators were excellent advocates for themselves and the students they worked with. As an example, during the first long session where the participating students and educators were exhausted by the end of the first three-hour session. One teacher noted that students had “Great energy and ideas at the beginning...” they were “fading” as the workshop entered its third hour. Another educator noted that she was excited but “Brain fried.” Others pointed out the challenge of scheduling the project after a full day of school. As a result of feedback and suggestions made by the participating adults and the exhaustion students exhibited, we shortened the schedule for mobile design initiative by one hour during the remaining weeks. Although the shortened schedule impacted the ability of teams to complete more than one interpretive design activity, all teams were able to complete an activity described in more detail in the next section. Advocacy on behalf of students and visitors, it should be noted, is an important educational role as well. Franco (2012) and Fensham (1985) note the importance educators function as within science curriculum development and implementation.

As noted on the activity schedule in Chapter 3, during the second and third weeks, design teams were creating prototypes of their activities through paper based modeling (Week 2) and

digital design (Week 3). Each team used a paper prototyping format ([Appendix D](#)) which was then converted to digital form in Week 3. The students were much more focused on the specific activities as evidenced in a sample of their responses in Table N-1 below.

Sample Student Responses Around Team Activities

To make missions on the Beach area. I made decisions and chose what to do on the beach.”	<i>Grade 5 Member Design Team #1</i>
“I wrote my introduction and clues for my app.”	<i>Grade 4 Member Design Team #5</i>
“My job was to fill out a pice [sic] of paper of inside and outside bones	<i>Grade 4 Member Design Team #2</i>
“Today, I was brainstorming with <i>my teammate</i> and adding on to her idea. I was mainly help with the ‘Phrasing’ of the sentences.”	<i>Grade 5 Member Design Team #3</i>

Table N-1: Sample and representative student responses around design activities.

Elementary and museum educator comments varied during this time with a key difference from both perspectives. Comments from elementary teachers were generally positive about the state of the projects at that time and provide important insights into the differing pedagogies of the participating educators. One elementary teacher noted, “Now that they have an idea what the app looks like they are excited and were much more engaged in the process. They got a lot more done and didn’t need as much help with the ideas.” Another intermediate teacher wrote that the “Kids were definitely engaged today and liked making decisions about what they will actually be in the app.” Many of the museum educators were concerned about the ability of teams to

complete their projects on time with one interpreter writing that the “Timeline is tight to create 3 activities today and we completed one.” For one museum educator, the group dynamics of the team changed when a student was absent, “Team of 3 last week, down to 2 and the dynamics and focus changed. Two students had difficulty making decisions on every step of the process, and kept envisioning original “crime game + shop.” The differences reflected here illuminated some of the educational differences and tensions existing between formal and informal educators discussed earlier in this chapter. In closing interviews, several of the museum educators noted the initial challenge of being perceived as an “outsider” by the students and teachers on their teams. While all the teams, as evidenced in the comments by educators during the third week in Table N.2 below, were able to navigate the complex tensions that can exist between formal and informal education (Wellington, 1991; Gassert, 1994; & Hoffstein & Rosenfeld, 1994), there was quite a bit of variation in how easily formal and informal educators in different design teams were able to navigate them. In addition to this, another important initial finding that required additional research within the process of triangulated analysis and is presented in following chapter revolved around the observed overlap between differing pedagogies and content goals among the participating educators. There appeared to be significant overlap around student centered approaches to learning within this group of formal and informal educators which is discussed in the next research narrative and in Chapter 6. However, formal educators tended to focus on academic content while informal educators embraced discovery based learning which is in line with the historic development and roles educators play within both formal and informal learning systems (Tamir, 1991; Wellington, 1991; Hoffstein & Rosenfeld, 1994).

