Examining Tools and Talk With Youtopia: Using Discourse Analysis to Reveal Design Opportunities for Supporting Collaboration With Tangibles

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Abstract

This study analyzes learners' use of speech and tools with a tangible tabletop system, with the goal to understand how learners used the system's tools to support their interactions as a way to inform future design. Six salient combinations of speech and tool use were found: 1. exploring the activity, 2. proposing plans, 3. advocating for a position, 4. hypothesis testing, 5. working cohesively, and 6. controlling decisions.

The findings contribute new understandings about how learners negotiate meaning-making by reflecting together on why they should make key decisions and develop next steps, and using information and tangibles to: develop verbal reasoning, regulate behaviours, support team needs, resolve conflict, and encourage buy-in before acting. As recommendations for design, TUIs which aim to facilitate negotiation should support: the pausing of the activity to engage in discussions, have multi-step actions or interdependent tangibles to support planning, provide low-risk/shared spaces to support deeper understanding of concepts/relationships, and should consider the implications of how tools will be used to influence power struggles and accountabilities in the activities.

Keywords: Collaborative learning; shared meaning-making; TUIs; tabletops; discourse analysis; speech acts

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Chapter 1.

Introduction

1.1. Overview

This research examines the relationship between learners' use of speech and tangibles in their collaborative learning experiences, utilizing a Tangible User Interface (TUI) called Youtopia. Youtopia is a land-planning activity that allows two children to learn about sustainability and resource use in a face-to-face environment through the exploration of tangibles and dialogue within a digital world. This research is grounded in the view that learning is socially constructed, and can be enhanced through dialogue as learners engage together in simulated learning environments. Given the complex problem of collaboratively creating a sustainable world, this study examines how speech and tangibles were used together to support the learning process as learners; verbalized, tested and defended ideas, shared meaning-making experiences, acted on their understandings, assessed their progress, made improvements and worked towards goals with guidance and feedback from the system. The main purpose of this study is to better understand the relationship between how learners use speech and tangibles to support their interactions in order to design computing tools which support group interactions for collaborative TUI systems.

Kreijns, Kirschner and Jochems (2003) describe that collaboration is reliant on social interaction and an ill-defined task for learners to solve (p.338). Key aspects of collaborative learning environments are the opportunities to engage in "social, off-task communication (e.g. casual communication)" and to "facilitate and increase the number of impromptu encounters in task and non-task contexts through the inclusion of persistent presence and awareness through time and space of the other members of the distributed learning group." (Kreijns et al., 2003, p.349). These encounters encourage

learners to make sense of their problem space together through “describing, explaining, predicting, arguing, critiquing, evaluating, explicating and defining” (Kreijns et al., 2003, p.338) using any means the learners have.

Although there is a lot of research that TUI environments can support aspects of collaboration (Dillenbourg & Evans, 2011; Zaman, Abeele, Markopoulos & Marshall, 2011), there is not a lot of information about how the physical tools play a role in supporting speech and the internalization and externalization of learner’s understandings in their processes together. There is some over expectation that learning naturally occurs in a tabletop learning environment (Dillenbourg, 1999, p.492), however design can be difficult as there are not many findings on the qualities that make these environments with tangibles successful. According to Dillenbourg (1999), the best goal with these systems is to find ways to improve the likelihood that beneficial types of collaborative interaction will actually happen (p.5). The research problem in this study is that more understanding is needed about how TUIs can support collaborative learning processes. By exploring how learners engage in meaning-making through speech and with the use of tangibles, readers will have a better understanding of what features of tangibles can be used support different types of goals and interactions.

This introductory section aims to provide some background on collaborative learning and shared meaning-making, followed by information on how mediating technology can support collaboration. This section also provides an overview on TUI technology, as well as its potential for supporting discussion and knowledge-building processes. This section concludes by providing information and examples about what we know about collaboration, dialogue and tabletop technology, as well as what is still to be discovered about how tabletop systems can support dialogue and negotiation.

1.2. The Role of Collaboration in Supporting Learning

Collaborative educational experiences can provide powerful ways for students to learn because as they participate in the process of explaining and negotiating ideas, they are able to engage in co-constructed learning experiences which teach them reasoning and decision-making skills. Vygotsky (1978) described that knowledge is relational to the social context in which it is being negotiated, and is shared between learners as they use cultural tools (including language) to articulate their understandings. In discussions about cultural tools, he also presented that children had roles in "forming an understanding of their cultural contexts, and express(ing) themselves and solv(ing) practical tasks with their eyes and hands in order to internalize experiences into information" (Vygotsky, 1978, p.26). By using tools (including speech), children direct their attention to the same things, develop a shared vocabulary, and help to control the actions of themselves, and their peers (Vygotsky, 1978). This aids learners' communication in developing shared understanding and plans together. Within the field of social constructivism, there are different approaches to how scholars view learning and knowledge and how this affects perspectives about technology's role. This research takes Vygotsky's perspective of meaning-making, in that it happens across learners' engagements and with the use of tools (in this case Youtopia's tangibles) and speech to help learners to share information and engage in meaning-making. More information about this will be described in the *Chapter 2: Literature Review.*

Shared meaning-making is an important part of the collaborative process and involves using language and interactions to form common understandings and experiences by a group of people over a period of time (Stahl, 2006). According to Bachour et al. (2010), "higher leaning gains" with TUIs are related to "elaborated explanation," and meaning-making opportunities including: "argumentation," "mutual regulation," "conflict resolution," "seeking and providing help" and learner awareness of progress and participation (p. 203). This study views collaboration as a process that uses language and tangibles to support learners' ability to share meaning as they discuss possibilities and work together. These types of learning experiences can be deliberately designed for and by better understanding how this happens, learners can be more supported in their knowledge processes as they use and talk with the tangibles.

