Exploring Context: Using Teacher Perspectives to Guide Tangible Multi-Touch Tabletop Design for Classrooms

by

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Abstract

The growing potential of Tangible User Interfaces (TUIs) for education in the child-computer interaction community has yet to explore how TUIs can best be designed and evaluated for complicated and dynamic classroom settings. This thesis aims to help researchers and designers gain a better understanding of what matters when embedding TUIs within a classroom environment by exploring themes of contextual concerns derived from teacher interviews. Through a comparative exploration, comprised of two studies, I examined both predictions of use and actual classroom integration in an effort to understand important design and evaluation considerations. I present results that are a culmination of data from both studies to form a more full picture of the problem space. I contribute both analytic themes and design considerations for TUI tabletops for primary educational classrooms. I introduce The Activity Checklist as a tool to guide existing qualitative inquiry methods for 'real world' deployments.

Keywords: Child-Computer Interaction; Tangible User Interface; Education; The Activity Checklist; Interactive Tabletop Design; Interactive Tabletop Evaluation
Dedication

I would like to dedicate the completion of this thesis to my always-supportive family. Thank you for always inspiring me and pushing me to be my best. I would not be where I am today without you. To my amazing husband – Erik I love you. To our coming baby – you were my little special thesis surprise.
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# Table of Contents

Approval .................................................................................................................................................. ii
Partial Copyright Licence ............................................................................................................................ iii
Ethics Statement ........................................................................................................................................ iv
Abstract .................................................................................................................................................... v
Dedication ................................................................................................................................................... vi
Acknowledgements ...................................................................................................................................... vii
Table of Contents .................................................................................................................................... viii
List of Figures ............................................................................................................................................ x
List of Acronyms ....................................................................................................................................... xi

## Chapter 1. Introduction ......................................................................................................................... 1
1.1. Overview ............................................................................................................................................... 1
1.2. Motivation and Research Goals ......................................................................................................... 1
1.3. Thesis Guide ......................................................................................................................................... 7

## Chapter 2. Background Literature and Related Work ............................................................................ 9
2.1. Overview ............................................................................................................................................... 9
2.2. Tangible and Multi-Touch Tabletop Interaction .............................................................................. 10
  2.2.1. Direct versus Indirect Interaction .............................................................................................. 10
  2.2.2. Combining Computation, Human Skills and the Physical World ............................................... 13
2.3. Collaborative Learning through Joint Activity .................................................................................. 16
2.4. Considering ‘Fit’ through Teacher Perspectives of Technology in Education .................................. 20
2.5. Chapter Summary ............................................................................................................................... 22

## Chapter 3. Methodology ......................................................................................................................... 24
3.1. Overview ............................................................................................................................................... 24
3.2. Research Questions for Studies 1 and 2 ............................................................................................. 25
3.3. Youtopia: Tangible, Multi-Touch Application Prototype ................................................................. 28
  3.3.1. Youtopia Affordances Designed to Support Collaborative Learning ....................................... 29
3.4. About the School ............................................................................................................................... 31
3.5. Situating the Research within a Phenomenologically-Situated World View
    and Adapting Theoretical Tools ........................................................................................................... 33
  3.5.1. The Propositions of Activity Theory ............................................................................................ 35
  3.5.2. Adapting The Activity Checklist to Structure Interviews .......................................................... 38
3.6. Study 1 and 2 Details .......................................................................................................................... 41
  3.6.1. Study 1 Procedure and Methods: Predicted Opportunities, Benefits, and Challenges ............. 41
    3.6.1.1 Study 1 Data Collection and Analysis .................................................................................. 41
  3.6.2. Study 2 Procedure and Methods: Actual Opportunities, Benefits, and Challenges .................. 42
    3.6.2.1 Study 2 Data Collection and Analysis ................................................................................ 46
  3.6.3. Study 1 and 2 Validity and Reliability Measures ......................................................................... 49
3.7. Chapter Summary ............................................................................................................................... 50
List of Figures

Figure 1. Youtopia TUI-touch tabletop application................................................................. 28
Figure 2. Bellamy's application of Cole and Engeström's activity analysis for K-12 education................................................................. 37
Figure 3. Placement of Youtopia for the Exhibition period in a room attached to the main classroom area. ......................................................................................... 46
<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SIAT</td>
<td>School of Interactive Arts and Technology</td>
</tr>
<tr>
<td>SFU</td>
<td>Simon Fraser University</td>
</tr>
<tr>
<td>TUI(s)</td>
<td>Tangible User Interface(s)</td>
</tr>
<tr>
<td>CCI</td>
<td>Child-Computer Interaction</td>
</tr>
<tr>
<td>HCI</td>
<td>Human-Computer Interaction</td>
</tr>
<tr>
<td>GUI(s)</td>
<td>Graphical User Interface(s)</td>
</tr>
<tr>
<td>ICT(s)</td>
<td>Information and Communication Technology(ies)</td>
</tr>
<tr>
<td>PD</td>
<td>Participatory Design</td>
</tr>
<tr>
<td>SA</td>
<td>Situated Action</td>
</tr>
<tr>
<td>AT</td>
<td>Activity Theory</td>
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Chapter 1. Introduction

1.1. Overview

There has been growing interest for the potential of Tangible User Interfaces (TUIs) in education within the child-computer interaction (CCI) community. But, we have yet to explore how TUIs can best be designed and evaluated for complicated, dynamic classroom settings. In this thesis I aim to help researchers and designers gain a better understanding of what matters when embedding TUIs within a classroom environment by exploring themes of contextual concerns derived from teacher interviews. Through a comparative exploration, comprised of two studies, I examined both predictions of use and actual classroom integration in an effort to understand important design and evaluation considerations. I present results that are a culmination of data from both studies to form a more full picture of the problem space. I contribute both analytic themes and design considerations for TUI tabletop sustainability applications for primary educational classrooms. I also introduce The Activity Checklist as a tool to guide existing qualitative inquiry methods for 'real world' deployments.

1.2. Motivation and Research Goals

Hands-on interaction and play is often discussed in conjunction with its educational or learning benefits for children within academic research, popular culture, parental know-how and institutional teaching pedagogy. For example, TV ads depict hands-on experimentation while asking parents “How does your child learn?” (e.g. (“Fisher Price Little People Wheelies Amusement Park TV Commercial,” n.d.). Tactile interaction is posed as being an innately human trait important for understanding both concrete objects and abstract ideas. In addition, it is recognized that we not only learn by doing ourselves but that we also benefit by communicating with others and watching
Recent advancements in commercially available interactive technologies (e.g. Microsoft Surface) allow us to more easily capitalize on these important characteristics. These interactive tabletop surfaces that support co-located interaction also allow us to more easily couple physical objects and touch interaction with digital information. This has provided us with the ability to create hybrid tangible multi-touch tabletop applications – spurring new excitement for the possibility of school integration.

Much of the enthusiasm for tabletop TUI-touch applications in educational environments is associated with our understanding of how sense making and collaboration processes occur. First, we gain knowledge through sensory experience and embodied interaction with others and the world around us. For example, TUIs afford physical object manipulation that aids spatial problem solving tasks (Antle, 2013a). In addition, learning can be reinforced and thinking aided by harnessing the benefits of physical gesturing (Roth, 2001). Since TUIs offer 'physical' affordances, researchers interested in hands-on learning have shifted attention to these interfaces (Resnick et al., 1998; Zuckerman, Arida, & Resnick, 2005). Second, we can learn better through active engagement with others and learning material – as opposed to being a passive recipient of information. This idea of creating a better understanding by doing, engaging and evaluating is reflected in the growing emphasis on educational pedagogies that channel these abilities, such as Problem-based and Project-based Learning (Barron et al., 1998). Many researchers have investigated ways to build learning environments that foster developing agency in addition to competency (e.g., (Brown & Campione, 1996; A. Collins, Greeno, & Resnick, 1992; Allan Collins & And Others, 1991; Scardamalia & Bereiter, 1991)). With this pedagogy in mind, TUIs have the potential to be useful in simulating complex tasks or real-world scenarios that allow for “small group interactions, opportunities to contribute, [and] peer review,” as well as providing “access to data about how others have thought about the same problem” (Barron et al., 1998). Third, studies on tabletop collaboration reveal benefits of gaining peripheral knowledge of others’ actions at a shared surface in addition to task-related benefits of partitioning physical space between group members (Scott, Carpendale, & Inkpen, 2004; Scott & Carpendale, 2010). With this in mind, much research within the human-computer interaction (HCI) and CCI community has focused on how to design TUI applications for learning, creativity, and/or affective inquiry (e.g. (Antle, 2007; Antle, Wise, & Nielsen,
However, many argue that there is room to expand our understanding of the complexities that educational TUI applications present – in both evaluation and design methods. Marshall points out “where tangible interfaces are used to promote an activity like learning” that “a more empirically grounded framework is necessary to facilitate design” (2007, p. 168). And though benefits of tangibility seem evident, Zaman et al. point out researchers may position work using “an a priori assumed superiority of tangibility” (2012, p. 375). Dillenbourg and Evans warn that over-generalization and over-expectation repeatedly occur when a new technology is touted for its intrinsic educational benefits – a problem that plagues conversations about interactive tabletops (2011).

Recently, researchers within HCI and CCI have focused on creating more systematic and formalized approaches to the design of TUIs-for-learning. For example, researchers have proposed design frameworks informed by theory (e.g. (Antle & Wise, 2013)) and classes of activities that may be better learned through tangible interaction (e.g. (Antle, 2013a; Horn, Crouser, & Bers, 2012)). Marshall (2007) put together six main perspectives in an analytical framework to help guide researchers’ and designers’ understanding about TUIs-for-learning. This framework included a discussion of the learning domains, learning activity, integration of representations, concreteness and sensori-directness, effects of physicality, and possible learning benefits. I see these advances as partly addressing deficits in the field in the way they provide bridges between theory and design.

However, like others within the community, I point to the need to understand educational TUI-touch tabletop applications more fully. Particularly, I hope to contribute to a better understanding of contextual concerns in addition to exploring the tools and theories necessary to undertake such an inquiry. As a pragmatist, I argue designing and evaluating tangible user interfaces for education necessitates a closer look into the contexts within which they are embedded. This view can help us understand how a
system is actually able to be used (or not) outside of controlled lab-like settings – particularly with respect to TUI integration within existing spaces and practices.

After all, though there may be excitement about tangible applications for classrooms in the research community, it’s not clear whether people in actual schools reciprocate this. Despite the apparent benefits and lowering costs of commercial toolkits for TUI development, integration of technology into classrooms happens extremely slowly. In 1980 Papert commented, “Most of what has been done up to now under the name of ‘educational technology’ or ‘computers in education’ is still at the stage of the linear mix of old instructional methods with new technologies” (1980, p. 36). Even now many schools in developed countries have low adoption rates for technology outside of the computer workstation and basic Internet access model (e.g. (“Education in Canada: An Overview,” n.d., “The NCES Fast Facts Tool provides quick answers to many education questions (National Center for Education Statistics),” n.d.)). In this typical use scenario *individuals* use technology to fulfill a *utility-based task* like word processing or Internet research. In most cases the use of technology in a typical primary school classroom seems much like it was 20 or 30 years ago. Many studies point to teacher’s beliefs, comfort and competency for technology (e.g. (Blackwell, Lauricella, Wartella, Robb, & Schomburg, 2013; Dillenbourg, 2013; Fisher, 2006; Mama-Timotheou & Hennessy, 2013)) as major factors impacting whether classroom integration happens. This research reveals that even if other barriers, such as cost, were to be removed that teacher perspectives of how the technology would fit into existing pedagogy and practice would heavily impact (support for) actual TUI use in the classroom. Additionally, Keppell and Riddle (2013) point out how the learning space itself can have an influence on the interaction between teachers, students and the technologies used. Though their work is explicitly focused on the design of learning spaces themselves, their emphasis on a space’s role in interaction and ongoing practices sheds light on why we should think more about the role of designing ‘fit’ for a particular educational environment and existing pedagogy.

My work is positioned to provide insight into teacher’s perspectives, specifically concerning a TUI-touch tabletop sustainability application. First, I delimited my research to *design(able) factors* revealed by the teachers. My specific interests were on learning
design, user interface design, and interaction design. Second, I only focused on a *single application* deployed on a TUI tabletop – therefore I did not investigate the tabletop as a standalone technology that could be used for other purposes. Third, I focused specifically on environmental and social issues since the application used for the study was created to explore the land use planning and sustainability *content domain*. Lastly, I focused my work further by considering the *collaborative learning* nature of the content domain, the application ‘affordances’ and the primary contextual concerns within the primary school classroom environment. By exploring this space through classroom deployment and teacher interviews we can better understand how classroom contextual concerns impact the way we think about *designing* TUI-touch tabletop applications around *social issues* (e.g. sustainability) for *educational environments*.

My overarching research question was: *What design-oriented opportunities, benefits, challenges and/or discrepancies do teachers identify when considering the integration of a collaborative learning TUI-touch tabletop application within a primary school classroom environment?*

I conducted a comparative exploration, which was completed in two studies over the course of two years (2013 and 2014). My overarching research question had several sub-questions or areas of inquiry, which were explored in both studies through structured interviews with two teachers. The goal of Study 1 was focused on creating *predictions* for how they saw the TUI-touch tabletop application, *Youtopia*, fitting in with their classroom based on personal use and limited student observations. A year later I was able to explore how actual use and deployment could differ from predicted expectations. I was able to leave the system at my participating school for roughly three months during which Study 2 was completed. The goal of the second study was to further explore the overarching research question but through teacher reflections on *actual* self-planned use of Youtopia in the classroom during a multi-month Exhibition period.

Specifically in Study 1, I explored how teachers envisioned using a collaborative learning TUI-touch tabletop in their classroom.
o S1-RQ1 What are the opportunities predicted by teachers related to using a TUI-tabletop sustainability application in the classroom for children aged 10-11?

o S1-RQ2 What are other benefits predicted by teachers related to using a TUI-tabletop sustainability application in the classroom for children aged 10-11?

o S1-RQ3 What are challenges predicted by teachers related to using a TUI-tabletop sustainability application in the classroom for children aged 10-11?

For Study 2, I explored how teacher’s opinions compared after using a collaborative learning TUI-touch tabletop as part of the student Exhibition on sustainability:

o S2-RQ1 What are the opportunities actually identified by teachers related to using a TUI-tabletop sustainability application in the classroom for children aged 10-11?

o S2-RQ2 What are other benefits actually identified by teachers related to using a TUI-tabletop sustainability application in the classroom for children aged 10-11?

o S2-RQ3 What are challenges actually identified by teachers related to using a TUI-tabletop sustainability application in the classroom for children aged 10-11?

o S2-RQ4 Are there any discrepancies in design-oriented factors predicted by teachers using the TUI-tabletop application in the classroom compared to factors identified after actual use?

The TUI-touch tabletop application deployed, Youtopia, consists of fifteen physical stamps and an interactive touch-sensitive tabletop. When a stamp is placed on
the screen it’s corresponding land use type is ‘stamped’ on the digital map displayed by
the screen. By placing different land use types on the map, the players change the
homeostasis of the environment. Youtopia’s content is derived from 5th grade (e.g.
children ages 9-11 years old) learning initiatives for sustainability. Players are simply
prompted to ‘create a world they would want to live in’. The goal is to learn about the
tradeoffs necessary in maintaining a healthy environment while also sustaining a healthy
human population. Players learn about this balance through exploring how different land
use types, in combination, affect the overall environment. There is no-winning state,
unlike a traditional game, and information is presented in neutral language so players
will be encouraged to form their own opinions of what’s ‘good’ or ‘bad’. The physical
stamps and system model are designed with interdependence so that when the stamps
are distributed into ‘roles’ actions from both players are required to fulfill a ‘development’
plan. These design choices were made to promote personal dialogue about the content
domain between players. Since the content domain is not a clear cut ‘right’ or ‘wrong’
topic, this collaborative learning task also requires players to navigate the interpersonal
social landscape – a place where each player may have differing views on the ‘ideal
world’, but must compromise to build something together.

The results that I present in this paper are a culmination of bringing the data from
both studies together to form a more full understanding of the problem space. I
contribute both analytic themes and design considerations for TUI-touch tabletop
applications intended for primary educational classrooms. I also introduce The Activity
Checklist (Kaptelinin, Nardi, & Macaulay, 1999) as a tool to guide existing qualitative
inquiry methods for ‘real world’ deployments.

1.3. Thesis Guide

In this thesis, I will first discuss the background literature and related work in
Chapter 2 that motivated and guided my research agenda. In Chapter 3 I discuss my
methodology, which includes descriptions of both Study 1 and 2, my primary research
instrument Youtopia, the adaptation of The Activity Checklist for teacher interviews, and
my data collection methods and analysis procedures. In Chapter 4 I discuss the results,
which includes a presentation of the design-centric themes derived from the teacher
interviews. In Chapter 5 I discuss the design considerations that were informed by the themes as well as discuss the limitations to my study and the potential for future research in the area of inquiry. In Chapter 6 I conclude the thesis by providing a summary of my research goals and contributions.
Chapter 2. Background Literature and Related Work

2.1. Overview

This chapter is made up of several subsections that situate my work historically within the fields of HCI, CCI and Tangible Interaction. I will also discuss in more detail current research that has provided motivation and guidance for the research presented in this thesis. Since the topic of this thesis is quite interdisciplinary a brief description of this chapter’s sections is provided below to act as an overview to the domains discussed.

- **Tangible and Multi-Touch Tabletop Interaction** (Section 2.2) – this section provides an overview of the field historically as well as outlines how the defining affordances and specifications of these systems may support educational or learning ‘goals’. This will also include a discussion about how these provide opportunities for certain behaviors. Specifically I will discuss the move from ‘indirect’ to ‘direct’ interaction, which paved the way for linking the physical and digital through computation, capitalizing on human skills for interaction and understanding, and leveraging the physical world for interfacing.

- **Collaborative Learning** (Section 2.3) – since the prototype, Youtopia, was designed to facilitate collaborative learning, I will discuss what this term means as well as how technologies (TUI-touch tabletop applications in particular) can support this type of learning. This section is intended to address both concerns by providing definitions as well as linking ‘affordances’ from the **Tangible and Multi-Touch Tabletop Interaction** section to this learning ‘process’.
Teacher Perspectives of Technology in Education (Section 2.4) – this section provides further insight into a common barrier – teacher beliefs – that contributes to the lack of technology adoption or integration within primary school education. This section further provides justification for why teacher interviews were chosen as a first way to explore the classroom contextual concerns that may impact the way we think about designing and evaluating TUI-touch tabletop applications for education.

2.2. Tangible and Multi-Touch Tabletop Interaction

Officially introduced at CHI 1997 by Ishii and Ullmer, TUIs were defined as systems that “augment the real physical world by coupling digital information to everyday physical objects and environments” (1997, p. 2). One of three goals of tangibility in this early work was to enable interactive surfaces that could transform aspects of the everyday, architectural space into active interfaces that bring together our physical and digital worlds (Ishii & Ullmer, 1997). This included features like walls, doors and ceilings as well as objects such as tables and desktops.

In addition to different interaction experiences, current TUI-tabletop applications have the possibility to foster and support collaboration based on system model design (e.g. computational model), physical setup (e.g. shared tabletop, shared or distributed tools, etc.), and natural human skills (e.g. eye-contact, gesture, etc). These will be discussed in the following chapter subsections.