Although the sample size of this project is too small to be definitive, other studies have shown that the unique social dynamics and personalities of each member of the design team may

have played a significant factor in what activities and learning processes are selected (Griffin, 2012; Barab & Hay, 2001). While all the design teams were progressing during this time, both formal and informal educators were concerned at the lack of time students had for research which affected the interpretive pedagogy discussed in the next section.

Sample Educator Responses Around Teaming Together

“Today was a much more focused day. Students + educators had clear agenda + understanding of tasks plus sense of urgency that helped us keep kids focused on tasks. Nothing like a deadline! Kids also felt much more comfortable with me + in working with me rather than always referring to teacher.”

Elementary Educator

And it was also interesting I think the playground was also a little bit level because neither of us knew exactly what the project was or how exactly it was going to work. So although I knew the museum and the content. She knew the students. So we were both bringing something to the...and I think that works. That worked well. It wasn't...I wasn't leading it. She wasn't leading it. But together we were finding our way through with the kids.

Museum Educator

Um...well I think for us...it is really key for us to align with the curriculum and the school system and to work with teachers for sure...uh...but as you know we have different objectives in situations like that so I did find that it was interesting on a couple of occasions where the teacher that I paired with...who was terrific...but she was really interested in making sure the kids understood the content of the gallery that they were in...reading, learning, and memorizing facts about the...and I am sure she is not the kind of teacher who is fact driven...it was just just that they were in this environment and here is something that kids could learn about.

Museum Educator

Table N-2: Representative comments by formal and informal educators around teaming together.

One museum educator noted that “Research time is as important as the design elements.” This was echoed in an elementary teacher’s statement that the young designers “-need more time to research, specific facts_on each item.” She further noted that the young members of her team “...are having fun and really engaged now that they can see their work.” One important observation around identity is that while museum and elementary teachers were in unison about protecting student identity, half of the elementary students (five out of ten responses) wanted to use their own names and personal information when creating and sharing interpretive apps. Typical responses for sharing personal authorship of digital material included statements by a Grade 4 student “Yes because children can know you are smart and then they would try to get smarter so they can learn the same thing.” Two young designers echoed each other with the statements “Yes. So people can know how beautiful you are.” and “Yes. So people can admire how beautiful you are.” There may be some interesting gender issues around these responses in terms of digital authorship as it relates to identity but was not the focus of this particular study.

By the end of the third week, three of the five teams had most of the design elements completed for their interpretive app activities. However, in order to make the final week more successful and enjoyable for each team, a supplemental after school session was planned for the following week where elementary students and teachers could come and work on their apps for approximately thirty minutes. As a result of participating in the after-school session, each team had at least one interpretive activity (see Fig 4.2 for examples) to share with peers during the final week of this mobile design initiative.

During the last session teams had an hour to refine their designs and share them with other teams. In video recordings and their final questionnaires, elementary students were able to reflect on the work they and their peers had created. As illustrated in Table N-3 reflective responses to

their peers ranged from straightforward comments about what they learned in testing other team’s apps to suggestions on making the apps better. Unfortunately, as will be discussed in the next research narrative, no teams had the time to revise their prototypes based upon peer feedback. Peer feedback and revision is an important aspect in both science education and digital design initiatives (Scaife, M., Rogers, Y., Aldrich, F. & Davies, M. 1997; Druin, 2009).

Sample Participant Reflections and Peer-Feedback

<u>Comments</u>	<u>Student</u>
<p>Team Member #1 - “I liked that you could work with a person.” Team Member #2 – “I like that it was only us and that we are such good friends and we work well together....the (teacher) let us do everything.”</p>	<p><u>Two Grade 4 Students on Design Team #4</u></p>
<p>“Early on it got quite stressful and I thought, ‘Oh no! Am I going to finish this on time?’ But in the end it worked out.”</p>	<p><u>Grade 5 Student on Design Team #1</u></p>
<p>Team Member #1 - “Honestly, it was kind of fun because we would not have been able to do this if we didn’t get this opportunity... Well, we all kind of had the same ideas and we could agree on the questions and the answers overall.”</p>	<p><u>Grade 4 Student on Design Team #5</u></p>

Table N-3: Elementary student video reflections and peer feedback around peer designs.

In addition to peer to peer feedback, the young designers shared their thoughts about working with elementary and museum educators. “At first I thought working with teachers will be scary.” one respondent whose grade was unlisted wrote. This was a common response when the participating elementary students were queried early on in the mobile design project. In the end, every young participant in this study appreciated working on this project with adult educators as evidenced in many of the representative comments in Table N-4 below.

Sample Student Responses About Working with Educators

“there awesome nothing to change”	<i>Grade 5 Member</i> <i>Design Team #3</i>
“I liked working with the adults my suggestion is for the adults that want to make apps with kids is do more often”	<i>Grade 4 Member</i> <i>Design Team #5</i>
“I think it was a little different with the teachers but I think it was a little better.”	<i>Grade 5 Member</i> <i>Design Team #2</i>
“they are good at giving ideas and helping out. none.”	<i>Grade 5 Member</i> <i>Design Team #3</i>
“it was fun working with teachers and museum educators. My advice is to just fiddle around and hope for the best. 😊”	<i>Grade 5 Member</i> <i>Design Team #5</i>

Table N-4: Sample responses by students the following question: What was it like working with teachers and museum educators on this project? What recommendations do you have for adults who want to work with students to design mobile apps?

Within the context of cultural spaces, the apparent tension between informal science design as either a process of enculturation (Fensham, 1992; Aikenhead, 1996) or transformative (Pea, 1994) whereby students and educators work together in creating new interpretive possibilities and discourses that replace older and more transmissive models of interpretive narratives within informal science and museum education. Thus, the educational roles surrounding participants as they worked together in designing mobile interpretive app prototypes might represent fundamentally new or different process of science enculturation was selected as a guiding theme within the process of thematic analysis presented in the next chapter. However, before discussing the results of that analysis however, it is important to turn to the second major area and the research narrative related to participant-based pedagogies.

Research Narrative on Participant-Based Curriculum Design

Research Narrative #2: Participant-based Design

In addition to the inclusion of ideas and activities of elementary students into interpretive design process, this research explored whether participant-centred and activity-based pedagogies were effective ways of including elementary students into the mobile interpretive design process for the RBCM. This question also examined how museums and science technology centers (STCs) might evaluate and/or assess the effectiveness of the mobile interpretive software and activities elementary students created with formal and informal educators. Like the previous research narrative on cultural space, the narrative analysis here relied on participant surveys, reflective videos, interviews, and the research field notes. Paper based and multimedia artefacts also form an important part of this narrative.

Research Question 2: *How might the interpretive pedagogies and the participation of young people within mobile design initiatives contribute towards the process of creating socially-engaged and self-directed learners within STC and museums?*

“I think there is huge potential for this to create better learning experiences. I think we have to be careful about identifying our objections. Mobile devices in a natural history gallery. What are they learning about nature?”

-Museum Educator, 2016

A significant problem emerged as I reflected on many of the individual and group comments students and educators made during this mobile design project at the RBCM. That problem was the inherent conflict and tension that exists between participant-based pedagogies and informant-based design. Before exploring how the conflict emerged and expressed itself within this particular study, it is useful to briefly review these two interpretive and mobile pedagogies within the context of activity theory (Plakitsi, 2013). As explored in Chapters 1 and 2, participant-based and learner-centred pedagogies emphasize learning processes and activities that emphasize a model of learner-centered design where the participant is an equal member of the design group (Druin, 2009; Fails, Druin & Guha, 2010; Churchill, King & Fox, 2016).