2.2.1. Direct versus Indirect Interaction

Advances in technology that allowed for direct, versus indirect, interaction, in part, spurred the rise of tangible and multi-touch research within the human-computer interaction field. However, our understanding of what is considered direct and indirect has adapted as the input and output media have diversified and become more robust.

In early HCI research directness was conceptualized as a way to make the understanding of data and processes easier through graphical data representation and a
more ‘natural’ interaction style. For example, Shneiderman classified command-line interaction as indirect whereas manipulation of graphical representations of the same data or processes was considered direct (1982, 1997). It is important to note that changes in interaction in this case are not a result of changes in input modalities or devices themselves. Rather this work focused on making the interaction more direct through the ‘intuitiveness’ of the representation (e.g. folders, icons, graphs, etc) and the deployment of interaction task strategies analogous to innate ‘human’ behaviors (e.g. grabbing, pointing, storing, moving ‘things’ through ‘space’, etc). Particularly when this work first began the forms of interaction with the system itself, for both novice and trained computer users, were typically facilitated through the mouse, keyboard and/or button input devices. Though Shneiderman points to using physical action in place of complex syntax as integral to direct manipulation, input with the system itself in these cases was not tangible, multi-touch or gestural as we typically conceptualize physical interaction today (e.g. as an input modality or interaction style itself). Rather physicality referred to an ability to manipulate your data or processes as ‘things’ instead of computer command abstractions. Impelled by the rise of computer use by “novice and non-technically trained people” in the workforce and everyday life (Shneiderman, 1982, p. 237), there was a need to move beyond the unnatural command line to a more direct form of creating, accessing and manipulating data and processes. In essence, this work as part of the early human factors movement in human-computer interaction pointed to a need to minimize trained behaviors (unintuitive, indirect) and make it so interaction tasks were conceptually comparable to non-computational ways of doing and thinking.

Excited by the idea of direct manipulation (human analogous representation and behavior), but concerned by the lack of explanation of what produces the feeling of directness, Hutchins et al. (1985) examined this from a cognitive perspective. The authors pointed to two phenomena that can result in an interface eliciting such feelings in its users – distance and engagement. First, distance refers to the closeness of one’s thoughts to the physical requirements of executing operations on the system. Having a ‘short’ distance means that the translation of a thought to physical action is straightforward. In addition, a short distance would imply that the results of that action or the output are readily available as well as interpretable so that action can easily continue (continuing on the same path, amending the plan, etc). Second, direct engagement
requires that the interface elicit a feeling or sensation of acting upon ‘things’ themselves. Informed by the model-world metaphor in human-computer interaction (as opposed to the conversation model), the interface may be designed in a way that it is the world – a place where a user acts or behaves and the world state changes in response. This creates a feeling of directness because “when an interface presents a world of behaving objects rather than a language of description, manipulating a representation can have the same effects and the same feel as manipulating the thing being represented” (Hutchins et al., 1985, p. 320).

Essentially this early research was a move towards ‘intuitive’ interaction. But, what does intuitive really mean? Like an inanimate object can reveal inclusive and exclusive actions to be made with it through inherent properties (e.g. size, shape, etc.), “an interface can support people to intuit how to interact successfully with it,” and this is what “is meant by the term intuitive interface or intuitive interaction” (Antle, Corness, & Droumeva, 2009, p. 236). Building on this idea, Jacob postulated that “future input mechanisms may continue this trend toward naturalness and expressivity by allowing users to perform ‘natural’ gestures or operations and transducing them for computer input” (1996, p. 179). It seems we have arrived. Advances in technology have continued to bring new modes of interaction, which have also brought new ways of thinking about direct interaction. Modern tangible and multi-touch systems allow for the actualization of what Hutchins et al. (1985) point out in their discussion about direct engagement because to a high level the model-world metaphor is not simply a metaphor anymore. Direct manipulation no longer needs to be thought of as simply a conceptual model that provides the illusion of real world engagement. Physical, gestural and touch interaction modalities seem to move us beyond mere feelings of first-personness with ‘digital’ or semantic objects to an embodied interaction experience.

Moving from the command line to graphical user interfaces (GUIs) was a leap in interaction, usability and user experience, but it still lacked the naturalness that comes from interacting with or through physical materials in a physical environment (Ishii, 2008). The emergence of tangible and multi-touch systems has brought with it new ways of thinking about direct and indirect interaction because they have expanded the modalities available for control and representation. Direct interaction in many cases, and
for the purposes of this thesis, has come to be thought of as interaction that allows direct physical manipulation of data and representations through either touch, gesture and/or computationally augmented physical objects in the world. For example, if I want to access data on my screen I can touch it directly or manipulate it through its physical manifestation in the world. Indirect interaction, on the other hand, refers to interaction that must be done by proxy of a neutral impersonal mediator, like a standard mouse, that often serves many purposes depending on the current task. According to van den Hoven et al. (2013) direct control to manipulate system parameters and the direct accessibility of the information or representation are at the heart of tangible interaction. Though GUI interaction allows users to manipulate digital ‘things’, these systems can only allow for a minimal amount of direct control due to the fact that often one mediating device must serve many purposes (van den Hoven et al., 2013).

Though direct interaction is a leading characteristic of modern tangible systems, the field of tangible interaction has other foundational qualities that define it. Tangible interaction is distinctive in that it links the physical and digital through computation, capitalizes on human skills, and leverages the physical world (van den Hoven et al., 2013). I will also discuss the tabletop interaction as the prototype, Youtopia, couples these ‘tangible interaction’ traits with the benefits of tabletop interaction in collaborative learning. These qualities, which will be explored in the following sections, make tangible interaction models and interfaces a particularly strong candidate for collaboration, learning and educational contexts.

2.2.2. Combining Computation, Human Skills and the Physical World

On one hand, tangible interaction is focused on capitalizing upon human skills and lived physical world familiarity. On the other, computation is traditionally expressed through a system’s functionality, not human interaction (van den Hoven et al., 2013). Though these at first may seem incompatible, computation itself is what distinguishes tangible and multi-touch systems from mere non-digital physical interaction in the world. Computation is the means to creating relationships between what is physically existing and what is considered purely digital (van den Hoven et al., 2013). Tangible interfaces
provide physical manifestations of digital information that can act as both the control and representation so that computation allows manipulation of digital information directly through the hands (Ishii, 2008). Combining tangible interaction with multi-touch capabilities greatly expands the nature of interaction and control with and through the interface.

The capacity for tangible systems to couple the digital and physical computationally has many proposed benefits, particularly for children’s learning and collaboration. Through natural multi-model interaction (e.g. sight, touch, hearing, moving etc), tangibles open up the possibility for multiple ways of communicating and knowing through computational artifacts. Below I discuss how interface characteristics can support specific processes or mechanisms associated with learning and collaboration:

- physical objects for representation and control support collaborative behaviors and meaning making
- face-to-face interaction supported by tabletop applications support collaborative behaviors and meaning making
- acting physically in the world can add to our understanding and/or make certain tasks easier
- cultural and social meaning embedded in our everyday world can be exploited to aid learning and meaning making

First, collaboration and meaning making are facilitated by the physical objects and face-to-face interaction working together. Tangible tabletop systems provide a space where gaze, gesture, verbal communication, etc can be employed to coordinate tools and physical actions as well as collaborate on more abstracted trajectories specific to the overall activity. Physical objects can be easily shared or divvied up between users to create different interaction experiences (people-to-people, people-to-system, etc.). Tangible representation through dedicated controls that inhabit their own physical space (known as space multiplexed input) can promote collaboration with concurrent co-located users, while a GUI’s generic singular control device serves to control different
computational functions at different points in time (known as time multiplexed input) (Ishii, 2008). Partially because the tools are space multiplexed, all users have equal access to information about what tools exist, which tools are available, how to use them, the consequences of their use, etc. Tangible interaction, particularly with interactive tabletops, makes use of “observational and action periphery, thereby exploiting the entire attention field and it can provide information at a glance by using abstract information, such as an object’s color and shape, instead of concrete information, such as text and numbers” (van den Hoven et al., 2013, p. 72). Essentially, physical objects require physical action to be taken with them and are visible to all users simultaneously. This allows any users at any time to have (peripheral) knowledge of the tools available or in use. This can provide direct or indirect support for collaboration and learning by allowing users to coordinate action plans, see what others are doing (successfully or unsuccessfully), etc.

Second, acting in the world can add to our understanding and/or make certain tasks easier by harnessing both cognitive and perceptual-motor skills. Maches and O’Malley pointed out that there are two main mechanisms for learning from physical manipulation, which include the ways it can help offload cognition and provide conceptual metaphors (2012). Antle pointed out that “children may find mental operations associated with memory, perception, or computation difficult depending on the task,” but that children “may be able to use their environment in some way to improve their thinking” (2013b, p. 33). A common example of this is physically rotating an object in the world instead of performing this task in the head in order to make spatial problem solving easier (e.g. rotating a Tetris or puzzle piece, etc.). Having the ability to free up cognitive resources by ‘offloading’ mental effort onto the physical world (objects and actions) can support the achievement of tasks that may normally be overly challenging or time consuming.

Third, cultural and social meaning embedded in our everyday world can be exploited in the design of tangible interfaces (e.g. through form, color, purpose as situated in place or activity, etc). Antle and Wise point out “informational relations are the collection of couplings between the digital objects, the physical objects and actions that can be taken on them and references to real-world entities. While a physical object may
represent something specific in the TUI, it can also carry meaning from the real world (for example, referring to an everyday object, action or phenomenon)” (2013, p. 5). For example, each stamp in Youtopia represents a land use type (e.g. farming). However, the physical tool used for interaction, a stamp, is also imbued with physical use characteristics (e.g. grab handle, lift, put down) as well as cultural knowledge of what a stamp does (e.g. leaves a copy of what it represents exactly where its stamped). In the context of a sustainability land use planning exercise, stamping land uses onto a virtual map can add another level of cultural/social meaning making. For example, the act of ‘stamping’ a farm onto a map and seeing its impact mimics building a farm in the real world and considering its particular carbon footprint effect. Though the act of ‘doing’ to a virtual environment is a much more simplified version of taking ‘physical’ action to a real world environment, the tools and process echo culturally and socially relevant phenomena.

2.3. Collaborative Learning through Joint Activity

What exactly is collaborative learning? Why do we care about its consideration in design, particularly for socially and culturally focused topics or applications? Though these seem like simple questions, collaborative learning can mean a lot of things to a lot of different people. As Suthers points out, clearly defining our understanding of the term also defines our “choice of an epistemology of collaborative learning” which “can affect how we approach the design of computer mediation and questions we ask in our research” (2006, pp. 322–323). Like Suthers, Roschelle and Teasley point out that having a particular orientation on what constitutes collaborative learning “leads to consequences for the design and analysis of computer-supported collaborative learning situations” (1995, p. 71). In this thesis Roschelle and Teasley’s definition of collaboration is adopted. They define collaboration as a “coordinated, synchronous activity that is the result of a continued attempt to construct and maintain a shared conception of a problem” (Roschelle & Teasley, 1995, p. 70).

Roschelle and Teasley believe engaging in collaborative problem solving is a social activity that creates a space where student motivation can be maintained and face-to-face verbal interaction can take place. Like many theorists (e.g. Dewey, Mead,
Piaget and Vygotsky) that deviate from traditional cognitive psychology, Roschelle and Teasley argue that learning is a fundamentally social activity where meaning making “takes place in a negotiated and shared conceptual space, constructed through the external meditational framework of shared language, situation, and activity – not merely inside the cognitive contents of each individual’s head” (1995, pp. 70–71). The authors propose that a “shared conception of a problem” is central to collaborative problem solving and that a Joint Problem Space (JPS) is continually (re)shaped by socially negotiating: goals; descriptions of the current problem state; awareness of the available problem solving actions; and associations that relate to goals, features of the current problem state, and available actions (1995, p. 70).

Similarly, Suthers and Koschmann both point out the importance of understanding meaning making during collaborative activity as a product of joint activity. According to Suthers, interpretation is “constituted of social interactions” where meaning “can be jointly created through interaction in addition to being formed by individuals before they are offered to the group” (2006, pp. 317–318). Meaning making can happen through both agreements and disagreements concerning shared information (Suthers, 2006). Suthers’ argues that to really understand or assess collaborative learning it is necessary to “study the practices (the activity itself)”, which necessitates a deeper investigation into the ways groups make sense of situations and of each other (2006). Like the Joint Problem Space introduced by Roschelle and Teaseley, interpretation is viewed as dynamically changing throughout a joint activity where all parties are engaged in face-to-face participation and reification (Wenger, 1998). Suthers explains “interpretation functions as much on moment to moment ephemeral reifications such as thoughts, utterances, facial expressions, and gestures as on persistent inscriptions and artifacts” (2006, p. 321). Koschmann emphasizes that there is a necessity to consider how mean-making can be mediated by designed artifacts “in the context of joint activity” (2002, p. 20). But as Suthers asks, “in what ways can we bring technology,” specifically TUI-touch tabletop applications, “to bear on the problem of supporting collaborative learning?” (2006, p. 322).

Youtopia was designed to support collaborative learning about sustainability-related issues between co-located children. In addition to meeting grade 5 environmental
learning outcomes, it was also important to ensure that specific design decisions were considered to foster ‘true’ collaborative joint activity. As Roschelle and Teasley point out, there is a difference between collaboration as defined above and cooperative work where labor is divided among participants who are individually responsible for a portion of the work (1995, p. 70). According to Antle et al. “while TUIs enable several children to actively use the system at the same time, previous non-TUI research has shown that this often results in a non-collaborative situation of parallel play” (2013, p. 566). In an effort to combat this problem, Youtopia was designed with co-dependent inputs in an effort to promote positive interdependence in a collaborative joint activity. Essentially, this means that while children may have a set of their ‘own’ tools or inputs, the system acts on actions collectively so that actions from multiple children/tools are required for any goal to be achieved. One child cannot simply act upon independent goals without support of those goals through speech and action of his peers. This supports the type of social processes crucial to collaborative meaning making discussed in Roschelle and Teasley’s Joint Problem Space.

Additionally, Youtopia’s content domain is socially/culturally focused where there is not a straight-forward or ‘correct’ solution to problems (Antle, Warren, May, Fan, & Wise, 2014). For example, land use planning (the focus of Youtopia) is a topic that encompasses “conflicting values, moral positions and belief systems” (Antle et al., 2014, p. 39). With this type of content domain, users come together with heterogeneous values about what the world should be like. One of the main learning goals is that students should engage in an open exchange of their own ideas as well as understand that there may be multiple ways to approach such complex sustainability planning. This goal is both pedagogically important in the school and an objective for the content domain itself. For Youtopia, the interdependent design of the tools and underlying system model are not meant to simply promote conversation for conversation’s sake. This design decision works together with the multi-faceted content domain to encourage face-to-face joint experimentation, negotiation, and compromise between users. By doing so users can, in a way, teach themselves and each other about the tradeoffs necessary in real world sustainability and land use planning.
While collaborative learning has been somewhat assumed as an inherent quality of face-to-face interaction, research reveals that simply putting people together around a table does not ensure collaborative work. This assumption seemed to also expand to the TUI-touch tabletop application space where the assumption was that since multiple users can physically come together synchronously that collaborative joint activity would naturally follow. We now see that true collaboration must be encouraged and application design can play a substantial role in supporting and sustaining collaborative learning activities.

But, Wallace and Scott (2008) point out that “as digital tabletop systems mature and move beyond the research laboratory, important challenges remain to secure user adoption.” They point out that there is still much to be understood about how co-located, collaborative tabletop technologies ‘fit’ within different usage contexts in terms of form and function. They present five contextual design considerations for the tabletop design process, which include the social and cultural context, activity context, temporal context, environmental context, and motivational context. First, social and cultural context “refers to the factors that impact the social and cultural norms that govern group behavior in a given context” (Wallace & Scott, 2008). Second, the activity context “refers to the type of task or activity in which the group is engaged, and the characteristics of that activity that influence tabletop design” (Wallace & Scott, 2008). Third, temporal context “refers to how often and how long groups are likely to use the table, as well as how much time pressure groups are under when performing tabletop activities” (Wallace & Scott, 2008). Fourth, the ecological context “refers to the environment in which the table is situated, the table’s role in this environment, and its relationship to other objects and devices in it” (Wallace & Scott, 2008). Lastly, the motivational context “refers to the personal and professional goals that motivate the activity(ies) for which the table is used, including the group’s motivation for using the table rather than alternative computing devices” (Wallace & Scott, 2008). Wallace and Scott argue that it is these contexts themselves that have a big impact on how a tabletop technology should be designed in terms of the software interface, its physical form and whether/how it has connectedness to other devices. While this research is a great step towards providing insight into contextual factors that can potentially impact the design of co-located collaborative tabletop systems, there is still more to learn. First, Wallace and Scott do not specifically address
tangible tabletop applications, which have additional affordances compared with a simple interactive touch tabletop. Second, the authors do not specifically address any particular use environment, scenario or content domain. My research aims to fill these gaps by providing contextual design considerations specific to TUI-touch tabletop applications and by filling in some of the contextual classroom knowledge gaps through teacher interviews based on real deployment observations.

In the next section I will further discuss how facilitating collaborative learning via TUI-touch tabletop applications is not just a process students themselves engage in or that is fully designed into a technology. Part of our ability to understand TUI-touch tabletop application design to support collaborative joint activity in a classroom requires an understanding of the contextual factors within that environment that impact it’s use and usefulness. To gain a better understanding of the contextual factors that can impact the design and adoption of TUI-touch tabletop applications within a classroom, I have decided to first look at the opinions of those that manage and facilitate the activities within this space – teachers. As will be discussed in the next section, teacher perspectives on the use of technology within the classroom are an important place to begin this inquiry because teachers themselves play a lead role in deciding what’s considered useful, relevant, worthwhile, etc. Ultimately, teacher insights can provide important considerations for design and ‘fit’ within the classroom space and culture.

2.4. Considering ‘Fit’ through Teacher Perspectives of Technology in Education

Outside of Child-Computer Interaction, the Computer-Supported Collaborative Learning and Education communities are interested in technology to support collaboration, the shared construction of knowledge, and ‘fit’ within educational environments. Many studies point to teacher’s beliefs, comfort and competency for technology as major factors impacting whether classroom integration happens. This research reveals that even if other barriers, such as cost, were to be removed that support for and actual use of TUIs in the classroom would be heavily impacted by teacher perspectives of how the technology would fit into existing pedagogy and practice.
Dillenbourg (2013) has focused on classroom orchestration and its implications for the design of educational technologies that could “incrementally improve school efficiency” by shedding light on the teacher’s extrinsic activities (e.g. core activities, extraneous events, etc) and extrinsic constraints (e.g. time, curriculum relevance, discipline, etc.) that should be considered. Others have also focused on teacher beliefs and practices as having a huge impact on the use, adoption and success of new technologies in the classroom. For example, Mama-Timotheou and Hennessy (2013) present a typology of teacher beliefs and practices for Information and Communication Technologies (ICTs) in education through the introduction of 4 belief groups – broken down by competence/home use, classroom practice, perspective on ICT in education, beliefs about the value of ICT use in teaching, beliefs about the value of ICT use in learning and the perceived impact of ICT use on practice. Blackwell et al. (2013), though focused primarily on early childhood education, also point to extrinsic barriers and teacher attitudes as impacting the integration of technology into existing practices. They reveal that though “educator’s access to technology is influenced by extrinsic properties,” it is often the case that “when it comes to actual use, personal properties matter, especially on the affordances of technology” (Blackwell et al., 2013). Some have argued (e.g. (Fisher, 2006)) that what makes the educational space so difficult to understand, discuss and design for is the more ‘philosophical’ view of technologies’ purpose in the domain and the language used to discuss technology integration.