In contrast, informant-based design, according to Scaife, Rogers, Aldrich & Davies, they narrow the focus of participation by young people to ‘informant’:

So, by ‘informant design’ we mean an interplay between privileged observations from potential users and ourselves with another set of skills. Hence, in treating

children as native informants, we hope to be able to discover what we did not know rather than to confirm what we thought we knew. We also do not treat them as equal partners, as we are realistic as to how much they can be involved, since they neither have the time, knowledge or expertise to participate in the collaborative model prescribed in PD approaches. (p. 23, 1997)

In reviewing survey comments and the transcriptions from interviews, it appeared that an important difference emerged in how students and educators viewed the level of their control and participation in this study. Students tended to report higher levels of participation and satisfaction with the designs and activities their team created while adults, perhaps more aware of their role as informants rather than participants, appeared more frustrated with the design and structure of the educational software and their role within the mobile design process. However, it appears that many of the participating educators, over the period of four weeks during which the mobile design project ran, were much more aware of the fact that they were informants rather than participants. Early comments such as the one by the elementary teacher stating, “I am excited to make an app that makes the museum more interactive” and museum educator’s, on Design Team #2, view that, “Co-design and co-creation is an important value in my learning approach to working with youth” illustrated an optimistic and participatory view of design.

Over time, however, and in conjunction with the complexity of the app prototyping tool and its inherent structure and limitations, many of their views began to change. In thinking about the software itself, one elementary educator from Design Team #4 wrote, “If I am not understanding between *Design & Learn* (prototyping app), it is easy to lose them.” The same museum educator quoted above put it more bluntly:

“I would not consider the project ‘designing educational software’, rather it is co-designing content. This distinction was a major point of confusion at the beginning of the process. Yes, of course designing software and content with target group involvement is important, but the question is what is being tested/developed.”

From this initial observation, I decided to utilize *informant* and *participatory* as two of the five most comment thematic elements of participatory-based design explored more fully in Chapter 6. While too early to be definitive at this first stage of research, I was interested in testing the limitations of Informant Design (ID) in terms of its ability to authentically include the ideas and activities of elementary students. I was interested in knowing if the process of ID itself created tension and a desire or even more participatory-based models of educational design within this case study. However, at this stage, it does appear that the informant-based model itself partially compromises the position of authentic and equal participation of elementary students and educators co-authoring mobile interpretive apps. Both the process of thematic analysis and a full discussion on the desire for more participatory-based design by the participants in this study are examined and discussed in Chapter 6.

In addition to the observation of the tension around participant-based pedagogies, data from elementary students during the first two weeks also suggested an expansion of their interest in coding, gaming and exploring virtual environments, including the creation of place based and real world digital content related to an active exploration RBCM’s natural history gallery they were creating for peer users. For example, comments by participants in the first session such as, “I like programing, coding and just helping” by a Grade 5 member of Design Team #2 illuminate a strong association many elementary students have between software and coding. Other students

expressed an interest in creating action packed games or virtual galleries for this project. While educators in two of the five teams noted that the students in their group were initially disappointed, by end of the first session most students were excited about the diverse topics they had selected to design an activity around as exemplified in the following comments:

Grade 4 student – “I want to design something about Pangea.” (April 7, 2016)

Grade 5 student – “An app to help people learn what they can do to help wildlife.”
(April 7, 2016)

Grade 5 student – “An app about aquatic creature” (April 7, 2016)

During the final session, an interesting phenomenon appeared among the participants in this study, it appeared that the young designers were much more content with the digital prototypes they had designed. When the participating elementary students were asked what they might change in their app. Responses included:

“Nothing. I think Its perfect” (Grade 5 Student, April 28, 2016)

“Nothing. I like It takes you about the natural history gallery.” (Grade 5 Student,
April 28, 2016)

“I liked the animals I chose and I like learning things I Did not know if I could Do it
agaig I would probably change it to birds!” ♥ (Grade 4 Student, April 28, 2016)

During this same period, educator comments tended to echo some of the same frustrations around the use of older iPad 2 systems and the complex structure of the experimental *Design &*

Learn software, which was new to them as well. Like their younger peers, most of the participating educators were proud of the work their design teams had completed though they offered more suggestions about making improvements to their designs, the technology used in this project, and the learning activities each team completed as exemplified in the following comments:

I liked the variety and enthusiasm. I would change the way things were connected -> try to go deeper into learning than wider. (Elementary Teacher, April 28, 2016)

I like that they chose the topics + areas that interested them. I would add more images (to the station) to help the user know where to go/where to look. I would like more open-ended questions/tasks. (Museum Educator, April 28, 2016)

The students did have to research a little bit to develop questions. This activity then allows them to determine their focus on their stations + photos. This seemed to be backwards to the way we were thinking of developing apps; but it worked! (Museum Educator, April 28, 2016)

Based on an initial review of participant responses, comments and patterns emerging within surveys and learning artefacts created in this study by each design team (including both the paper and digital prototypes each team created), student ideas on design and activity were identified as additional topics of interest in this study. More specifically, as the primary researcher, I was interested in understanding the underlying intention and purpose around how young designers created interpretive apps to facilitate peer user activities around informal science learning with the topics/exhibits teams selected. Both the topics of participant-based

design and the underlying intentions around user activities were included within the process of thematic network analysis described in the next chapter. The final research narrative explored user theory and mobile learning within design and use of technology operating as educational mediating and design tools is examined in the next section.

Research Narrative on M-Learning & Technology

Research Narrative #3: User Theory and Mobile Learning

The third area explored how interpretive apps might facilitate learning among and for elementary students. More specifically this research sought to understand ways in which STCs and museums might utilize cooperative/informant design theory into mobile interpretive design initiatives for young people. Understanding what other educational and interpretive infrastructure is necessary to support mobile interpretive software and sharing for young people forms another important facet of this question. In addition, the research narrative analysis below is designed to illuminate many of the opportunities and challenges existing as it relates to the design and use of mobile interpretive software for students in STCs and museums.

***Research Question 3:** What opportunities and challenges exist in the development and use of mobile interpretive apps for facilitating social and self-regulated learning among young people in STC and museum environments like the RBCM?*

“The one thing I do like about being able to send yourself from the app that you made is that you take ownership over what you are doing. It is not just...I am going to take a picture and be silly and make some videos. You are actually creating something.”

-Elementary Educator, 2016

The underlying structure within the process of Informant Design (ID) is well suited to narrative analysis. ID, as presented in Chapter 2, describes a model of participant-based software design within the field of User Theory where participants, in this case students and educators, act as “native informants.” As informants the participants in this study provided important insights into their roles and experiences as they related to the process of advising and/or informing software designers. As an example, the participating elementary and museum educators provided an important source of information for mobile development based on their experiences of having designed and taught educational activities for students. The students also provide important insights into the process of mobile design. As experts in the “lived experience” elementary students bring their ideas and experiences in both formal and informal settings to the process of software design (Druin, 2009; Fails, Druin & Guha 2010; Churchill, King & Fox, 2016).

In the first stage of informant design (see the research calendar in Chapter 3 for a description), the participants generated their ideas about mobile learning and app design. Members of the Design Team #1 wanted to design “scavenger games.” Design Team #4 wanted to create an activity where the app users earned “museum money.” Design Team #5 proposed the idea of creating a virtual environment where users had adventures related to marine environments. These initial ideas illuminated preconceptions many elementary students have around the design and use of mobile software as primarily connected to coding and the creation of content/activities based within virtual environments rather than the physical environment of the RBCM’s natural history galleries this project explored.