Consider the following:

Dynamic use contexts and social situations lead to indirect and multiple goals. Consider the shifting goals of interactive learning technology: ultimately K-12 student learning goals are relatively specified, but the relationship between student experience and learning outcomes is speculative. Furthermore, student use of technology is mediated by a teacher who is also a user and whose goals and concerns must also be met by the design of the program...Classroom level interventions that utilize sophisticated, interdependent claims about fit entail
complex reasoning about means and ends. Classroom level interventions that utilize sophisticated, interdependent claims about fit entail complex reasoning about means and ends. The benefits of the technology have to do with its relationship to this complex setting rather than its prima facie novelty or unique contribution to learning (Harrison, Tatar, & Sengers, 2007, p. 5)

As designers and researchers, we have little control over the extrinsic barriers of teachers, but we can factor in the extrinsic constraints by also exploring the technology or application as part of the complex setting. My work contributes to alleviating use concerns by creating design considerations specific to the (primary school) classroom environment and collaborative learning activities.

Though I have discussed the proposed educational strengths that can be capitalized upon in the design of educational TUI-touch tabletop applications, Dillenbourg and Evans (2011) argue that TUI-tabletops don’t offer inherent educational effectiveness. Rather, the affordances of the system can create experiential differences in terms of system-learner interactions, social interactions, classroom orchestration, and positioning within an institutional context. Their work outlines complex ‘circles of interaction’ that are tied to system affordances. These provide ‘broad stroke’ food for thought to designers. But, static or abstract knowledge of affordances alone does not ensure successful integration within an actual classroom. We must also consider how those decisions are impacted or play out in a dynamic environment. My work adds to this research by directly exploring the deployment context (a primary school classroom).

2.5. Chapter Summary

In this chapter I discussed the history of tangible technology and computing. This exploration shed light on how advances in the technology itself brought about a move from ‘indirect’ to ‘direct’ interaction. This paved the way for linking the physical and digital through computation, capitalizing on human skills for interaction and understanding, and leveraging the physical world for interfacing. I then focused on how tangible tabletop
applications provide opportunities to support collaborative learning through joint activity. I provided examples of Youtopia design considerations to highlight that co-location and shared resources are not necessarily enough to elicit truly collaborative problem-solving and meaning making. I argue that there is also much to learn from the context of the educational space itself, particularly from a teacher’s point of view, that can add to our knowledge on what collaborative learning looks like in the classroom. Additionally, I provide insight into the common barrier – teacher beliefs – that contributes to the lack of technology adoption or integration within primary school education. The next chapter, Methodology, provides more details about the specific tools and methods used to provide structure to my contextual design-focused inquiry.
Chapter 3. Methodology

3.1. Overview

This chapter is made up of several subsections that describe the tools and methods chosen to address my research questions as well as provide information about study details (e.g. the school, participants, etc.). Below is a brief overview to the subsections of this chapter.

- *Research Questions for Studies 1 and 2* (Section 3.2) – this section outlines my overarching research question and the sub-questions for Study 1 and Study 2. It also provides a short description of each study.

- *Youtopia: Tangible, Multi-Touch Application Prototype* (Section 3.3) – this section provides a detailed description of the prototype used for both Study 1 and 2, including a sample of design goals. This section also provides details about how Youtopia was intended to support collaborative learning through joint activity.

- *About the School* (Section 3.4) – this section provides information about the school used in my studies. Specifically I discuss details about the school’s pedagogical position, the Exhibition purpose and goals, and why these are important to my inquiry with Youtopia.

- *Situating the Research within a Phenomenologically-Situated World View and Choosing a Lens* (Section 3.5) – this section briefly outlines the move to support ecological inquiry within HCI and CCI. By taking a quick walk through the three paradigms of HCI (Human-Factors, Classical Cognitivism/Information Processing, Phenomenologically-Situated), I elaborate on the importance of situating TUIs-for-learning research within the
latter paradigm. I discuss why Activity Theory – and The Activity Checklist – provides structure for this type of exploration within in my own research. Lastly, I discuss how The Activity Checklist was adapted to support for my interviews and provide a sample of adapted checklist interview questions.

- **Study 1 and 2 Details** (Section 3.6) – this section provides the study details (e.g. procedure, participants, etc) for both Study 1 and 2 respectively. Additionally, this section provides the methods for data collection and data analysis specific to Study 1 and 2 respectively. Lastly, this section provides a brief discussion about the measures taken to maintain reliability and validity in both studies.

### 3.2. Research Questions for Studies 1 and 2

My overarching research question was: *What design-oriented opportunities, benefits, challenges and/or discrepancies do teachers identify when considering the integration of a collaborative learning TUI-touch tabletop application within a primary school classroom environment?*

I conducted a comparative exploration, which was completed in two studies over the course of two years. My overarching research question had many sub-questions or areas of inquiry (e.g. integration, learning process, learning outcomes, short vs. long-term benefits or drawbacks), which were explored in both studies through structured interviews with two teachers. The methods and procedures of each study will be discussed separately in their own subsections, but the sub-questions can be found below.

The goal of Study 1 was focused on creating *predictions* for how the teachers envisioned Youtopia fitting in with their classroom. This work was part of a larger study where 21 pairs of 5th grade (aged 10–11) students from a local primary school used a TUI-touch land use planning application implemented on a Microsoft PixelSense digital tabletop for up to 30 minutes to create ‘the world they would want to live in’ (to learn more about this study and its results see (Antle et al., 2014; Wise, Antle, & Warren,
The purpose of this study was to explore the intersections of collaborative learning and design. It must be noted that as part of this study the teachers gained knowledge about Youtopia prior to Study 1 because they briefly played the game, 'peaked' in on this study and heard children participants talk about their experience. Additionally, I was involved in conducting this study within the school as well as contributed to qualitative and quantitative data analysis. The potential limitations presented by these issues are discussed later on in this thesis. At the conclusion of this study, I took advantage of the opportunity to explore teacher perspectives through structured interviews because the system was already placed within the school. In Study 1, teacher perspectives on the system’s usefulness or 'fit' within the classroom were the primary areas of interest. Each teacher watched two pairs of children play full Youtopia sessions. The teachers were also asked to play Youtopia themselves followed by a short debriefing session.

A year later I was able to bring Youtopia back to the school to explore how actual use and deployment could differ from the predicted expectations revealed in Study 1. I was able to leave the system at my participating school for roughly three months during which Study 2 was completed. The use of Youtopia during this period was fully dictated by the teachers themselves. The goal of the second study was to further explore the overarching research question but through teacher reflections on actual self-planned use of Youtopia in the classroom during the multi-month Exhibition period.

Specifically in Study 1, I explored how teachers envisioned using a collaborative learning TUI-touch tabletop in their classroom.

- S1-RQ1 What are the opportunities predicted by teachers related to using a TUI-tabletop sustainability application in the classroom for children aged 10-11?
- S1-RQ2 What are other benefits predicted by teachers related to using a TUI-tabletop sustainability application in the classroom for children aged 10-11?
For Study 2, I explored how teacher’s opinions compared after using a collaborative learning TUI-touch tabletop as part of the student Exhibition on sustainability:

- S2-RQ1 What are the opportunities actually identified by teachers related to using a TUI-tabletop sustainability application in the classroom for children aged 10-11?

- S2-RQ2 What are other benefits actually identified by teachers related to using a TUI-tabletop sustainability application in the classroom for children aged 10-11?

- S2-RQ3 What are challenges actually identified by teachers related to using a TUI-tabletop sustainability application in the classroom for children aged 10-11?

- S2-RQ4 Are there any discrepancies in design-oriented factors predicted by teachers using the TUI-tabletop application in the classroom compared to factors identified after actual use?

To provide clarity to each of these sub areas of interest, I provide a short definition of each below:

- **Opportunities** – This is how the application provided a new and/or different way to support goals and/or practices that is not provided in any other way.

- **Benefits** – This is how the application was seen as helpful and/or useful in supporting goals and/or practices (may be able to be supported in other ways).
o **Challenges** – This is how the application was seen as (potentially) countering existing goals and/or practices.

o **Discrepancies** – This are differences in how the application was predicted versus what the teachers really saw play out or not (these areas may need further investigation).

### 3.3. Youtopia: Tangible, Multi-Touch Application Prototype

Youtopia is a tangible user interface application intended to support collaborative learning and interaction in children during a sustainability and land use management task. Youtopia runs on a hybrid tangible and multi-touch digital tabletop where the main activity is to use physical stamps on the interactive map. It was designed to meet basic British Columbia, Canada learning outcomes for 5th grade environment and sustainability topics (roughly ages 9-11). When a stamp is placed on the screen its corresponding land use type is ‘stamped’ on the digital map. By placing different land use types on the map (detected by unique fiducial tags), the users change the homeostasis of the environment. The goal is understand the tradeoffs necessary to maintain a healthy environment while also sustaining a healthy human population. Children are meant to collaboratively learn about this balance by exploring how different land use types, in combination, affect the overall environment. The children are told to create a world ‘they would want to live in’. For images see Figure 1.

![Figure 1. Youtopia TUI-touch tabletop application.](image)

Sample design goals included:
- Make mappings between the form and behavior of physical and/or digital objects and real-world entities coherent

- Design objects that allow for spatial re-configuration that can enable mutual adaptation of ideas

- Create configurations in which participants can monitor each other’s activity and gaze to help support the development of shared understandings

- Distribute roles, information and controls across the TUI learning environment to help promote negotiation and collaboration through constrained or co-dependent access points

In the real world, land use planning is a complex challenge that involves many people with interdependent responsibilities working together. In Youtopia individuals can be assigned the roles of natural resource planner (allocated natural resource stamps) and human development manager (allocated development tool stamps). Together they are responsible for providing people with food, shelter, and energy for the land area on the digital map. When roles are assigned, each person is responsible for his or her own set of tools and their associated responsibilities, but the actions of each player are required to meet the populations’ needs, much like in real-life decision making. For example, someone must turn forests into lumber, before that lumber can be used to build housing. Or someone must build irrigation near the river before that water can be used to supply farms or gardens. This interdependence built into the design of the application is intended to support communication about values and collaboration on creating a world all players are satisfied with.

### 3.3.1. Youtopia Affordances Designed to Support Collaborative Learning

With respect to our research questions, Youtopia was designed to provide opportunities and benefits to the collaborative learning process. Of course, designing for a particular purpose or experience can differ from the actual experience of using the application, which is why I was also concerned with the challenges and discrepancies
revealed by the teachers in their interviews. In this section I outline the major affordances purposefully designed into Youtopia that were intended to support collaboratively learning sustainability-related content.

Support for Co-Located Collaboration: Youtopia allows for face-to-face communication where gaze and gesture can aid verbal discussion. However, the application itself, through computational artifacts, can aid verbal and gestural communication processes between collaborators (Roschelle, 1996; Suthers & Hundhausen, 2003). Suther’s (2006) points out systems that allow for this interaction are able to be embedded in classrooms more easily since the culture of this environment is based on face-to-face or co-located interaction styles (e.g. (Lingnau, Hoppe, & Mannhaupt, 2003; Scardamalia & Bereiter, 1991; Toth, Suthers, & Lesgold, 2002)). As previously touched upon, collaboration becomes the best means to progress in the activity since jointly working together is supported through system design and the assignment of roles via tool allocation.

Coupling Action and Perception: Fjeld et al (2002) pointed out that it’s important to avoid a separation between action space (input) and perception space (output), and argued to create designs that better coupled these spaces. Youtopia affords this coupling and allows people to “employ their everyday motor faculties in their interaction” (Fjeld et al., 2002). When the stamps are handled “the space in which [the handlers] act coincides with the space from which [they] receive (visual) feedback” (Fjeld et al., 2002) – essentially the handler and others involved in the activity can see what is being done and how it is being done.

Support of Referential Artifact Creation: The environment children create together in the planning activity changes over time as new digital artifacts are created or removed from the application map. There is a complex interplay between these jointly created artifacts because they “become imbued with meanings for the participants by virtue of having been produced through a process of negotiation” (Suthers, 2006). The co-created artifacts and digital simulation are objects through which learners can engage in meaning making (Roschelle, 1996). Youtopia has been designed in a way that allows these “to lead to productive conversation” (Suthers, 2006). To learn more about how
Youtopia was designed for ‘productive’ dialogue and collaboration see (Antle et al., 2014).

**Support for Activity Reflection:** Systems for learning should not simply allow interaction with tools, learning material and other learners, but should allow for ability to draw meaning from their interactions. *Youtopia* allows children to easily interact with the world they’re creating through stamps and fingers. However, Youtopia has two ways embedded within its design for children to stop interaction, question and reflect on what’s happening in the world. First, the info tool freezes interaction and provides information on a specific resource, its role in development and its relationship to the environment. Second, the impact tool freezes interaction and provides a snapshot of how the population’s needs for food, housing and energy are being met and how healthy or polluted the environment is. For collaborative learning purposes, these tools ‘freeze’ the whole application so that independent parallel play cannot occur. If these tools are used, regular interaction with placing land use types on the map stops.

### 3.4. About the School

Understanding the type of school, its pedagogy and its specific learning/assessment criteria for the content domain under investigation are all crucial to providing deeper context to the teacher’s perspectives (e.g. expectations placed upon them, institutional influence on teaching philosophy, etc). Additionally, these details along with school demographics provide both a sense of the generalizability and uniqueness of our findings based on study environment and participant pool. This school was chosen based on for both studies based on convenience and ease of accessibility. The children of the primary designer and lead researcher in charge of the Youtopia application both attend the school used in the study.

While the participating school is a unique, independent school within the local community known for having a more ‘open’ inquiry-based approach, the school is part of a larger global community dedicated to this type of teaching and learning. The participating school is part of the International Baccalaureate® (IB) non-profit educational foundation, which works “with 3,754 schools in 147 countries to develop and
offer four challenging programmes to over 1,175,000 students aged 3 to 19 years” ("About the International Baccalaureate,” n.d.). The Primary Years Programme (PYP) is a curriculum framework designed for students aged 3 to 12, focusing “on the development of the whole child as an inquirer, both in the classroom and in the world outside” (“The IB Primary Years Programme,” n.d.). The main goals are to help children develop knowledge and skills in six transdisciplinary themes through inquiry-based learning. This means that pedagogically the school is dedicated active participation of their students through dialogue with a focus on understanding facts, values and opinions. Youtopia incorporates inquiry and dialogue based interaction, which is in line with the practices and culture promoted institutionally. This is important to acknowledge since determining Youtopia’s ‘fit’ or ‘usefulness’ is partly dependent upon how it supports (or doesn’t) the existing learning and cultural environment.

A year after Study 1, I was motivated to explore how actual use and deployment could differ from predicted expectations. I left Youtopia at my participating school for roughly three months during which Study 2 was completed. The goal of the second study was to further explore the overarching research question but through teacher reflections on actual self-planned use of Youtopia in the classroom during the three month Exhibition period. The PYP Exhibition has a number of key purposes. Some of these objectives include (International Baccalaureate Organization, 2008):

- engaging students in in-depth, collaborative inquiry;
- providing students with an opportunity to demonstrate independence and responsibility for their own learning;
- providing students with an opportunity to explore multiple perspectives;
- and demonstrating how students can take action as a result of their learning.

For the Exhibition, students were required to choose a local sustainability issue or problem to be explored (e.g. forestry). Given the content domain of the year’s Exhibition and the overall objectives, my participating teacher’s asked to integrate Youtopia into the materials available to students to explore the domain.
3.5. Situating the Research within a Phenomenologically-Situated World View and Adapting Theoretical Tools

Context matters for understanding educational TUI-touch tabletop applications, but contextual inquiry itself hasn’t always been supported in the HCI and CCI community. While there is now ‘official’ space to conduct situated research there are still many calls to action within the tangible interaction community to explore in this area. For example, Zaman et al said, “realizing the context dependence of the potential of tangible interaction is not only important in terms of user experience but also important to understand the product’s learning, usability, or collaboration benefits” (2012, p. 375).

The early HCI research focused primarily on two paradigms: Human-Factors and Classical Cognitivism/Information Processing (Harrison et al., 2007). Though research in these paradigms is still extremely prevalent and useful today, the focus of these approaches is not on context-dependent factors. As the field matured, more and more researchers began to realize that there is another ‘space’ unaccounted for, which does not provide a ‘better’ perspective per se, but that allows us to explore the phenomenologically-situated worldview. Harrison et al explain that this third paradigm in HCI and CCI allows us to more fully understand the “totality of experience, including aspects that may be irrelevant to the immediate goal of the interaction” (2007, p. 6). Operating under this view moves us beyond simply asking “how does context give our design meaning?” to also inquire “how does our design accommodate the context?” (Harrison et al., 2007, p. 6). I find this shift in perspective particularly important given the issues pointed out concerning teacher perspectives in the previous section.

While I find my work aligning with the third paradigm in HCI and CCI, it brings up many considerations for design and evaluation approaches. What exactly are the methodological tools available within this epistemological space? What aspect of ‘context’ should I focus on exactly? What questions should I ask? Although I knew, based on the literature in the previous section, that I wanted to focus on teacher concerns (e.g. seeing our prototype through their view of context), I still had questions about how to structure my inquiry. Consider the following (Harrison et al., 2007, pp. 5–6):
…questions that arise resolve around how to complement formalized, computational representations and actions with the rich, complex, and messy situations at hand around them. Thus the three interlocking elements of the phenomenologically situated paradigm are (1) focus on meaning and meaning creation, (2) based on human experience, and (3) therefore represented through multiple perspectives, and the relationship amongst those perspectives… Because of its emphasis on multiple perspectives, the third paradigm does not espouse a single, correct set of methods or approaches to answer these questions.

This helped me understand the main elements of this position, but I was still left with a choice about approach. Some initial theoretical lenses came to mind.

Though not considered a ‘true’ contextual theory, rather a design practice, Ehn’s (1989) participatory design (PD) integrates context within the design practice itself by virtue of working with those that are being designed for. Though this approach originated as a practice within typically adult settings (e.g. the workplace), in recent years PD has become particularly popular within the CCI community – integrating children into the design and evaluation process of technology intended for them. Children can provide invaluable insight about their wants and needs in most contexts and be extremely effective communicators and prototypers. Druin found that “children ages 7-10 years old make the most effective prototyping partners” because they are able to self-reflect and communicate what they are thinking without seeming too influenced by how things ‘should’ be – a problem that older children seem to have more frequently (1999, pp. 595–596). When discussing my research I was often asked why I didn’t go with a PD approach that involved both the teachers and students if I wanted to design for a classroom community – especially since the age group of my children users aligned with Druin’s ‘ideal’ age group. For the purposes of my research, a PD approach would have necessitated co-creation as an initial and ongoing process, which was not practical for a couple of reasons. First, the prototype was already finished so this evolutionary process
was not an option. Second, pragmatically speaking the teachers and students have extremely busy schedules in the context of a given school day – a schedule which is dictated and facilitated by many different stakeholders. To engage in a process over any length of time would be difficult, at best, to get approval for and coordinate. Additionally, the formal educational space is a unique space where children may not understand their own developmental needs or how to meet them – which is of course necessary in the development of educational technologies.

Suchman’s (1987) situated action (SA) provides insight into contextual or human-centric matters. Though SA can help us move beyond user models and plans, it does not explicitly focus, as activity theory does, on “persistent structures that stretch across activities through time and space” that can affect use (Nardi, 1996). Because SA is more individually focused it does not provide much in the way of structuring collaboration or group inquiry. For me it seemed SA could be a great contextually situated usability tool, since it helps focus on breakdowns between how someone is trying to ‘do’ versus how the technology ‘assumes’ it will be done. This approach helps provide context to why or how this mismatch is happening. However, this was not a useful approach to answer my research questions because I wanted a wider-angle view than individual-system interaction.

In the next section I discuss why Activity Theory (AT) was a more useful theoretical lens to get at the elements of the phenomenologically-situated paradigm based on my research goals and questions: (1) focused on meaning and meaning creation, (2) based on human experience, (3) therefore represented through multiple perspectives.

3.5.1. The Propositions of Activity Theory

Vygotsky posited that children learn through a constant process of internalizing external activity and can move beyond what is ‘simply’ evident by “actively changing the external world to support new ways of thinking” about others, artifacts, learning material, etc (Bellamy, 1996). Since engaging with the world through different activities is a fundamentally ‘social’ process, Vygotsky acknowledges social interaction as a key
aspect of a child's development as mentioned in the earlier discussion of collaborative learning. AT, derived from Vygotsky's work (1978a, 1978b) and developed by Leont'ev (1981), is based primarily on the idea that tools mediate thought. For Vygotsky, the environment was seen as the main factor in shaping our mind. Artifacts mediate the internalization of our experiences – through different activities within our environment. However, Vygotsky also believed that we are not simply receivers of information or stimuli, but that we further (re)shape the world through the use and creation of shared artifacts. This cyclical internalization/externalization process shapes how we continually (re)act in the world.

To add to Vygotsky’s conception of activity and artifact, Leont’ev (1981) and Cole and Engeström (1991) further developed the notion that to gain a better understanding of ‘activity’ one must focus on the cultural context specific to the activity. Artifacts mediate the experience between the subject of an activity (the individual) and the object of the activity (the individual’s purpose). As we think of activity theory today, a key concept to understand is “that the development of thoughts and cognitive activity requires social interaction and exchange with a physical environment” where the physical environment “is used for the externalization of thoughts and as external memory” (Fjeld et al., 2002). By mediating activity, tools connect people to the world they live in, which includes connection to others (Ehn, 1989). Tools, activities and context all play a role in shaping unique, embodied collective experiences and understanding (Leont’ev, 1981).

We can consider activities as collective, in that multiple individuals (subjects) may be involved, yet at the same time "each activity is conducted through the actions of individuals" (Bødker, 1996). Each action we take to pursue the object (objective) is actually implemented through operations. Operations are connected directly to real-world, physical or social environmental factors of a given circumstance (Bødker, 1996). Cole and Engeström (1991) present two main factors that impact an individual’s actions or choices within an activity to meet the object (objective): (1) the tools (artifacts) used, and (2) the community and its rules, the division of labor within community.
Bellamy (1996) further fleshed out Cole and Engeström’s activity analysis based on typical K-12 education, which allows us to see the contextual complexity of these educational environments (Figure 2). According to Bellamy, “the introduction of new artifacts into an activity affects, from the perspective of the activity, the kinds of processes, social and individual, that develop” (Bellamy, 1996). Positioning new technologies into existing communities or practices affect the learning activities, and the use or integration of that new artifact (Bellamy, 1996). The design and understanding of a particular system must extend beyond user models and affordances because other factors – such as rules, community and division of labor – can play a role in how effectively a system can mediate particular objectives and activities when embedded in primary school classrooms.

With the phenomenologically-situated paradigm in mind, Harrison points out that “we can interpret the nodes and connections in activity theory as a particular set of structures that encourage or demand the researcher to take a broad view of context” (2007, p. 8). Given my educational-context focus activity theory provides structure to an inquiry in a complex environment where learning is mediated through many different means. First, AT emphasizes meaning and meaning creation as a social process that is mediated by an activity’s tools or artifacts. Second, AT is explicitly focused on human experience – specifically how learning and development are shaped via social interaction and the tools that we share and act through in the world. Third, AT can be focused on multiple perspectives that exist simultaneously but that also interact with one another. For example, Cole and Engeström’s (1991) analysis of activity – and extension
of AT — encompasses relationships between mediating artifacts, individuals/groups, rules, the community, division of labor, and the purpose (object) of the activity.

AT has gone through many adaptations over the years, particularly as each new field of inquiry brings with it new socio-cultural factors and mediating artifacts for examination. As part of AT’s HCI-specific transformation, many tools have emerged to bring AT down from a high-level framework to ‘tools’ that can be used for technology design and evaluation, many of which come in the form of a checklist to help guide attention to the aspects of human activity that are most pertinent (Kaptelinin & Nardi, 2012). Quek and Shah (Quek & Shah, 2004) point to these tools as support for “asking the right questions” when analyzing, designing and evaluating interactive systems – particularly when human behavior is tied to socio-cultural or contextual concerns.

One of these tools, The Activity Checklist, “is a guide to the specific areas to which a researcher or practitioner should be paying attention when trying to understand the context in which a tool will be used” (Kaptelinin et al., 1999, p. 28). This checklist was chosen to provide structure and focus to my teacher interviews. It allowed me to explore the space of the primary classroom context while maintaining technology design and evaluation as the primary focus. The details about how The Activity Checklist was adapted and used will be covered in more detail in the next section.

3.5.2. Adapting The Activity Checklist to Structure Interviews

The Activity Checklist is not intended to produce ready-made solutions rather is best used by researchers and designers to frame meaningful questions. The authors point to strength of the checklist as support for established methods and techniques that already exist. The authors specifically point to the checklist’s potential to support traditional qualitative interview inquiry, stating that “the Checklist can help identify the most relevant issues to be covered in an interview” (Kaptelinin et al., 1999, p. 33).

I not only found adapting the checklist helpful for ensuring relevance, but also for minimizing bias in my inquiry process. In the case of my history with Youtopia, one could argue that my direct involvement with Youtopia usability testing and previous research studies at the participating school could have biased what I was looking for (data
collection) and how I interpreted what I found (data analysis). Since I was aware of this potential conflict, the Activity Checklist provided structure and guidance to the focus of the interview inquiry – ensuring that questions didn’t simply ask for reflection on affects that I wanted to hear about. Additionally, this checklist was chosen because it allowed me to explore the space of the primary classroom context for designing and evaluating educational interactive technologies. Though ‘context’ was my concern, to contribute design knowledge we needed to ensure that my focus stayed Youtopia centric. Since the checklist questions provide ‘generic’ or ‘abstracted’ technology and context as its focus, it was important for me to understand the main point of each category (as noted in the previous list), how this mapped to my classroom context (target actions, users, goals, rules, etc), and how the system (target technology) fit, or didn’t, into each question.

With the ‘evaluation’ section of the checklist and the sample questions table as a guide, I adapted my interview questions to explicitly reflect the TUI as my target technology. Note that as a result I did not adapt questions for all the evaluation checklist questions provided. I adapted those that I felt were most pertinent to answering my research questions. Two questions were adapted from areas 1 and 4. Three questions were adapted from areas 2 and 3. The checklist allowed me to identify areas of concern so “they can be explored more deeply” (Kaptelinin et al., 1999) to address my research questions. Below I provide a brief description of each of the four checklist categories, a sample checklist question from each category, and my adapted interview question mapped to the checklist question. A full table mapping the AT checklist category, checklist questions and adapted interview questions can be found in Appendix A.

1. **Means and Ends**: This focuses on the “extent to which the technology facilitates and constrains the attainment of users’ goals and the impact of the technology on provoking or resolving conflicts between goals” (Kaptelinin et al., 1999, p. 33).

   - Sample checklist question: Are all target actions actually supported?
   - Adapted interview question: How do you see Youtopia fitting into the overall sustainability curriculum? Do you think it supports all of the learning goals?
2. **Social and Physical Aspect of the Environment**: This focuses on the “integration of target technology with requirements, tools, resources, and social rules of the environment” (Kaptelinin et al., 1999, p. 33).

- Sample checklist question: Is target technology integrated with other tools and materials?
- Adapted interview question: In your view can a system like Youtopia be integrated with other learning resources and materials in your classroom, including non-computer resources and materials?

3. **Learning, Cognition and Articulation**: This focuses on the “internal versus external components of activity and support of their mutual transformations with target technology” (Kaptelinin et al., 1999, p. 33).

- Sample checklist question: Is the whole ‘action lifecycle,’ from goal setting to the final outcome, taken into account and/or supported?
- Adapted interview question: In your view does Youtopia take into account the whole cycle of learning, as you understand it?

4. **Development**: This focuses on the “developmental transformation of the foregoing components as a whole” (Kaptelinin et al., 1999, p. 33).

- Sample checklist question: What are the consequences of implementing the target technology on target actions? Did expected benefits actually take place?
- Adapted interview question: In your view, what did you find as the benefits and consequences of trying to bring Youtopia into the classroom? And are these different than what you might normally expect or have experience with other computer technologies?
3.6. **Study 1 and 2 Details**

In the following sub-sections I discuss the specific procedures for each study, including a description of the participants, description of the tasks and research instruments, as well as the data collection and analysis methods. After each individual study sub-section, I dedicate a sub-section to the validity and reliability measures taken in the studies.

3.6.1. **Study 1 Procedure and Methods: Predicted Opportunities, Benefits, and Challenges**

Two teachers (one male, one female) familiar with the students and the 5th grade sustainability curriculum were tasked with playing Youtopia together. These teachers were chosen primarily because the target users for the content domain and learning outcomes of Youtopia were geared specifically towards 5th grade British Columbia students. Due to the teacher’s busy schedules, they were only able to use the system themselves on ‘their own time’ after the regular school day was over. However, this introduction provided the teacher’s with an understanding of Youtopia’s design, some deployment options, etc. in a stress free way where full attention could be focused on the application. This helped alleviate concerns of fixing ‘glitches’, orchestrating both the class and Youtopia use, time spent planning 'new' activities around the system, etc. The teachers were briefed after this session to see if they had any questions or concerns about the system itself before they observed student users.

A few days after their own Youtopia session, the teachers were asked to observe as many pairs of children using Youtopia as they had time to do together. The teachers were able to watch two pairs of children who were able to stay after school to use Youtopia. Each pair of students used Youtopia for 30 minutes each while the teachers observed their use. The teachers ensured the students were paired based on similar curriculum/technology competencies (equal playing field between partners), mixed gender (minimize effects of gender by having all pairs boy/girl partnerships), and track record for working together (equal opportunity for collaboration distributed across all pairs). The observation periods with the student were conducted in a separate controlled room off the main classroom where other after school activities were taking
place. This helped ensure that the teachers would have full attention for this task while the other students were engaged in activities by another school facilitator in their regular classroom. I was present for these sessions to share the teacher’s observation experience and help in case of questions or technological issues.

### 3.6.1.1 Study 1 Data Collection and Analysis

Directly after the student sessions, the teachers were interviewed individually face-to-face with semi-structured interviews that contained the 10 adapted checklist questions. To maintain consistency between interviews, the teachers were only asked to elaborate on or clarify their answers to the set of checklist questions. For example, if unknown acronyms (e.g. IB to denote International Baccalaureate) or educational jargon (e.g. action cycle) were used the teachers were asked to explain these to gain full understanding of problem space from the teacher’s point of view. Each interview lasted between 70-90 minutes. These interviews were audio and video recorded.

My data analysis is built on the general interactive process for qualitative data analysis discussed in Creswell (2009):

1. **Organize and Prepare Data for Analysis** – First, I transcribed each interview’s raw audio data in its entirety. This served as a refresher of the interviews that had been conducted a few days prior to the transcription date. Then I created a spreadsheet that contained a column for (1) checklist category (e.g. means/ends), (2) each original checklist question taken from that category, (3) each adapted interview question, (4) Teacher A’s transcribed responses broken down by interview question, and (5) Teacher B’s transcribed responses broken down by interview question.

2. **Read Through All Data** – Once the transcription data was organized by interview question and teacher in the spreadsheet, I added a new column for the first themes derived from responses of both teachers for each question. In this first pass I was not specifically concerned with answering the research questions or thinking specifically about design-focused concerns. I simply wanted to consolidate the teacher’s shared thoughts into short concise
summary statements. For example the following question was asked: “How do you see Youtopia fitting into the overall sustainability curriculum? Do you think it supports all of the learning goals?” The preliminary themes for this question were as follows: Youtopia (1) supplements existing governmental education deliverables, (2) provides a visual and hands-on way to explore sustainability tradeoffs and compromise, (3) creates dialogue between students (which can be good for those that are shy, particularly). This helped me “obtain a general sense of the information and to reflect on its overall meaning” (Creswell, 2009, p. 185) shared within the community.

3. **Begin a Detailed Analysis** – The second pass through the data included both a revisit to the transcribed data and to the preliminary themes to further get a feel for the overarching teacher concerns that spanned at least two checklist categories. For example, is Youtopia mentioned as providing ‘a visual and hands-on way to explore’ in answers by both teachers in response to more than one interview question and/or checklist category? This pass allowed me to formulate ‘top-tier’ themes of importance that both teachers agreed upon that were mentioned across multiple interview questions and checklist categories. A third pass was done during this stage where I went back through the top-tier themes to ensure design implications since a goal of my study was to contribute design knowledge.

4. **Formalize Themes/Descriptions** – At this stage I had abstracted what was revealed in the data to three themes that could have implications for design or existing application evaluation, which included:

   a. **Support for the Development/Practice of Social Skills and/or Norms** – This was discussed in two main ways. First, Youtopia was predicted as creating dialogue and coordinated actions between students. Second, Youtopia was predicted as helping mediate different learning styles and personal dynamics. Specific examples of how these were/could be manifested were derived from interview transcripts and outlined for each point.
b. **Support for Institutional Goals** – This was discussed in two main ways. First, Youtopia was predicted to add value by integrating into the culture of the classroom activities for the intended content domain/curriculum. Second, Youtopia was predicted to add value by making abstract ideas more understandable by ‘doing’. Specific examples of how these were/could be manifested were derived from interview transcripts and outlined for each point.

c. **Support Reflection, Self-Discovery and Assessment** – This was discussed in two main ways. First, Youtopia was predicted to provide opportunities for students’ reflection and self-discovery of personal traits/styles, values, problem solving and learning strategies. Second, Youtopia was predicted to maintain the model/pedagogy of reflection, self-discovery, and assessment that is embedded within the unique classroom culture. Specific examples of how these were/could be manifested were derived from interview transcripts and outlined for each point.

In preparation for Study 2, as noted above, I wanted to provide more descriptive examples of how each theme manifested itself according to the teacher’s interviews following the student observation period. To do this I went back to the interview transcriptions to note verbatim accounts of how each theme was represented so quotes could be extracted for support. I also outlined these examples in my own words for each theme so I could map the emergent data for Study 2 to these defining characteristics.

This study allowed me to gain an initial, albeit speculative, reflection from the teacher’s as to how they saw Youtopia either fitting in or not with existing practices, deliverables, etc. within their classroom (physical space and learning culture). As will be discussed in the next section, the themes formed in Study 1 were revisited in light of the actual experience of classroom integration over a multi-month Exhibition period. The emergent data from Study 2 interviews was added to and compared with the themes from Study 1 to contribute finalized themes of concern and design considerations.
3.6.2. Study 2 Procedure and Methods: Actual Opportunities, Benefits, and Challenges

Upon the request of Youtopia for use in their 5th grade Exhibition on local sustainability topics, I was able to partner up with the same two teachers to further explore my research questions. The two teachers were responsible for teaching the whole 5th grade between their two classes with a total of 40 students. These same teachers were chosen for the follow-up study for several reasons. First, their students were of the intended age and grade for Youtopia’s content domain and ‘learning’ outcomes, which is important for assessing the actual appropriateness and/or usefulness of the application. Second, the teachers were already familiar with Youtopia and were therefore best equipped to implement it most naturally within their planned curriculum/activities. And lastly, because the teachers had participated in Study 1 they could best speak to a comparison of how they predicted Youtopia to be used/useful versus how authentic use turned out.

To ensure an authentic use period, the teachers were responsible for all planning and facilitation of Youtopia during the three month Exhibition period. The teachers created Exhibition groups consisting of 4 students each. Children were put together by balancing a combination of metrics, which included the following:

- topic of interest (had to be a local sustainability issue),
- an understanding of who works well together (based on introvert vs. extrovert ‘quizzes’ taken by the students),
- student self-reflections of what’s most important to them from the IB ‘basic needs’ circle (e.g. power, freedom, fun, belonging),
- as well as what type of learner they identify as (e.g. auditory, kinesthetic, visual).

For the Exhibition, the area of inquiry for the 5th grade under the larger ‘sustainability’ umbrella was natural resources. The children were required to pick a local natural resource and explore how it is used, discuss varying stakeholder arguments for
managing that resource, how the resource could be used/managed more sustainably, etc. The children were guided to multiple resources for self-inquiry on the topic (curated book selections, Internet searches for new articles, field trips, reserved times for Youtopia, etc). Youtopia was set up in a room connected to the main classroom spaces, but that was not fully visible from the main ‘class’ rooms (Figure 3). Student Exhibition groups were allowed to sign up for time slots of 40 minutes to use Youtopia. Each group used Youtopia at least once over the course of the three-month Exhibition period, but no group used the system more than three different times. When it was a group’s turn to use Youtopia the teacher provided them with a quick demo on how to use it as well as spent time checking in on the group throughout their session. The teachers did not stay in the Youtopia session room the whole time since the rest of the class was engaged at their desks on other work. At the end of each group’s session, screen shots were made of the group’s final ‘world’ state (e.g. a map of the land uses as they were placed by the team and an image of the Impact tool screen) and saved onto USB drives by the teachers.

![Figure 3. Placement of Youtopia for the Exhibition period in a room attached to the main classroom area.](image)

### 3.6.2.1 Study 2 Data Collection and Analysis

At the end of the three-month Exhibition period, both teachers were interviewed individually. In addition to revisiting the adapted checklist questions that were used in Study 1, I also asked the teachers about the Exhibition itself (e.g. what is it actually?
How does the Exhibition integrate with and/or differ from regular ‘class’? How was Youtopia used in the Exhibition? etc.) and how students were grouped together. Each interview lasted between 90-110 minutes. These interviews were audio and video recorded.