Like the students they were working with, the participating educators were also curious about the possibility of designing educational apps with students. One elementary educator with the Design Team #3 wrote, “This would be a totally new experience as I have never done any type of ‘design.’” The museum educator on the same team echoed this same interest when noting, “I am eager for the opportunity to observe how the students interact with the technology and how they meet the design challenge.” While many educators noted that they or their students used iPads and other mobile tablets to look up information and take photos or video in school and home settings, the idea of designing an app for students to use within the physical gallery itself was intriguing. One museum educator wrote, “I am very curious about what the students will contribute. I am eager for the opportunity to observe how the students interact with the technology + how they meet the design challenge.” As illuminated in some of the learning artefacts the design teams created during the first session, most teams were focused on developing mobile activities that were game-based such as a scavenger hunt (Design Team #5), earning points, or museum money (Design Team #4). For both the students and educators participating in this project, the concept of mobile interpretive apps that elementary students could design and share with peers within elementary museum settings was novel.

The second stage of Informant Design revolved around paper prototyping (Druin, 2009). At this stage the members of the design team used clipboards and paper based activities to design the activities they wanted to digitize with the *Design & Learn* app. While many paper-based activities within the process of ID are open-ended, the limited time available (one session) required a paper shell and scaffolding activity (see [Appendix D](#)) where students could design their content for immediate input into the software. Four of the five teams completed paper based prototyping activities before transferring them to the *Design & Learn* software. Interestingly, one

team (with a young and technologically advanced teacher) skipped completing the paper framework and instead used it as a guide for creating the digital content directly within the software itself.

The limitations of the older iPad 2-and the complexity of the *Design & Learn* app were also major topics of discussions among the participants as teams began completing the digital apps based on the paper prototypes they had completed. While elementary student comments tended to focus on the coolness of team names and the specific tasks they were working on as illuminated in statements such as this one from a Grade 4 member on Design Team #4, “I wrote my introduction and clues for my app.” Stress and dissatisfaction with the capabilities of the iPad and complexity of the app were strongly evident. One museum educator exasperatedly wrote, “iPads not producing great pictures and sound poor!” In the follow-up survey another elementary educator wrote, “The quality isn’t good on the iPad 2s (especially for the app to be created).” In this study, the paper prototyping framework generally were completed before digital conversion with the exception of Design Team #2 that chose to utilize it as a digital guide and reference.

The third and final stage of informant design revolved around digital prototyping and evaluation. Both processes occurred during the last two weeks of the mobile design initiative. For most of the participating elementary students, the narrative experience shifted from addressing the challenges and frustrations they experienced using complex technology to the satisfaction of completing and peer reviewing the mobile app prototypes everyone designed. Young participants also offered many recommendations around the future development of mobile design projects with elementary students at the museum. One Grade 5 member of Design Team #3 wrote, “It was pretty fun. Take the opportunity if you can. You won’t regret it. It’s easy and hard at the same time.” Another Grade 4 student on Design Team #1 stated, “It was really

cool processing this app at times. We got stressed but overall it was fun!” Both of these comments typified the general satisfaction elementary students had with the design of their team’s learning activities.

Like their younger counterparts, many of the educators also struggled with both the technology and complexity of the prototyping software. Examples of the kinds of technical issues they experienced with the software and iPad 2 systems design teams faced are echoed in this response by a museum educator on Design Team #4 “The galleries are dark and noisy which makes getting clear and audible videos and adequate photos. (It) takes a lot of trial and error and perhaps some helpful suggestions.” Another elementary educator frustrated when the audio from her Team’s iPad failed wrote, “No-sound. (The researcher) have to make sure that works before we get there.” All the iPads were checked prior to the project and two working spares were included in case of a software or technical issues such as the one this team experienced. The single iPad failure, when later examined by UVic’s Technology Specialist, was unexpected but common software fault with the audio recording features of the iPad 2. The team was issued a spare iPad that allowed them to successfully complete their mobile activities. Despite this temporary setback comments like, “It was the adults’ challenge with the iPad software that was a challenge. Challenging that the field labels are not descriptive enough. We were quite lost as to “where” we were in the software design.” noted another museum educator with Design Team #3.