My data analysis process for Study 2 was adapted slightly from Study 1 based on changes in research goals. The first goal was to compare the preliminary predictive themes from Study 1 with the emergent data revealed from actual usage in Study 2. The second goal was to refine the themes and create design considerations based on the culmination of data from both Study 1 and Study 2. My process for Study 2 was as follows:

1. **Organize and Prepare Data for Analysis** – First, I transcribed each interview’s raw audio data in its entirety. This served as a refresher of the interviews that had been conducted a few days prior to the transcription date. Then I added Teacher A’s transcribed responses broken down by interview question, and Teacher B’s transcribed responses broken down by interview question to the spreadsheet created in Study 1. The information provided about how students were broken into groups and the details of the Exhibition were recorded as separate entries since they were meant to help contextualize the checklist question answers.

2. **Read Through All Data** – In my first pass of the Study 2 data I again wanted to consolidate the teacher’s shared thoughts into short concise summary statements. As with Study 1, I went through the responses from each teacher for each question and quickly noted down the shared themes.

3. **Begin a Detailed Analysis** – At this stage I already had three themes with descriptions/examples from Study 1, which I used when conducting the second pass. These existing ‘top-tier’ themes were used to compare with the preliminary themes from the first pass on Study 2 transcripts. At this stage I was able to see whether the emergent data from Study 2 could be categorized under one of the existing themes, whether themes needed to be
changed to meet the newest data and/or whether new themes needed to be created to account for the new data.

4. **Formalize Themes/Descriptions** – At this stage I had a new set of abstracted themes – a culmination of what was revealed in the data from both Study 1 and 2. As with Study 1, I ensured the descriptive examples of how each theme manifested itself during the Exhibition period were added where necessary. To do this I went back to the Study 2 transcriptions to note clear accounts of how each theme was represented, particularly if an opportunity was noted or if a new way of describing an existing theme was present. These finalized themes of concern are discussed in detail in the next Results chapter (Chapter 4), which includes a comparison of data revealed in each study.

5. **Revisit Finalized Themes to Create Design Considerations** – My finalized themes, a culmination of findings from both Study 1 and Study 2, were used to create the design considerations contributed in this paper. The design considerations are presented in the Discussion chapter (Chapter 5). After the emergent data in my themes was finalized, I took multiple passes over the data and examples. I used Wallace and Scott’s (2008) five contextual design considerations for co-located collaborative tabletops as a framework to guide the organization of my own design considerations. I found their five areas of concern and definitions useful for parsing my own data into the “who, what, when, where and why questions that are commonly used to understand the user context and establish design requirements” (Wallace & Scott, 2008). For example, the ecological context (‘where’) places emphasis on considering how the use environment itself may impact the role of a technology and its relationship to other objects and materials within the environment. This allowed me to create and categorize design considerations revolving around these types of benefits, concerns, and/or opportunities revealed in my data. The design considerations I contribute are categorized by the five contextual considerations put forward by Wallace and Scott, but contribute novel research in two ways. First, Wallace and Scott do not specifically address
tangible tabletop applications, which have additional affordances compared with a simple tabletop that may be interactive and/or support touch. My considerations reflect these differences and provide examples specific to TUI-touch tabletop applications. Second, the authors do not specifically address any particular use environment, scenario or content domain throughout their discussion. I focused my contextual investigation and my design considerations with the primary educational space in mind, providing design knowledge specific to this use and deployment scenario.

3.6.3. Study 1 and 2 Validity and Reliability Measures

Several measures were taken to help ensure qualitative validity and reliability in both studies. Creswell (2009, p. 191) introduces several measures to help ensure qualitative validity which is described as taking steps to ensure that findings are accurate from the point of view of the researcher, participants and/or readers. First, I triangulated interview data from multiple perspectives over two different studies to build “a coherent justification for themes” (Creswell, 2009, p. 191) to add validity to my research. Second, I “present negative or discrepant information that runs counter to themes” (Creswell, 2009, p. 191) if and when it was present in the data. Lastly, I clarify the bias that I may bring to the research study by being honest and open about how my interpretation of the findings could be shaped by my background (Creswell, 2009, p. 191). Most of the measures presented by Creswell (2009) discuss ensuring qualitative reliability when multiple researchers and/or projects are the focus, but my thesis data collection and analysis procedures were done alone. Despite this, I employed several measures to help ensure consistency in my procedure and accuracy in data transformation. All main interview questions were written out in advance to ensure that interview protocol was consistent with each participant across both studies, and, could (hypothetically) be followed by another researcher. All interviews were audio and video recorded to ensure that a verbatim transcription could be done and to ensure the raw data could be revisited if need be at a later date. Full transcriptions of all interviews were done by myself and rechecked to ensure that they did not contain any mistakes. Though multiple coders were not used in my thesis data analysis process, tables were made to map the AT
checklist categories and questions, adapted interview questions, and transcriptions to the emergent themes.

3.7. Chapter Summary

This chapter provides a detailed description of the methods and procedures used in both Study 1 and Study 2 of my thesis, including a focus on how data collection and analysis were completed. I provide support for the choices of teacher interviews, real-world deployment and the use of an Activity Theory lens by positioning these methodological decisions within an evolutionary view of epistemology in HCI and CCI. I discuss how within the tangible interaction community specifically there has been a push to inquire into the ecological concerns that move us from questions of technology’s usability to ‘fit’. To provide better context to Youtopia’s fit, I provide both a detailed description of the school used in both studies and of Youtopia, the main research instrument, itself. Along with the discussion of teacher barriers provided in Chapter 2, these discussions provided justification for why teacher interviews were chosen as a first way to explore the classroom contextual concerns that may impact the way we think about designing and evaluating TUI-touch tabletop applications for education. Furthermore, the Activity Checklist – derived from Activity Theory – was introduced as an adaptive tool to provide structure my inquiry in both Study 1 and 2. In the next chapter, I discuss the results in the form of four main themes of concern that were derived from the teacher perspectives revealed in the interviews from both Study 1 and 2.
Chapter 4. Results

4.1. Overview

The themes that I present in this section are a culmination of bringing the data from both studies together to form a more full understanding of the problem space. The adapted checklist interview segments from Study 2 were compared to the themes generated in Study 1. I looked for both support of Study 1’s existing themes as well as changes that may have occurred as a result of the authentic integration process. The themes, presented in Section 4.2, outline the four areas the teacher’s noted as most important to them in considering a TUI-tabletop application for use in their classroom. These themes were revealed in both studies.

4.2. From Teacher Perspectives to Themes of Concern

Within each theme the insights revealed in each study will be discussed. In many instances Study 2 provided the teachers with a new or different way of viewing how Youtopia supported or didn’t their objectives within the classroom. Each theme section will discuss any opportunities, benefits, challenges or discrepancies revealed in the interviews in order to address my research questions.

4.2.1. Support Social Development

In both studies, the teachers revealed that providing children with support for social development is extremely important within the culture of collaborative learning in their classrooms. This came up in the teachers’ responses to my adapted questions from checklist categories 1, 3 and 4 – providing insight into S2-RQ1 (opportunities) and S1/S2-RQ2 (benefits). The teacher’s noted that they feel nuturing social skill development is not only an important part of primary education, but a life skill generally...
speaking. This is reinforced by the institutional expectations of the participating school. The IB PYP explicitly asks children to work on understanding their own social skills and respect that others are different. The teachers pointed out in the dilemma of putting the children into groups for the Exhibition that the social issues within this age group of children has a huge impact on their success and happiness, particularly on group work.

The teachers said that support for structuring social behaviors so that they play out in a positive way was an opportunity and benefit of using Youtopia in the Exhibition. Teacher A noted that she used to really focus on grouping by interest first and foremost. But said these groups work together for a long time so “I really think I underestimated the social aspects at this age and how those played a part in how [the children] did in the Exhibition.” She added that this is why her and teacher B worked together to explore social dynamics and learning styles when creating groups this year – as well as asking the children to reflect on these differences between people. The teachers revealed that the system created a support ‘structure’ for social comfort and development in two main ways.

First, it helped create dialogue and coordinated actions between students. This was revealed as a benefit in both studies (S1/S2-RQ2) with the Youtopia application and was articulated in three main ways.

1. Youtopia provided beneficial opportunities for children to oscillate between internal thought processing and external strategies of what actions to take next and how to coordinate them (e.g. having tools and system mechanics that allow for both personal and group reflection about personal values and deciding what plans of actions to take next, etc.).

2. Youtopia created beneficial social situations where children could engage in conflict resolution and compromise (e.g. posing a reflective question potentially causing children with different values about an ‘ideal’ world to come to common ground, etc.).

3. Youtopia created beneficial social situations where children could learn how to tackle views/values and property of others. (e.g. articulating plans and values because a common goal must be reached, agreeing on what actions
to take next and using ‘shared’ resources to make it happen, etc.).

Teacher A reflected, “I liked the dialogue between the kids... we saw one of the kids, they just kind of grab right? And plunk down their stamps, but it also shows that with certain kids you need to ask properly... if it was two kids that didn’t know each other as well within a classroom I think the dialogue has to be there and they have to really compromise and talk it out. So I like the social part of it too, to use it not just for sustainability, but for the social teaching and the proper way to interact socially. And compromise. I could see possible conflict brewing over ‘well, that’s mine’ or ‘that’s my job to do it’, but again that lends itself to teaching the social part, right? So it’s almost like killing two birds with one stone...”

Second, Youtopia helped foster team building through the course of joint social activity. This was revealed as an opportunity in Study 2 (S2-RQ1) of the Youtopia application and was articulated in the following ways.

1. Youtopia provided an opportunity to help mediate equality and agency through a combination of tool distribution and game mechanics.

2. Youtopia provided an opportunity to help mediate different learning styles and personal dynamics through tool distribution and game mechanics.

Since interdependence was designed into both the physical artifacts and the computational model of Youtopia, the interaction style could be set up so that both parties must contribute to achieve any one goal. In Youtopia individuals can be assigned roles through the allocation of the physical stamps (e.g. land use manager and natural resource manager). Together users are responsible for providing people with food, shelter, and energy for the land area on the digital map. When roles are assigned, each person is responsible for his or her own set of tools and their associated responsibilities, but the actions of each player are required to meet the populations’ needs, much like in real-life decision making. This is because the underlying system model registers individual actions, but only acts based a desired ‘set’ of inputs. For example, someone must turn forests into lumber, before that lumber can be used to build housing. Or someone must build irrigation near the river before that water can be used to supply
farms or gardens. This interdependence built into the design of the application was intended to support communication about values and collaboration on creating a world all players are satisfied with.

Despite their efforts to group students that complemented each other, Teacher B reported that the system provided support to one group that had problems working as an Exhibition team. In this case Youtopia helped overcome feelings of unequal project contributions, work ethic and learner styles that had negatively impacted other Exhibition activities the group was engaged in. Teacher B reflected that sometimes to have an activity that is outside of the norm is beneficial: “They had that step away from sitting in the same places and falling into these roles.” There were barriers between the students due to differences in learner types and an unequal power balance came about. Teacher B pointed out that Youtopia, through the interdependent design and open-ended task, brought about new ways of working together (physically and verbally).

Coming together where they had to make and accomplish goals, as a group, was beneficial to restoring order. Teacher B said their experience with Youtopia changed how they worked together in other areas of the Exhibition. He said, “they came out of it talking together as four students. They stood on their own sides of the table with a set of tools [distributed by either housing, energy, nature reserves or food] and there wasn’t reaching over. It was no longer two together and one and one… It’s really hard when you play a game with someone to really not like them. It kind of harkens to that.”

He continued by saying that as a teacher one benefit he now sees in a system like this that he didn’t before is using it to create a feeling of togetherness or a team spirit. In hindsight he felt he should’ve started the group with the activity so they opened up communication by being linked across the table and in between each member from the beginning. He noted group tension may have been alleviated at first because ‘games’ are fun and there was excitement about using Youtopia. But he added that games also involve trust and Youtopia can help build that. It was noted that the interdependence built into Youtopia, where physical tools must be shared or requested for use by other players, is important. The group must create goals. Accomplishing them requires that you become respectful of one another. He said that they left their session
talking about their resource together (water) and that they continued to actually work as group afterward.

While Teacher B revealed a case of mediating agency, equality and different learner types in Study 2, both teachers are not sure how Youtopia would actually faciliate learner types or personal dynamics as they predicted them in Study 1. This revealed discrepancies (S2-RQ4) in the type of mediation they predicted occuring versus what actually occurred. In Study 1, they predicted that particularly for groups that had shy and more aggressive kids partnered together Youtopia could help equalize the playing field. They saw the potential for Youtopia, and it’s interdepent design, to create a better experience through empowering shy kids to live up to their ‘roles’ and making aggressive kids ‘take a step back’. In Study 1 Teacher A said: "I wonder for those kids that need a little bit of time to process. I think if you were maybe working with a partner, and one of you is a processor and the other not so much, I wonder if that would hinder things…. I don't know if for those non-communicators, the kids that aren't so great with the verbal dialogue, if it would be as successful… But then that's teaching social skills as well… I think creating the roles helps because then each person has to contribute equally, right?" In Study 2 the teachers said it was still a bit hypothetical to know for sure whether this would really play out. Because they went to such great lengths to avoid these personality and learner pairings for the Exhibition, they never had proof that these learner types or personality traits (shy/passive vs. outgoing/aggressive) would be benefit from group work together with Youtopia. However, both teachers said that being able to support both of these types of learning and personality types would be very valuable. They joked that at minimum it could help alleviate some of the stress associated with trying to make perfectly matched groups.

These results point to a need to consider the importance social interaction and behavior – particularly as it is unique to the age group that an application is intended for. In the PYP and the Exhibition children in the 10-11 age range are particularly encouraged to explore their own values and opinions while learning to respect that others may not feel the same way. As part of this process different types of learning styles or personality types may clash. Its important to provide children with a safe and
productive way to work out these differences together where equality and agency are promoted.

4.2.2. **Support for Institutional Goals**

Both studies revealed that TUI-touch tabletop applications should provide support for institutional goals. This takes into account factors related to integration and expected goals or outcomes. This came up in the teachers’ responses to my adapted questions from all four checklist categories – providing insight primarily for **S1/S2-RQ2 (benefits)**. As previously discussed the participating school is an IB PYP school dedicated to self-inquiry and exploration. The teachers revealed that one of main ‘pillars’ of the IB PYP program is integrating subjects or concepts of inquiry with each other and across grade levels. They revealed that they preferred not to categorize learning as one subject by itself, rather thinking of each thing being taught as how it relates to other subjects and things happening in the real world. I was told that many different areas of inquiry make up sustainability (conservation, renewable v. non-renewable, human v. natural need, etc) and may be covered across different discussions within 5th grade and are also built up over time across grades. The IB PYP pedagogy subsumes that different ways of learning are accommodated so that students feel compelled to explore, experiment and ask questions. The teachers pointed to a need to have access to tools that support these goals.

The different supports for institutional goals that were pointed out as most important can be broken down as follows. These were revealed as **benefits (S1/S2-RQ2)** in both studies with the Youtopia application.

1. Youtopia added value by integrating into the culture of classroom (e.g. supports inquiry, asking questions, formulating your own opinion, can supplement other materials, etc.)

2. Youtopia added value by making abstract ideas more understandable by ‘doing’ (e.g. allows you to see the consequences of actions without real world penalty, explore tradeoffs of decisions, etc)
3. Youtopia added value by providing an interactive visual and hands-on approach to explore curriculum (e.g. creates a new medium for exploring a problem so that different learning styles can be accommodated, etc.)

As part of Study 2 the system was used to supplement ‘traditional’ learning materials (e.g. books, Internet searches, etc.) to provide new types of experiencing the topic. Teacher B noted, “What Youtopia does, that I couldn’t do, is give them a ‘real’ situation to manipulate and play with. To see the interplay [between resources]. It’s the best kind of learning you can do. You can learn with your hands. Exploration doesn’t actually damage the real world.” Reflecting on this Teacher A said that “the hands-on is the great component to reading an article or watching video and then you come and manipulate and do it… I think that’s the best part of this, is that hands-on component. And I would say most educational environments would love that hands-on component… the other thing I like is how the kids can see when you use a particular resource, the effect, the impact. I really like that visual component for the kids and the circle [part of impact tool visualization] and can see how by using one, how the other is affected. So that check-in I think is really important, especially for the kids.”

The benefits predicted in Study 1, were congruent with what the teachers found during actual use of Youtopia in Exhibition. Teacher A speculated in Study 1 that “you can read about sustainability and then go to something like this. You can do a classroom activity about sustainability or about farming or fishing or whatever it might be and then supplement, right, with this… for the kids that can read something and understand it, great. But for those kids that need a little more this is fantastic…” The teachers believed that an ideal technology would take into account all three factors mentioned above for supporting institutional goals. Teacher B said added that there is little added benefit for standalone devices. He said, “We try to weave things together and have things make meaning and be connected. There is this doing to find out, to have conversations. I think that’s what we would want to do more often.”

Though the teachers believed that Youtopia aligned well with institutional goals, the teachers said they are generally weary of using technology for technology’s sake. As pointed out new technology, or learning material, must serve a purpose. The teachers’
cautious attitude for technology further points to a need to intentionally design for added value by aligning with the goals and intentions of the institution in question.

Teacher A said, “I appreciate that I work in a place that isn’t where they have these technology initiatives. I was talking to a friend that works at another school and they have to get something or have to use something. Like some local schools here all grade 3 and up in the next year have to have an iPad or some kind of tablet. I almost think its one of those things in 20 years we’ll be like ‘oh yea remember when we like forced technology down everyone’s throats’ thinking this was the solution to everything. Like anything in education, used well, in a thoughtful way, can be really effective. Just by using the nature of technology doesn’t make it great. I think sometimes when teachers see their kids excited about something they think ‘oh I’ve done my job’ and this is too easy to think.”

Teacher B agrees that we should really question what we are using in classrooms and why they are being used. But, he said in his Study 2 interview that Youtopia offered an experience that aligns with the goals he has within his class – providing some insight to S2-RQ1 (opportunities). He said of course the novelty of the piece itself has a huge draw and that the kids get excited about that. But, excitement doesn’t mean that there aren’t benefits. Picking up one of the stamps, he said “they like this type of interaction. It’s not keyboard or mouse interface. It’s even different from an iPad. And it’s huge, I think the size matters. I don’t know if anything done in any other medium would be as enticing. I think if it was an iPad size and they were just kind of dragging and dropping with their individual tablets it’d be different. One of the things we really like about this is the minds coming together. It’s a good size for that. Last year we had 2 and this year we’ve had 4 [working at the table] and both have worked really well. And I’m not sure if you had something smaller or without the physical tools [pauses] That could be a subtle thing that does create a really different experience.”

These results point to a clear need to understand the institutional expectations on several different factors beyond ‘curriculum’ itself. Of course, ‘curriculum’ learning is important, but the teachers seem to be pointing to bigger questions of student experience – how children go about learning and engaging with material. Learning more
about how TUI-touch tabletop applications can add value means understanding the classroom culture and how affordance choices align with those goals (e.g. how teaching is executed, how students are expected to work, what students are expected to reflect on, etc). There will be some institutional goals that seems to spread across all types of educational institutions (e.g. teacher A saying she feels all schools want hands-on learning experiences), but to some degree designers themselves will need to take the necessary steps to investigate the institutional/classroom needs within their own deployment contexts. For example, it was noted by our teachers that an inquiry-based learning teaching and learning style was extremely important, especially for topics with multiple viewpoints. The teachers also emphasized the importance of physically bringing students together while also ensuring that they bring their minds (along with individual viewpoints) together. The teachers point to several physical and digital characteristics of Youtopia as working together to support these important factors, including: accommodating small group interaction via the size of tabletop, using physical tools to facilitate sharing and engagement, and providing an open-ended consequence free exploration of a complex topic.

4.2.3. Support Exploration and Reflection of Learning Concept

This theme focuses on the importance of thinking about how or in what ways a TUI-touch tabletop application can support a child's ability to explore and reflect, in self-directed inquiry, on the concept being learned. These concerns were illustrated in relation to all checklist areas and help provide insight to S1/S2-RQ1 (opportunities) and S1/S2-RQ2 (benefits). The teachers noted in both studies that it is extremely important to consider how the TUI-tabletop can support the IB PYP goals of getting students to think about what they are doing, why they are doing it and, most importantly, how it relates to the real world.

The teachers revealed the importance of allowing children to problem-solve and develop learning strategies through group exploration. These were revealed as benefits (S1/S2-RQ2) and opportunities (S1/S2-RQ1) with the Youtopia application in both studies. These were articulated in a few of ways:
1. Youtopia provided beneficial consequence-free exploration where different strategies could be explored to better understand the tradeoffs associated with decisions (e.g. impact tool can be used to reflect, eraser tool can remove previous decisions, etc)

2. Youtopia, through beneficial periods of reflection and dialogue, allowed children to think about their values and the knowledge they have gained elsewhere about the topic – allowing them to think beyond game play to the wider context of their region and/or community.

3. Youtopia provided an opportunity for children to continue to explore their own topic and the topic of other Exhibition groups even when groups were not directly engaged in the activity.

The teachers both said that one of the biggest hopes that they have for their students as far as outcomes are concerned, especially for sustainability, is taking the time to understand that its all about tradeoffs. The Exhibition itself asks that the students choose a natural resource and explore different stakeholders’ points of view. They are also asked to think about how a resource could be used more sustainably. At a broader level, the teachers said that they want kids to reflect outside of the classroom in all concepts that they investigate.

Teacher A said “One of the big things with us with IB is that you Choose, Act, Reflect. Which is the action cycle… you’re making, you’re looking at something and you have to make a choice. ‘Okay pollution is going up’ and ‘we need to house these people’- you need to act. So you need to take your stamps and take something away or add something and then you need to look back and reflect on it… this follows our action cycle quite well… in terms of ‘is it how we teach kids?’ Yeah. Is it what we want kids to know? Definitely…”

Teacher B pointed out that, as a teacher, he is there to provide support, but said, “we try not to direct it…‘that this is what sustainability is’, ‘this is why we need to do it this way’. We try not to be so talk-down and try and have them sort of uncover things and
find out… and not necessarily take on our opinion, but learn about the situation or concept and develop their own understanding…”

The teachers pointed out that Youtopia is great for exploration and reflection because the game asks you from the beginning, ‘what type of world would you want to live in’ and has no ‘winning state’. They pointed out that the group dynamics also make this process interesting because students are put in a position to figure out what they want their world to be together. Everyone brings in their own knowledge and opinions so children aren’t just thinking about the ‘game’ itself but the tradeoffs and issues it raises.

The teachers revealed that students were excited about continuing to discuss their time using Youtopia with other students had not used the system yet and with those that had already had a chance to use it with their group. Teacher A pointed out that though the teachers had saved each groups final maps and impact, the teachers had not explicitly planned to use them for verbal presentation. She said she was requested by the students themselves to print the maps so that they could show their classmates and share what they did. The teachers were surprised by the request but said that it was nice to be able to have this type of continued reflection happen ‘organically’ after the actual session was over. Teacher A said that though she would’ve like to have an ‘official’ 5th grade-wide share/reflection with the images there was unfortunately not enough time in their schedule to do it. She said despite this that they ended up putting images up in the room and that hypothetically if they used the system again that this something that would be formally planned – providing insight to S1/S2-RQ1 (opportunities) and S1/S1-RQ2 (benefits).

However, the teachers did have one concern about the usefulness or playability over time in Study 2 – providing some insight to S2-RQ3 (challenges). They reflected that its great that Youtopia is flexible to different deployment styles (e.g. how stamps are distributed, different maps and population sizes etc) and student groupings (who and how many are playing). Youtopia allows students to have many different experiences playing over many different sessions because it is fairly open-ended in terms of the complex content-domain and value-based input by individual users who may come together with different opinions of an ‘ideal world’. But, the teachers revealed they worry
that once the ‘mechanics’ of meeting the world’s populations (small and large) are learned that students would start to focus more and more on meeting these more traditional ‘game’ objectives. So while Youtopia was designed to have ‘no winning’ state, it could be questioned whether this is really possible. Teacher A said “There was that element where once they got the hang of it, it’s not clear they were explicitly thinking about natural resources or the tradeoffs, they were sort of trying to balance it out so it looked right on their scales [on the Impact tool].” The challenge for designers is to consider how to design TUI-touch tabletop applications that can provide long-term flexibility in order to keep the ‘benefits’ of having no winning state.

These results reveal that providing opportunities for students to learn through a process of consequence-free inquiry was very important to meeting the teacher’s expectation for student outcomes. I also found that thinking more about the long-tail usage and benefits may be a design challenge that could affect the success of a TUI-tabletop application in a classroom over time.

4.2.4. Support Teachers’ Student Assessment Practices

This theme focuses on the importance of thinking about how or in what ways a TUI-touch tabletop application can support teacher assessment practices (e.g. how do teacher’s assess students). This concern was illustrated in relation to all checklist areas and helped provide insight to S1/S2-RQ1 (opportunities), S1/S2-RQ2 (benefits) and S2-RQ3 (challenges). The teachers pointed out that it’s very important that they have clear ways to integrate TUI-tabletop applications with existing student assessment practices.

The teachers revealed that one must support both the ‘while’ using and ‘after’ using experience. These were revealed as benefits (S1/S2-RQ2) and opportunities (S1/S2-RQ1) with the Youtopia application in both studies. This was articulated in the following ways:

1. Youtopia provided benefits by urging children to verbalize their thoughts while playing. This is key for a teacher’s assessment of an individual’s thinking –
especially important for group or pair exercises. This also allows the teacher to know when/how to scaffold their activity if necessary.

2. Youtopia provided opportunities for the activity to extend beyond playing sessions themselves that could be used later discussions or presentations in class, etc (e.g. via screen shots and print offs of the world the groups created).

Though group work is fostered at my participating school, it is not always the case that groups work well together or stay engaged. For this reason, it’s important to consider ways to assess collaborative group work. Teacher B said, “*kids could be going along all the time in their mind and having great conversations with themselves and discussions and contemplating things but we feel really good when they ask a question. That way we know they’ve been doing all that thinking. So any time that something gets somebody talking we can then be a part of what their brain is going through and what thinking they’re having. So I really like that.*” Since Youtopia was designed to produce verbal communication and collaboration, the teachers found that it was easy for them to ensure that students stayed on task as well as understanding each members contributions. The teachers noted that this was a big benefit.

However, it was noted that the existing physical learning spaces (e.g. classrooms, additional workrooms, etc) layout could impact the existing assessment practices. For instance, in the participating school Youtopia was kept in a side room off the main classroom so the students were not always within direct ear or eyeshot of the teacher. Considering how to overcome this challenge (**S2-RQ3**) could be important for design. In Study 1, this challenge was not really noted since the teachers were present during the whole student session and students did not need to also be monitored in a separate room. In the case of Study 2, the teachers said that they were able to pop in the room or stick their head at the door to listen in on how the groups were working together. They noted that if the group activity didn’t ‘force’ discussion then they would have had to take much more time to actually sit in with each group to ensure they were staying on task, since physical proximity was the only way to monitor Youtopia activity in real-time. The teachers said the room housing Youtopia for the activity was used
similarly for other activities (e.g. students individually, in pairs or small groups may use this room to engage during ‘flex’ time periods) so the room use itself wasn’t in opposition with regular practices. But, the teachers said that the worry of ‘how things were going’ in the other room was stronger with larger group activities using fairly novel technology as the main medium/learning activity.

The teachers emphasized the importance of continuing to assess student exploration and reflection after the actual Youtopia activity was over. The teachers noted they are concerned with how students work together and go about solving problems, but also how they can justify or discuss their decisions afterward. Teacher A said, “I love the idea of them printing [their map and Impact]. They loved looking at each others. You know one group had come in and just done [Youtopia]. They were like ‘oh yea we also had two hydro dams’ or ‘wow you guys have so many gardens, we didn’t have that many gardens’. I love the idea of once everyone has done it hanging up their maps and their impact tools – having them look at what they think about the differences. Why do you think this team did it this way and you did it that way? We think a lot about justification in our assessments of students. There’s the comprehension level. There’s the application level. And there’s the evaluation level. So when they have to justify or explain, it adds that critical thinking piece.”

Youtopia was designed to facilitate student participation in the topic even after the activity at the tabletop itself was over. A physical tool could be used at anytime to take a screenshot of the current state of the world, which would save an image of the map and the impact tool. These assets could be emailed and/or printed to use in continued Exhibition activities. The teachers said that this was a nice benefit to the application that allows them to continue assessment after the activity itself. They added that this was also a nice way to allow children themselves to share the world they created with other Exhibition groups, who may have made different decisions. In this way it opened up further conversation outside of the activity itself for a discussion of values and choices.

My results reveal that understanding teaching and assessment styles are impacted by design decisions. Particularly, we need to consider how different
affordances may impact the interaction style ‘while’ children use the system and how to extend their learning experience beyond the TUI-touch tabletop application itself.

4.3. Chapter Summary

First, the teachers revealed that support for social development must be considered – particularly as it is unique to the age group that an application is intended for. It’s important to provide children with a safe and productive way to work out personal differences (e.g. different values on the content domain, learner type and/or personality traits) together where equality and agency are promoted. In both studies Youtopia was discussed as providing benefits (S1/S2-RQ2) by creating dialogue and coordinated actions between students. In Study 2, Youtopia was noted as providing an opportunity (S2-RQ1) by fostering team building through the course of joint social activity. One discrepancy (S2-RQ4) was noted between Study 1 and 2. The teachers had predicted that Youtopia could potentially provide an opportunity by equalizing the playing field between shy/passive vs. outgoing/aggressive students, but they were not able to say whether or not Youtopia actually supported this as a result of their Study 2 observations.

Second, the teachers revealed that support for institutional goals must be considered – beyond curriculum learning requirements. The teachers emphasized that classroom/institutional culture and pedagogy impact many aspects of the classroom learning experience. Particularly the teachers noted that they are concerned with how children go about learning and engaging with material. In both studies Youtopia provided benefits (S1/S2-RQ2) by supporting important classroom cultural, pedagogical and experiential expectations. In Study 2, an opportunity (S2-RQ1) was noted for Youtopia’s ability to provide a novel interaction experiences and excitement with the material.

Third, the teachers revealed that support for exploration and reflection of the learning concept must be considered. In both studies Youtopia was discussed as providing benefits (S1/S2-RQ2) and opportunities (S1/S2-RQ1) by allowing children to problem-solve and develop learning strategies through group exploration. The teachers emphasized the importance of providing opportunities for students to learn together
through a process of consequence-free inquiry. While Youtopia was noted as providing ways for students to continue reflection even after the activity itself was over, one consequence (S2-RQ3) regarding the longitudinal viability of application was brought up in Study 2. The teachers had concerns about the long-tail usage and benefits of the system, which may be a design challenge that could affect the success of a TUI-tabletop application in a classroom over time.

Lastly, the teachers revealed that support for teachers’ student assessment practices must be considered. In both studies Youtopia was discussed as providing benefits (S1/S2-RQ2) and opportunities (S1/S2-RQ1) by providing support ‘during’ use assessment practices and extending the ability for assessment beyond the Youtopia activity itself. In Study 2, one challenge (S2-RQ3) was noted about how the physical learning space combined with Youtopia’s physical and digital design limited or changed the type and amount of assessment and scaffolding that could occur. Considering how to overcome this challenge poses considerations for design.

The themes in this chapter, a culmination of findings from both Study 1 and Study 2, were used to create the design considerations that will be presented in the next Discussion chapter.
Chapter 5. Discussion

5.1. Overview

My results point to ‘benefits’ that have already been suggested in TUIs-for-learning research, such as hands-on interaction, embodied cognition and active engagement. But, they also point to other important areas that I suggest need to be investigated further in TUI-tabletop design and evaluation for classroom collaborative learning. These important areas reported in the themes, revealed benefits, opportunities, challenges and discrepancies that inform TUI-touch tabletop application design considerations for classroom collaborative learning activities. In this chapter I present design considerations that are aimed to help researchers and designers gain a better understanding of what contextual concerns matter when embedding these types of TUI-touch tabletop applications within primary school classroom environments. I also discuss the limitations to my research as well as areas of interest for future research.

5.2. From Themes of Concern to Design Considerations

In this section I will briefly discuss my process of moving from the areas of importance noted in my themes to design considerations. After my themes were finalized, I took multiple passes over the data and examples. I used Wallace and Scott’s (2008) five contextual design considerations for co-located collaborative tabletops as a framework to guide the organization of my own design considerations. The five contextual design considerations they present include the social and cultural context, activity context, temporal context, environmental context, and motivational context. I found their five areas of concern and category definitions useful for parsing my own data into the “who, what, when, where and why questions that are commonly used to understand the user context and establish design requirements” (Wallace & Scott,
This allowed me to create and categorize design considerations revealed in my data’s benefits, concerns, opportunities and/or discrepancies.

The design considerations I contribute are categorized by the five contextual considerations put forward by Wallace and Scott, but contribute novel research in the following ways. First, Wallace and Scott do not specifically address tangible tabletop applications, which have additional affordances compared with a simple tabletop that may be interactive and/or support touch. My considerations reflect these differences and provide Youtopia examples from my studies specific to TUI-touch tabletop applications. Second, the authors do not specifically address any particular use environment, scenario or content domain throughout their discussion. I focused my contextual investigation and my design considerations on the primary school educational space, a collaborative learning scenario, and an open-ended content domain, which provides design knowledge specific to this overall context.

I present my design considerations in sub-sections 5.2.1 through 5.2.5. Since my design considerations are mapped to the five context categories provided by Wallace and Scott, all design considerations are classified as being associated with one of the following: social and cultural context (5.2.1), activity context (5.2.2), temporal context (5.2.3), environmental context (5.2.4), and motivational context (5.2.5). At least one design consideration is presented in each category sub-section. For each category I provide a definition of the particular context, an overview of how my data supported the category at large and report how many design considerations will be included. I then present each consideration individually – providing a short discussion on the importance of the consideration as it was presented in my data – and present more abstracted sample design questions that can be asked during the design process. I conclude each sub-section by linking my themes to the design considerations presented and discuss the considerations in light of my related literature and Youtopia’s design.

5.2.1. **Think About the Social and Cultural Context**

First, social and cultural context “refers to the factors that impact the social and cultural norms that govern group behavior in a given context” (Wallace & Scott, 2008).
The focus here is on the ‘who’ matters for the design. My results revealed that social-cultural factors play a big role in the success and happiness of primary school aged children engaged in collaborative activities. Though some innate qualities of TUI-tabletop applications support social interaction (e.g. co-location, shared workspace, etc.), they do not necessarily ensure collaboration occurs. Furthermore, institutional culture also plays a role in the requirements and expectations for behavior within the school, classroom, specific learning activities, etc. It is therefore important to consider how design can support or elicit behaviors specific to the needs of the social and cultural community/space. I present three main design considerations associated with the social and cultural context, which are discussed below along with how this consideration manifested itself in my data and sample questions that can be asked during the design process.

1. Think about the relationship between group members and the impact this may have on how they behave or interact.

My results highlight the importance of understanding that children have different social and personality traits to consider and may have social history with their peers that extends beyond assignments or duties within the classroom. The teacher’s pointed out that in the past they had largely underestimated the affect of these social concerns in previous Exhibition years and ended up in some cases with unhappy or dysfunctional groups. The teacher’s pointed out there are myriad considerations for who works well together: introvert vs. extrovert, student self-reflections from the IB ‘basic needs’ circle (e.g. power, freedom, fun, belonging), as well as learner types (e.g. auditory, kinesthetic, visual). While TUI-touch tabletop application researchers and designers cannot control the external factors that dictate social structure in or outside the classroom as a whole, the teacher’s pointed out that TUIs have the potential to mediate different social dynamics and learning styles through system affordances during the course of their use.

- Design Question(s): What types of social problems (e.g. differences in communication style or personality types) working typically exist between students in this classroom and/or particular learning activity? How can the TUI support
reconfiguration or adaptation to address these issues when students are required to work together, especially when conflict or equality is a concern?

2. Think about the institutional culture or goals for group behavior and activities focused on joint meaning making.

The teachers pointed out the importance of flexible deployment strategies that can support children’s different needs for agency, learning styles, and social dynamics in ways that are consistent with the community’s commitment to best pedagogical practices. My results highlighted the importance of thinking of TUIs as mediating both social and learning activity, which are directly linked for content domains and activities intended for collaborative joint activity. My findings point to the need to look beyond the curricula or domain-related learning outcomes to support opportunities for children to practice and reflect on the development social and cultural norms. For instance, the participating IB school has expectations, which focus explicitly on developing social and emotional competencies based on the IB learner profile (e.g. being principled, open minded, caring). The teachers pointed out that its important that adopted technologies provide opportunities for children to practice developing these competencies in ways that fit their community’s values (i.e. IB profile) and rules (e.g. IB assessment rubrics for profile). These competencies form the foundation for interpersonal behavior expectations within the classroom. They are also considered life skills that are important to nurture from a young age (e.g. negotiation, compromise, verbalization of one’s own thoughts and opinions, etc.)

- Design Question(s): What skills of a child’s social development are focused on for the intended age group within the classroom and/or school? Does/can the TUI support opportunities to practice developing these skills? Are there specific social skills/norms within the classroom and/or school that can be ‘exploited’ to aid the curricular learning objectives (e.g. engaging in negotiation and compromise reinforces the learning objective of land use planning as complex social issue that requires tradeoffs)?

3. Think about the group size(s) that are expected for the activity, including how and in what ways these can be accommodated.
The teachers pointed out that being able to support different sized groups is important. My results revealed that students work together often, but not always in the same number. In Study 1, Youtopia was used with pairs of students since the original design was intended for pair interaction. However, in Study 2, where authentic use was planned for Youtopia, groups of four were a necessity for its use as a part of the Exhibition period. Having the ability to support multiple small-group sizes while maintaining the social benefits and interaction styles is something to consider. The physical size of the table and the visibility/shareability of its digital content are also important considerations for changing group sizes since these can impact student’s ability to physically position themselves, view and discuss referential digital artifacts, etc.

- Design Question(s): Does the TUI-touch tabletop application support adaptation for changing group sizes in the collaborative activity? Do different adaptations or deployment cases for different sized groups change the social learning experiences for students? If so, in what ways?

The teachers revealed support for these three design considerations in the following themes: Support Social Development, Support for Institutional Goals, and Support Exploration and Reflection of Learning Concept. Next I provide support for the design considerations by discussing them in light of my related literature and provide exemplification by discussing how they were manifested in Youtopia use and/or design.