As described in the second research narrative around informant-based pedagogies above, every team was able to complete at least one digital interpretive activity. The relief and satisfaction each team felt in completing, testing, and sharing their activities with other design groups represented another key turning point around the narrative as it relates to mobile design and learning. Eleven of the thirteen elementary respondents noted that the project was either

“fun” or “interesting.” When asked whether they thought their team’s app design could teach other students about the natural history of British Columbia, all thirteen elementary designers felt so as represented in this response by a Grade 4 member of the Design Team #5, “Yes. Because your making an app to teaching people about the stuff you are working on.” Another Grade 5 member of Design Team #1 agreed stating, “Yes, because it shows you all about every different place in BC.”

The educators echoed and supported the views and statements of the young designers during the last session. “The students enjoyed creating the content for this app and felt like they did a good job. It was a good experience for them. I also feel like it gave the students some ownership over the museum which is really neat.” responded an elementary educator with Design Team #3. Another elementary educator with Design Team #2 wrote, “It was a good experience. Once the students understood exactly, what they needed to do they got right into the project and it was great to see how excited they got about it.” For museum educators who were also influenced by the site of this project and the RBCM’s new initiatives in fostering digital learning, the comments were even more focused.

It was an interesting and fun process. My main comment is that I feel I would have been able to contribute more strongly had more time to learn the program/software before working with the kids. That was the main glitch in our group, the software not working for us. Otherwise, I think it’s an apt vehicle for group work at this age level. I think the task was age appropriate. It employed their creativity and executive functioning skills (and) social skills. (Museum Educator, April 28, 2016)

Another museum educator added:

In general, my thoughts are that I want to do more of this. Though because the window of design was relatively narrow (only 4 weeks), and the structure of the app was so set, I didn't feel like the students really designed much. It was more that we were following instructions. And there was a lot of value to this, the kids in my group took it and ran. But I don't feel like their voices really shaped what the end product was. It was more filling in blocks of content, than imagining what the box might be. So, while I see a lot of benefit in this method, I also want to find ways to have more open ended inquiry, design, co-design, etc. (Museum Educator, April 28, 2016)

The last comment illuminated the critical engagement with this project and an ultimate desire by many of the participating educators to offer suggestions related to technical and design issues with the software. Participants also discussed what role mobile technologies and design software might occupy within museum settings in the future. Both elementary and museum educators included important suggestions for creating a more participatory framework rather than the informant model utilized in this research project and discussed in the second research narrative above. Examples of participant comments around the design and use of mobile apps were found in the reflective group and individual interviews conducted in the weeks following the mobile design project. A particularly insightful comment by one elementary educator at the participating school sums up many of the thoughts and ideas of the group of educators as a whole:

Applying it to the real world...applying it to a museum where they go on spring break They go in the summer. They can go and see...oh...this app we created applies

outside of the classroom and presentations that we do in the classroom and I think that was a really valuable piece. (Elementary Educator, May 16 2016)

From the perspective of museum education, it was echoed quite thoughtfully as well:

What would be really interesting to me is if I had one or took my granddaughter and did this together in a science center or museum or wherever was to put the finished project/product sort of in...I don't know...some kind of portal and have it broadcast so that everybody else's on the screen so you could have little mini TVs or screens and see...and it would be very interactive and would make you feel like you have created something...Yeah...and I think people...other people see it but after you have done it...but...you no videos on Facebook that pop up...you know...that could be a way that somebody says, 'I went to the museum and this is the book I created.' It would be kind of a fun thing for somebody to do. (Museum Educator, May 28, 2016)

Each of these elements within the four stages of ID: preconceptions/views about mobile learning, technology/infrastructure required for design, challenges and opportunities were identified as potential thematic elements within the organizing theme of mobile technology and learning examined within the process of thematic network analysis described in Chapter 5. Other important issues discussed and identified by participants around author identity, visitor privacy and the integration/use of social media capabilities in the design software were integrated within the organizing theme of mobile learning and design as well.