TUI-tabletop applications can contribute to the development and mediation children’s differing social behavioral needs and institutional expectations. The tabletop nature of Youtopia allowed multiple students to interact via face-to-face communication where gaze and gesture could aid verbal discussion. Suther’s points out systems that allow for this interaction are able to be embedded in classrooms more easily since the culture of this environment is based on face-to-face or co-located interaction styles (e.g. (Scardamalia & Bereiter, 1991)). But, as Antle et al. (2013) have pointed out, bringing students physically together does not ensure collaborative meaning making occurs. Verbal engagement and joint meaning making were urged through purposeful design decisions. Youtopia was designed with co-dependent inputs and no-winning state in an effort to promote positive interdependence and continued verbal dialogue. These design
choices were intended to combat children engaging in independent parallel play where they may be cooperating, but not continually working together to create and achieve goals. My results revealed that this design decision facilitated team building and prosocial behaviors. As children jointly reflected on and communicated their wishes and values, Youtopia enabled children to practice conflict resolution and negotiation alongside learning about sustainability tradeoffs.

Understanding how different group sizes can be accommodated by the physical and digital configuration of the TUI is important because meaning making occurs in a co-located Joint Problem Space. This is continually (re)shaped by socially negotiating the following: goals; descriptions of the current problem state; awareness of the available problem solving actions; and associations that relate to goals, features of the current problem state, and available actions (Roschelle & Teasley, 1995, p. 70). These can all be impacted by how groups are accommodated using the application. First, in Youtopia the flexibility of physical stamp distribution to accommodate different sized groups (e.g. pairs and groups of four) maintained the benefits of the interdependent interaction model. Since Youtopia acts on actions collectively (e.g. actions from multiple children/tools are required for any goal to be achieved), one child cannot simply act upon independent goals without support of those goals through speech and action of his peers. This supports the type of social processes crucial to collaborative meaning making. Second, understanding the current problem state and possible actions with tangible tabletop applications is gained through the “observational and action periphery” affordance of “exploiting the entire attention field” (van den Hoven et al., 2013, p. 72). Physical table size and shape combined with student age may impact how students are able to assemble around the table and could therefore impact the beneficial affects of this affordance. Additionally, considering how digital content is accessed and shared (e.g. visibility, orientation, etc.) can also impact how easily the information is conveyed to and understand by all users positioned around the tabletop in the group.

5.2.2. **Think About the Activity Context**

Second, the activity context “refers to the type of task or activity in which the group is engaged, and the characteristics of that activity that influence tabletop design”
The focus here is on the ‘what’ – the type of task or activity that the application is for. My data revealed that activity, with a classroom educational focus, is informed by three main characteristics that can have implications for design: the content domain of application/curriculum (e.g. open-ended vs. closed material), the pedagogical approach to ‘instruction’ (e.g. student-led/inquiry focused and collaborative group work), and the pedagogical approach to assessment given the content-domain and instruction approach (e.g. self-guided collaborative work requires specific types of assessment practices). I present one main design considerations associated with the activity context, which is discussed below along with how the consideration manifested itself in my data and sample questions that can be asked during the design process.

1. Think about how the TUI-touch tabletop application supports the way(s) in which the intended type of content domain is pedagogically approached within the classroom and how the design aligns with existing assessment practices.

Both the Exhibition and Youtopia’s content domain was focused on an open-ended topic (e.g. social environmental issues). The teachers revealed that pedagogically the institution is typically focused on inquiry-based approaches to learning. They revealed that this is particularly true for complex open-ended topics that contain heterogeneous points of view (like that in Youtopia). Additionally, the teachers noted that group activities are often used with this type of content-domain to help foster discussion about the topic’s complexity. Youtopia supported these existing practices by eliciting self-directed inquiry through joint activity. The teachers noted that, particularly in joint activity, verbalization is the primary means to ensure both individual meaning making is occurring and that individuals are group contributing to the group. The teachers pointed out that this, in turn, impacts their abilities to provide individual assessments of a child’s progress and provide support in cases where it is needed in real time.

- Design Question(s): How are complex open-ended content domains (like the environment and land use planning) typically taught in the classroom? How can the TUI-touch tabletop application support or add value as a collaborative experience to the overall goals and expectations of teaching the content domain? How can the TUI-touch tabletop application encourage behaviors that support teacher
assessment during the activity (e.g. verbalization of personal values, topic knowledge, etc)?

The teachers revealed support for this design consideration in the following themes: Support for Institutional Goals, Support Exploration and Reflection of Learning Concept, and Support Teacher’s Student Assessment Practices. Next I provide support for the design consideration by discussing it in light of my related literature and provide exemplification by discussing how it was manifested in Youtopia use and/or design.

Suthers’ argues that understanding and supporting collaborative learning requires that we “study the practices (the activity itself)”, which necessitates a deeper investigation into the ways groups make sense of situations and of each other (2006). In an educational setting, how groups make sense of a content domain and each other can be influenced by interplay between the design of teaching materials (e.g. TUI-touch tabletop application) and the pedagogy in place for teaching and assessment. In our case, Youtopia’s content domain is socially/culturally focused where there is not a straightforward or ‘correct’ solution to problems. For example, land use planning (the focus of Youtopia) is an ‘open’ type of content domain where users come together with heterogeneous values about what the world should be like. One of the main goals of both Youtopia and the Exhibition was to engage students in an open exchange of their own values as well as understand that many approaches simultaneously exist in real world environmental and land use management. This goal is pedagogically important in the school and an objective for the content domain itself. But, Youtopia’s interdependent design model was not meant to simply promote conversation for conversation’s sake. This design decision combined with the multi-faceted content domain encouraged face-to-face joint experimentation, negotiation, and compromise between users.

The teacher’s pointed out that encouraging group discussion out loud while also providing some structure to ensure students stayed focus on environmental tradeoffs was important. Youtopia was designed for both by providing a mixture of opportunities for joint goal setting, plan actualization and decision impact reflection. First, the info tool froze interaction and provided information on a specific resource, its role in development and its relationship to the environment. Second, the impact tool froze interaction and
provided a snapshot of how the population’s needs for food, housing and energy were being met and how healthy or polluted the environment was. For collaborative learning purposes, these tools ‘froze’ the whole system so that independent parallel play couldn’t occur through regular resource stamping actions. These ‘freezes’ of activity resulted in verbal discussions about the world state and future plans. Combined with the interdependent model, these ‘freezes’ allowed children to stop and think about their own sustainability values, the effects of the land use actions they’ve taken, etc, but required that students externalize their opinions and thought process. This is consistent with Suther’s argument that its important to recognize meaning “can be jointly created through interaction in addition to being formed by individuals before they are offered to the group” (2006, p. 318). The teacher’s pointed out that this was valuable and also supported the type of assessment practices they wanted to employ. While I’m not arguing that all TUI-touch tabletop applications should have these particular mechanisms, I think they provide a concrete design example of how joint engagement in an activity can be elicited through a TUI-touch tabletop applications’ underlying mechanics and physical affordances.

5.2.3. Think About the Temporal Context

Third, temporal context “refers to how often and how long groups are likely to use the table, as well as how much time pressure groups are under when performing tabletop activities” (Wallace & Scott, 2008). This is concerned with the ‘when’ of the application’s use. In the case of my studies with Youtopia, the teachers did not address time pressure. However, my results revealed that concerns for temporal context were focused on the flexibility available for the length of deployment sessions and how continued use could influence added and/or maintained value. I present two main design considerations associated with the temporal context, which are discussed below along with how the considerations manifested themselves in my data and sample questions that can be asked during the design process.

1. Think about the level of flexibility the TUI-touch tabletop application offers for per use time commitments and how this integrates with the culture and curriculum.
The teachers revealed that time within the classroom is an important commodity. While the teachers wanted to say that everything always ran on schedule, they pointed out that realistically small adjustments need to be made all the time. For the studies, pairs and groups were all given equal times slots to use Youtopia so even a preset or rigid design could have been accommodated. However, it is important to consider flexibility of the time commitment required to engage in the application activity. The ability to have flexible use times can help with the technology’s fit within the classroom.

- **Design Question(s):** What are the primary goals of the application as its positioned in the overall curriculum (e.g. verbally negotiating, understanding aspects of the content-domain, etc.)? Keeping in mind how the application is designed to support these goals, how flexible is the application in terms of meeting those goals under different deployment time limits? Is there a final ‘end’ state that must be reached? If so, what are the consequences to terminating the activity early?

2. Think about how the TUI-touch tabletop application can add and maintain value within the classroom ‘while’ the application activity is happening and once the application activity is ‘over’.

First, the teacher’s pointed out that value is added by ensuring learning materials and tools (particularly technological ones) are not simply stand-alone learning activities. This is an important consideration for ensuring that student reflection (e.g. on social skills, content-domain, etc) and teacher assessment can extend beyond the TUI-touch tabletop application activity itself. The teacher’s pointed out that typically only a portion of children can use a TUI-touch tabletop application at a given time and/or teachers may not be able to accompany whole TUI-touch tabletop application sessions. By designing ways to extend the learning process beyond the TUI use itself, allows teachers to more easily and naturally integrate the system into existing assessment practices and with activities involving other learning materials. Second, the teachers revealed concerns about maintaining added usefulness over time as students become more and more familiar with applications underlying mechanics and myriad ‘game’ trajectories.

- **Design Question(s):** How can the TUI add value beyond the course of its use by supporting student learning and teacher assessment? How can the TUI-touch
tabletop application maintain its value once student’s become familiar with it over time?

The teachers revealed support for these two design considerations in the following themes: Support Social Development, Support for Institutional Goals, Support Exploration and Reflection of Learning Concept, and Support Teachers’ Student Assessment Practices. Next I provide support for the design considerations by discussing them in light of my related literature and provide exemplification by discussing how they were manifested in Youtopia use and/or design.

Youtopia was designed with an open-ended no winning state experience to help foster discussion about personal values on the content domain instead and group created goals about how to achieve the ‘world they wanted to live in’. The application use ends when the students have reached agreement on being satisfied with the world they’ve created or a time limit is imposed on how long the session can last. These design decisions allow for flexibility in the length of time needed for individual use sessions. Additionally, screen shots of a group’s progress can be made at any time during the activity and as frequently as one wants. This feature helps minimize the consequences of sessions that must be terminated earlier than anticipated by saving artifacts that can be revisited at a later time.

My results revealed that providing support through referential artifact creation could allow children to reflect shared meaning while engaged in the activity, as well as extend their experience into regular classroom activities. For example, the world children create together in the Youtopia planning activity changes over time as new land uses are created or removed on the map. Additionally, Youtopia allowed the printing of the artifacts (e.g. maps, etc) that could be shared with others and reflected on long after the activity itself was over. Continued content-domain meaning making can continue to occur and team building social benefits can continue to develop because the jointly created artifacts “become imbued with meanings for the participants by virtue of having been produced through a process of negotiation” (Suthers, 2006). The co-created artifacts and digital simulation are objects through which learners can engage in meaning making (Roschelle, 1996). Youtopia was designed in a way that allowed the
production of these jointly created artifacts could “lead to productive conversation” both during the course of the application activity and after a use session is over (Suthers, 2006). The world that the children created together could be saved, printed, and used to support other learning activities as well as engage in informal conversations with group members and classmates. As pointed out in my results, both the productive conversation created during play and the shareable referential artifacts allowed teachers to use assessment practices that were already part of their classroom culture.

The teacher’s revealed one temporal concern that could present a specific design challenge. While Youtopia was designed to create self-directed discussion and ‘world’ plan trajectories, the teachers wondered whether enough variety and/or complexity would maintain itself over time as students learned how to meet the world’s needs (e.g. reflecting with the Impact tool). Though there is technically no ‘winning’ state built into the activity, it could be argued that over time students would create their own winning states through learning how to achieve the world states that are important to them. The fear is that, if this happened, the benefits of the Youtopia activity itself could be minimized because students would feel less inclined to explore alternatives and/or feel less need engage in in-depth discussions about their values. While a flexible no-winning state approach does not impose a predetermined end state for the ‘world’ and perhaps provides more ‘playability’ than a traditional game, we point to the need to explore additional ways that temporal longevity can be achieved or enhanced.

5.2.4. Think About the Ecological Context

Fourth, the ecological context “refers to the environment in which the table is situated, the table’s role in this environment, and its relationship to other objects and devices in it” (Wallace & Scott, 2008). This is concerned with the ‘where’ of application use. My data revealed that the physical and cultural characteristics of their classroom had implications for design that could impact whether an application was considered to ‘fit’ within the space. I present two main design considerations associated with the ecological context, which are discussed below along with how the considerations manifested themselves in my data and sample questions that can be asked during the design process.
1. Think about how the physical classroom environment where the TUI-touch tabletop application will be deployed can impact its ‘fit’ with regards to the classroom cultural expectations for the activity.

My results revealed a concern that the physical spaces of the classroom could impact regular assessment and scaffolding practices. While more than one tabletop was offered to the teachers for use during the Exhibition, they declined because the physical space required to store two tabletops over an extended period of time was not a possibility. The teachers noted that they had to house Youtopia in a separate room from the main classroom area where their desks and the children’s regular tables are positioned. They said that while this room is directly connected to their main classroom and it is regularly used for side activities and/or group work – they had several concerns about using the space for group work with a (novel) technology. Because only a single Exhibition group could work at any one time on the tabletop they had to split students between the main classroom and the Youtopia room. This, of course, meant that they could not be in both places at one time so had to make a point to ‘pop’ into the Youtopia room every few minutes leaving the rest of the class working at their desks. They said this could impact their ability to assess group work (e.g. students were out of ear and eye shot if the teacher was not physically present) and supply scaffolding for learning if necessary (e.g. help answer questions, pose questions to the group, etc.). Overall, the teachers revealed the importance of considering how the physical environment itself could play a role in a TUI-touch tabletop applications design and therefore its fit within that space both physically and culturally.

- **Design Question(s):** How many students are in the class and will be working at a single TUI-touch tabletop application at a given time? Where will the TUIs be stored and/or used by these students? Does the physical space allow for more than one application be used/stored at the same time? Is it in ear and eye shot of the rest of the students and/or the teacher at all times or separated?

2. Think about how the TUI-touch tabletop application is expected to integrate with other objects, materials and/or practices within the intended classroom deployment environment.
As discussed in the Temporal Context section designing ways to extend the learning process beyond the TUI use itself not only expands student reflection opportunities, but also provides more opportunities for the teachers to assess learning outcomes. This ability to extend Youtopia beyond its actual use also allows teachers to more easily and naturally integrate the system into existing practices and with other learning materials. It was emphasized that the deployment environment’s (e.g. school and classroom) culture emphasized the use of tools and topics that add value over time and/or across curriculum. Part of why this is important is because student assessment was not simply done on a strict ‘assignment’ or ‘test’ basis – rather on growth over time on overarching metrics. As such, Youtopia was one of many materials for learning and discovery over the multi-month Exhibition period. The teachers revealed that they have very little use or interest in using technology simply for ‘technology’s sake’, but that it must add value in some way to the learning experience. In the case of Youtopia, the teachers emphasized that one of the major benefits was that it provided a new and different way to think about, explore and experiment with the complexities of environmental planning compared to any other materials (e.g. books, Internet research, videos, etc.) used for the Exhibition.

Design Question(s): Can the TUI-touch tabletop application be used as a stand-alone activity and also provide ways to be integrated with other learning activities or materials? In what ways can the application add value by providing new or different ways to explore the learning material(s) (e.g. hands on engagement, experimentation, etc.)? In what ways can the application add value by providing new or different ways to learn or practice socially and/or culturally important behaviors associated with the activity goals (e.g. understand complexity of content domain through negotiation, etc.)?

The teachers revealed support for these two design considerations in the following themes: Support Social Development, Support for Institutional Goals, Support Exploration and Reflection of Learning Concept, and Support Teachers’ Student Assessment Practices. Next I provide support for the design considerations by discussing them in light of my related literature and provide exemplification by discussing how they were manifested in Youtopia use and/or design.
My results revealed how the intended deployment environment’s physical learning spaces can be potentially problematic for a TUI-tabletop application’s ‘fit’ based on existing assessment and activity scaffolding practices. This concern is consistent with Keppell and Riddle’s (2013) emphasis on considering the design and evaluation of learning spaces. Though their work focused on the design of the learning space itself and my research did not have this goal, it is important to understand how a new technology application can integrate into an existing learning space (e.g. physically, socially, etc). Considering how the TUI-touch tabletop application design (e.g. size, number to be used, electricity/connectivity requirements, etc.) interacts with the physical environment and pedagogical culture can have a potentially huge impact on whether the application is considered usable and useful within the intended context. Particularly, the concerns noted in my data reveal how some of the often talked about benefits afforded by TUI-touch tabletop applications for educational contexts can be negated or minimized by the constraints imposed by the physical space of deployment.

For example, a benefit of tangible systems is that they offer (peripheral) visibility. While this is still a benefit for the users themselves working together at a TUI-touch tabletop application, the benefits of visibility for teacher facilitation and assessment are impacted by the degree to which the physical environment impairs this affordance. In the case of my studies, the teacher’s visibility of the ‘what’ (e.g. listening to students’ discussions, etc.) and ‘how’ (e.g. seeing physical actions taken, how children are working together, etc.) children learn was greatly reduced by physical constraints of the classroom environment itself. Youtopia was designed with the assumption that a teacher would be (continuously) physically available to provide scaffolding and assessment as well as ensuring that students generally stayed on task. However, the deployment space did not actually provide for this opportunity in a real-usage context (Study 2).

Perhaps one way to help overcome the physical environmental constraints that impact teacher facilitation while maintaining the benefits for student users, is to consider the design of an application’s connectedness to other devices or materials already existing within the environment. For example, one could envision a hybrid approach where the teacher could have a mobile way to at least check in on progress being made without physically going into the other room (e.g. a mobile or desktop app explicitly to aid
facilitation on the teacher’s end where the current map and world state can be accessed in real-time).

Additionally, some might argue that it would be ideal for all groups to be working on their own TUI-touch tabletop applications at the same time as a way overcome some of these issues. Setting the cost counter argument aside, the physical constraints at the school used in my studies negated this optimistic view of a multi-TUI deployment (e.g. there is literally not the physical space to store and use the amount of tabletops necessary to accommodate all groups at a given time). While these ‘physical’ constraints were voiced as a concern, it’s not totally clear that having a separate space for such an application is always a bad thing. For example, physical separation might have an unexpected benefit of helping children feel a sense of agency in their own educational goals and choices. In the participating school – particularly in the Exhibition – children are encouraged to work as groups in self-guided inquiry. It is essentially up to them to decide on a sustainability topic, the learning materials to use and to some degree set their own learning goals based on their own ‘research’. Having Youtopia as an independent activity in a separate room could align with the goal of promoting students’ agency in their own learning. Exhibition groups had to sign up for their own time slots to use Youtopia and guide their own goals while playing. A ‘top down’ model of deployment where everyone uses their own table at the same time and is constantly watched by a ‘facilitating’ adult seems to come in conflict with some of these other benefits.

While physical space could have the potential to impair teacher ‘visibility’, there seems to be a ‘trade off’ in terms of what is considered the ‘ideal’ deployment. Issues of visibility could be overcome by considering connectedness. As pointed out, connectedness would not only allow teachers to ‘keep an eye’ on students, but would allow them to gain the potential benefits of fostering and supporting agency in the learning experience. Additionally, other design decisions made for Youtopia allowed the teachers to add value by extending the experience beyond time at the tabletop itself. Since teachers could not be physically present at the tabletop at all times, they noted that having the ability to save and print referential artifacts (e.g. maps, etc.) provided the opportunity to integrate these materials into other classroom/Exhibition activities.
Additionally, the teachers pointed out that another way to add value in the classroom was to integrate tools or materials that added value to the way in which a particular curriculum or content-domain was taught. The teachers stated that Youtopia allowed for hands-on, consequence free exploration and experimentation of the tradeoffs necessary in environmental and land use planning – an experience that other learning materials couldn’t offer. They also pointed out that the way Youtopia elicited the articulation of individuals value and opinions on the content-domain was also a major benefit because it provided another way to students reflect on issues at both a micro (e.g. this is what happens when we do this in the ‘game’ – the amount of trees and how they’re used has an effect on housing and pollution) and macro level (e.g. how I want to manage resources in the ‘game’ is a reflection of my real-life, real-world values on meeting both human and environmental needs). Youtopia was purposefully designed (e.g. co-dependent access points, interdependent interaction model, open ended social content domain) to encourage these behaviors.

5.2.5. Think About the Motivational Context

Lastly, the motivational context “refers to the personal and professional goals that motivate the activity(ies) for which the table is used, including the group’s motivation for using the table rather than alternative computing devices” (Wallace & Scott, 2008). This is concerned with the ‘why’ of choosing a TUI-touch tabletop application. My data revealed that the motivations for a choice of tangible tabletop applications over types of types of devices was related to the physical tool impact on social behavior, hands-on interaction benefit for learning, and the design decisions for increasing activity engagement. I present one main design consideration associated with the motivational context, which is discussed below along with how the consideration manifested itself in my data and sample questions that can be asked during the design process.

1. Think about how the TUI-touch tabletop application can add value to the collaborative learning activity and/or social experience by providing opportunities not supported by existing tools, materials and/or methods.
Throughout other themes I’ve discussed the ways in which the Youtopia experience was said to have beneficial attributes – essentially, how Youtopia can be integrated with the existing classroom culture, institutional objectives, physical environment, etc. But, when thinking directly about the motivation a *choice* of technology, my results point to need for *added* value. The teachers made a point to emphasize that, particularly for technology-based tools or materials, added value was a top consideration for whether it could be argued as *necessary* within the classroom. My results revealed that the *tangibility* aspect itself offered some benefits and opportunities that other existing tools or materials did not seem to provide. First, the teachers pointed to out that Youtopia provided a unique hands-on way to explore the content domain by allowing the students to explore and ‘learn by doing’ in a consequence free way. Second, the teachers said that this ‘learning by doing’ group experience is great so long as students work well together and stay on topic. The teachers revealed that having physical tools that could be distributed to act as mediator and moderator between different personality types directly helped ensure this goal was realized. Lastly, the teachers pointed out that though they wouldn’t adopt a technology *only* because it created more engagement, they pointed out that specific characteristics of Youtopia provided an experience that motivated students to come together and learn.

- **Design Question(s):** In what ways can the tangible tabletop affordances provide opportunities that existing materials do not? Or to put it another way, what are common problems or pitfalls in teaching the intended skills and/or content domain can be addressed by capitalizing on characteristics of tangibility and co-location?

  The teachers revealed support for these two design considerations in the following themes: Support Social Development and Support for Institutional Goals. Next I provide support for the design consideration by discussing it in light of my related literature and provide exemplification by discussing how it was manifested in Youtopia use and/or design.

  My results revealed that for the content domain of the Exhibition no other materials or methods existed that allowed for hands-on exploration and experimentation. Youtopia directly provided this experience in a *consequence free* way – which the
teachers pointed out as being particularly important because real-world sustainability issues were the focus. Essentially, children could feel like they were physically engaged in real-world practices (although simplified) without actually ‘damaging’ real-world or needing to leave the classroom. This is consistent with the idea that TUIs have the potential to be useful in simulating complex tasks or real-world scenarios that allow for “small group interactions, opportunities to contribute, [and] peer review,” as well as providing “access to data about how others have thought about the same problem” (Barron et al., 1998).

My results revealed that while engaging small groups in joint activity is promoted in the school and supported by the co-located nature of Youtopia’s tabletop design, simply assigning children to groups does not ensure on-task and harmonious collaboration. The teachers pointed out that Youtopia’s physical tools (stamps) could be distributed to act as mediator and moderator between different personality types, which directly helped ensure this goal was realized. By tapping into existing social and cultural expectations about space and object sharing, Youtopia’s interdependent interaction model combined with the content domain acted together to keep the groups on-topic and working together towards goals. The stamps could be distributed to assign roles to students and this physical assignment of artifacts is reinforced by social norms concerning ‘property rights’ – essentially I won’t grab for ‘your’ stamp because it was assigned to you and its within close proximity of your body. Additionally, this assignment of physical tool is tied to a role within the interaction model of Youtopia, which was designed to ensure that users couldn’t achieve plans alone. This means that while children may have a set of their ‘own’ tools or inputs, the system acts on actions collectively so that actions from multiple children/tools are required for any goal to be achieved. One child cannot simply act upon independent goals without support of those goals through speech and action of his peers. These affordances provided by Youtopia’s tangible objects helped ensure on-topic, groups-focused learning.

Additionally, the teachers pointed out that the combination of physical stamps and table size added to student engagement with the material by peaking the children’s initial curiosity and sustaining their excitement to ‘keep at it’. It was said that this was one of the major benefits of the TUI-tabletop system over other technology choices (e.g.
smaller tablets or computers) and interaction styles (e.g. mouse, keyboard, only touch with drag and drop). While the teachers admitted that engagement wouldn’t be the only reasons for supporting a TUI over other tools or materials, it can go a long way motivating and sustaining an activity.

In the next section I present the limitations to my research as well and concluded the chapter with a discussion of directions for future research.

5.3. Limitations and Future Work

In this section I discuss the four main limitations to my research, which include: school and student type, sample sizes, data collection and analysis techniques, and personal biases. I conclude this section with a discussion of future areas of research.

1. Limitation: School and Student Type – One limitation to the work is that the school I worked with fosters many group activities where children are practiced in working quite optimally together. Students were paired (Study 1) and grouped (Study 2) primarily on the basis of which students tend to work well together. Since Youtopia was designed partially to explore collaborative learning about sustainability this sample of children and how they were grouped may not have provided the most generalizable findings about how to best design for collaborative work issues like conflict mediation. Despite this, as my teacher’s revealed, even finding optimal groupings within their group of students was a difficult task that didn’t always work out as they had hoped. Additionally, it does not seem like much of a stretch to say that it’s regular practice in most schools to employ ‘happiness’ or ‘keeping the peace’ strategies when assigning students to group work or creating seating arrangements. Ideally, continued research in TUI-touch tabletop applications for collaborative learning can further examine classrooms with different pedagogical practices and student demographics to shed more light on the types of concerns that could impact design.
2. **Limitation: Sample Sizes** – One limitation to the work is that the sample size is quite small, especially in Study 1 where teacher observations were limited to only two pairs of students. This was constrained in large part due to the nature of the classroom environment and context of study. The teachers busy schedules as well as not interfering with regular and required practices had a big impact on when Study 1 could be conducted as well as who was able to participate. Study 2 did include all students at the school within the age group Youtopia was designed for, which consisted of the entire set of 5th grade students. Also only two teachers were interviewed for their opinion on the observations in both studies. One could argue that more teacher observations and interviews would make the case stronger for the generalizability of the design considerations, but the most qualified teachers for the assessment of the student sample was used (both 5th grade teachers at the school participated). I also argue, from my phenomenologically-situated inquiry, that “describing identified factors and conditions is a crucial contribution,” despite “context [not being] widely accepted as a centrally important notion” (Harrison et al., 2007, p. 5). This research (both studies) was positioned as exploratory research intended to map out the contextual design space for TUI-tabletop applications in classroom education. As such, the hope is that future research can be continued to build upon the themes and/or considerations presented in this thesis.

3. **Limitation: Data Collection and Analysis Techniques** – While I triangulated data from multiple perspectives and deployment scenarios, it could be argued that ideally qualitative inquiry also triangulates on multiple forms of data to arrive at the most robust results and interpretations (e.g. interviews and researcher observation, etc). I chose only to focus on the teacher perspectives from interviews because the choice of technology ‘fit’ and ‘use’ within a classroom is in large part influenced by their interpretation of usefulness. While personally observing and recording all student sessions could have added to the validity of results by providing another source to draw upon for rich descriptions, my literature review revealed teacher perspectives on technology were primary barriers to use, integration, etc.
Validity was maintained by taking steps to ensure accuracy (e.g. recordings, transcripts done myself, etc), but could have been improved by using member checking “taking the final report or specific descriptions or themes back to participants” to determine whether they confirm their accuracy (Creswell, 2009, p. 191). Admittedly Study 2 concluded at a time where teacher availability to do member checking was not something they could fit into their schedules. Measures to help ensure reliability were taken, such as checking “transcripts to make sure that they do not contain obvious mistakes made during transcription” (Creswell, 2009, p. 190). But, other traditional procedures could have potentially been taken to help ensure stronger reliability (e.g. use of multiple researchers to ‘theme’ the data, etc.).

4. **Limitation: Personal Biases** – Though many procedures were followed to help ensure reliability and validity during data collection and analysis, it must be noted that I was involved with the usability testing and other research studies involving Youtopia at the participating school. As such the teachers at the participating school already had an interest in using Youtopia when they were approached about their participation in Study 1 and 2. While qualitative research often involves close interaction with the community of inquiry, it could have had an unintentional influence on how the teachers revealed the benefits and challenges of using the technology. Additionally, one of the lead researchers on the Youtopia project has children that attend the school. These issues in combination with the overall novelty of Youtopia could have led to overly positive responses in the interviews. The biases were considered in advance and the interviews were prefaced with statements urging the teachers to please reveal their true feelings even if they were negative because problems they experienced were equally important to my research and the overall understanding of these systems in real classrooms. Again, this work is positioned as exploratory in nature and the hope is that continued research in more classroom deployments will both distil and expand on the themes and considerations in this thesis. Furthermore, once could argue that my direct involvement with Youtopia usability testing and previous research studies at the school could have biased what I was looking
for (data collection) and how I interpreted what I found (data analysis). Since I was aware of this potential conflict, reliability and validity measures were taken to help ensure unbiased research was conducted. For example, the Activity Checklist provided structure and guidance to the focus of the interview inquiry – ensuring that questions didn’t simply ask for reflection on affects that I wanted to hear about. Additionally, audio/video recording my interviews and conducting analysis from full transcriptions helped ensure that analysis and interpretation were directly derived from what the teachers themselves actually revealed in the interviews.

5. Limitation: System Novelty – As briefly discussed in the previous limitation, one could argue that the pure novelty of Youtopia could have led to overly positive feedback from the teachers. However, the teachers – particularly by Study 2 – were quite familiar with the system through using it in my Study 1, but also with a previous study done at the school prior to my research. Additionally, one could argue that the system novelty could have the largest impact on the children playing the system and – by proxy – play a role in what the teachers observed and how they interpreted opportunities, benefits and challenges. With this in mind, I found that the teachers themselves were quite aware of this potential affect. For example, discussed a potential challenge of ensuring that complexity and continued (beneficial) use over time once children became more and more familiar with Youtopia’s mechanics and content. They pointed out that Youtopia suited many goals well (e.g. learning tradeoffs through encouraged open-ended dialogue, excitement to engage with the learning material, etc.) during their study, but that they had some concerns about lasting or continued impact once novelty no longer factored into the experience. The real affects of novelty need further investigation.

I would also like to put forward some food for thought for further the inquiry into collaborative learning and educational contextual concerns.

First, in an effort to refine and expand on the themes and considerations presented in this thesis it is my hope that future research seeks to investigate
classrooms with different teaching styles (e.g. outside of inquiry-based approaches). It will be important to explore whether these types of contextual changes impact teacher’s perspectives on the usefulness or ‘fit’ of these systems in their practices. Refinement will allow us to have better design knowledge based on the pedagogical view and student demographic of the intended deployment environment. Expansion of these considerations can provide us with a broader and/or more generalizable view of TUI-tabletop application design for a wider variety of educational deployment scenarios. This type of investigation would be concerned with how changes in teaching philosophy and pedagogy create changes in the community’s values, types or styles of learning activities, etc. The job then would be to analyze how these nuances could have effects on design and perceived ‘fit’ within these varied contexts.

Second, student demographics may play a large role in what is consider important for a TUI-tabletop design ‘fit’. Changes in student age, gender, the societal culture in which the learning environment is couched, etc. can all have an impact on the types of goals that are important within a particular classroom, what types of approaches are taken to teaching and how children interact with each other. Gaining a better understanding of deployments across a wider demographic of children users will help us expand on the themes and considerations important for educational TUI-tabletop design.

Lastly, I would like to point out that my exploratory inquiry was focused solely on teacher interviews about what usefulness and ‘fit’ meant to them after student observations and a single real world deployment scenario. While I provided reasons for this singular focus, based in existing literature, I would like to see continued research refining and expanding the knowledge I present based on investigations of different stakeholder perspectives within the educational community. Additionally, many calls to action within the TUIs-for-learning research community encourage continued development of methods for inquiry focused on creating design knowledge. One of the goals of my own research was to explore and expand upon this by introducing The Activity Checklist as a theoretically based tool to help structure interview inquiry methods. However, as others before me have pointed out, there is still a necessity to continue expanding upon the methodological ‘tool belt’ within this research community.
In the next and last chapter, I provide the conclusion to this thesis. In the conclusion I provide a general overview of my position as a researcher as well as provide a summary of my overarching research question and the goals of my inquiry. The chapter is concluded with a brief summary of the themes derived from my teacher interviews in addition to the five areas of focus for the design considerations.
Chapter 6. Conclusion

Like others within the community, I point to the need to understand contextual factors more fully in addition to investigating the tools and theories to do so. As a pragmatist, I argue designing and evaluating tangible user interfaces for education necessitates a closer look into the contexts within which they are embedded. This brings to light the need to think about the design of technologies for learning with “considerations of the community, the rules, and the divisions of labor in which the technology will be placed” (Bellamy, 1996, p. 127).

I conducted a comparative exploration, which was completed in two studies over the course of two years to explore “What design-oriented opportunities, benefits, challenges and/or discrepancies do teachers identify when considering the integration of a collaborative learning TUI-touch tabletop application within a primary school classroom environment?” My overarching research question was explored in both studies through structured interviews with two teachers. The goals of the studies were aimed at comparing predictions of use with actual classroom integration in an effort to better understand, from a teacher’s perspective, contextual factors that may impact design and evaluation.

The results that I presented in this thesis are a culmination of bringing the data from both studies together to form a more full understanding of the problem space. I also introduced The Activity Checklist (Kaptelinin et al., 1999) as a tool to guide existing qualitative interview methods for investigating ‘real world’ deployments. I contributed both analytic themes and design considerations for TUI tabletops for collaborative learning in primary educational classrooms. The themes, presented in Section 4.2, outline the four areas the teacher’s noted as most important to them in considering a TUI-tabletop application for use in their classroom, which include: Support Social Development, Support for Institutional Goals, Support Exploration and Reflection of
Learning Concept, and Support Teachers’ Student Assessment Practices. In Section 5.2, I presented multiple design considerations categorized by Wallace and Scott’s (2008) five contextual design considerations for co-located collaborative tabletops. I used their overarching contextual concerns as a framework for organizing my own considerations and design questions into the following categories: social and cultural context (e.g. who), activity context (e.g. what), temporal context (e.g. when), environmental context (e.g. where), and motivational context (e.g. why). Though Wallace and Scott’s contextual concerns and definitions provided me with guidance for organizing and creating my own considerations and design questions, my research contributes novel design knowledge in two ways. First, Wallace and Scott do not specifically address tangible tabletop applications, which have additional affordances compared with a simple tabletop that may be interactive and/or support touch. My considerations reflected these differences and provided Youtopia examples from my studies specific to TUI-touch tabletop applications. Second, the authors do not specifically address any particular use environment, scenario or content domain throughout their discussion. I focused my contextual investigation and my design considerations on the primary school educational space, a collaborative learning scenario, and an open-ended content domain, which provided design knowledge specific to this overall context.

Lastly, I presented the limitations of my research and the areas that I see most important and useful moving forward in this research community. Particularly, I hope my research opens the door for continued inquiry into the design educationally embedded TUI-touch tabletop applications intended for collaborative learning as well as an expansion of tools and methods for such investigations.
References


99


### Appendix A. Checklist Category, Checklist Questions and Adapted Interview Questions

<table>
<thead>
<tr>
<th>AT Checklist Category</th>
<th>AT Checklist Question</th>
<th>Adapted Interview Question</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Means/Ends</strong></td>
<td>Are all target actions actually supported?</td>
<td>How do you see Youtopia fitting into the overall sustainability curriculum? Do you think it supports all of the learning goals?</td>
</tr>
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<td></td>
<td>Are there conflicts between different goals of the user? If yes, what are the current trade-offs and rules or procedures for resolving the conflicts?</td>
<td>What conflicts or tradeoffs do you envision if any for students learning with Youtopia in the classroom?</td>
</tr>
<tr>
<td><strong>Environment</strong></td>
<td>Are computer resources necessary to produce a certain outcome integrated with each other?</td>
<td>In your opinion, can a computer resource like Youtopia be seen as necessary or integral with the learning goals or outcomes that you have for your class?</td>
</tr>
<tr>
<td></td>
<td>Is target technology integrated with other tools and materials?</td>
<td>In your view can a system like Youtopia be integrated with other learning resources and materials in your classroom, including non-computer resources and materials?</td>
</tr>
<tr>
<td></td>
<td>Are characteristics of target technology consistent with the nature of the environment (e.g. central office work vs. teleworking)?</td>
<td>Do you see Youtopia as being consistent with the nature of learning that typically happens in your classroom at this school?</td>
</tr>
<tr>
<td>Learning/Cognition/Articulation</td>
<td>Is the whole 'action lifecycle,' from goal setting to the final outcome, taken into account and/or supported?</td>
<td>In your view does Youtopia take into account the whole cycle of learning as you understand it?</td>
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<td>---------------------------------</td>
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<td></td>
<td>Is externally distributed knowledge easily accessible when necessary?</td>
<td>Can a system like Youtopia help externalize knowledge or information as part of the learning process, and if so, do you think that externalizing knowledge or information can help students work together when they're coordinating activities on the tabletop?</td>
</tr>
<tr>
<td></td>
<td>Are there external representations of the user's activities that can be used by others as clues for coordinating their activities with the framework of the group or organization?</td>
<td></td>
</tr>
<tr>
<td>Development</td>
<td>What are the consequences of implementing the target technology on target actions? Did expected benefits actually take place?</td>
<td>In your view, what do you see as the benefits and consequences of trying to bring Youtopia into the classroom? And are these different than what you might normally expect with other computer technologies?</td>
</tr>
<tr>
<td></td>
<td>Did the system show increasing or decreasing benefits over the process of its use?</td>
<td>In your opinion, does Youtopia show increasing or decreasing benefits over the process of its use?</td>
</tr>
</tbody>
</table>