1.3. Mediating Social Learning Environments With Technology

Theories of social constructivism are highly influential in the development of Computer-Supported Collaborative Learning (CSCL) environments and the relationship that learning has with its afforded technology. Stahl, Koschmann and Suthers (2006) described that CSCL is “carried out in the social world rather than in individuals’ heads” (p.9). This highlights the relationship between learning as part of a social activity which includes use of the technological tools provided. The use of roles, perspective sharing, negotiating rules and pedagogical support (or scaffolding) have been explored deeply within the CSCL field, and tools can be seen as mediums which are used to help communicate about concepts with peers (Stahl et al., 2006, p.6). In particular, the uses of scripts or prompts for communication have also helped learners to mediate interactions in their learning environments. For example, in the study of Battocchi et al. (2010), learners with Autism Spectrum Disorder were provided with scripting to support social engagement with other learners to ensure the topics of specific learning goals were discussed. In a different study with technology, Chan (2012) also found that shared learning environments mediated by technology can: enhance teamwork and communication skills, improve opportunities for joint problem-solving, co-regulated learning, and develop shared visual representations of understanding. Mediating technologies can also support reflection of actions and opportunities for improved practice while also promoting frequent communication. For example, Phielix, Prins and Kirschner (2009) introduced a reflection tool into their designs for learners to monitor participation and group progress, and found that teams reported improved team communication, lower conflict levels, and more positive attitudes towards collaborative problem-solving as the learners became more aware and accountable for their actions.

Speech is worth examining because of the possibility to explore both the literal and implied meaning as representations of the learning process (Vygotsky, 1978). Johnstone (2008) noted that through study of discourse, it becomes clear “how speakers indicate their semantic intentions and how hearers interpret what they hear, and on the cognitive abilities that underlie human symbol use” (p.6). Vygotsky’s approach to learning fits with this perspective because of the important approach to understanding

shared knowledge processes through the internalization of speech as well as examining the use of other mediating tools support these processes. Building on Vygotsky, Woolfolk-Hoy, (2005) described that “problem-solving or memory strategies” could be supported through “physical tools such as pencils or paint brushes directed toward the external world” (p.45), because as learners use tools, they integrate their understanding of their interactions to modify how they interact together. In this shaping of environment, they “transform the tools as they construct their own representations, symbols, patterns, and understandings (Woolfolk-Hoy, 2005, p.45). In general, technology can support group talk in various ways; some characteristics can include tools that make learners more aware of their contributions and support accountability to their partners (Phielix et al., 2009), help learners explain their thinking (Stock et al., 2009), and promote more opportunities for verbalized reflection (Kharrufa, Leat & Olivier, 2010).

1.4. About Tangible User Interfaces (TUIs) and Tabletop Technologies

Tabletop technologies and tangibles hold exciting opportunities to support collaborative processes. A TUI tabletop system consists of a visual display surface that can interact with digitally augmented physical objects (tangibles) (Ishii & Ullmer, 1997) which can have representation and/or act as controls to “allo(w) users of computer systems to interact with digital content through the manipulation of physical objects” (Schneider, Jermann, Zufferey & Dillenbourg, 2011, p.222). This technology permits learners to engage face to face while working with tangibles on a digital tabletop. This setup can facilitate the use of shared external representations which can serve as reference points in natural conversation (Zhang & Norman, 1994). While this study explores the use of tangibles as part of a tabletop system that function as tools, it is important to note that tangibles can also exist as self-contained objects, where the digital augmentation is independent of other devices.

Advancements in educational research and HCI have improved the usability, functionality and tracking of physical artefacts which can interact with attractive digital game surfaces. Some examples of opportunities for learning include: increased play and exploration (via indications of a wider range of solutions explored and better task

performance with a broader range of solutions attempted (Schneider et al., 2011; Do-Lehn, Jermmann, Cuendet, Zufferey & Dillenbourg, 2010), enhanced brainstorming (Hunter & Maes, 2008), delayed responsive action and providing moments for learners to reflect on decisions (Price et al., 2010). The next section discusses in more detail about the exciting opportunities for TUIs to support collaborative learning processes.

1.5. Potential for TUIs to Support Collaborative Processes

Tabletop technologies can provide exploratory learning experiences where learners can engage with problem-based activities, experience real time feedback, and initiate specific discussions and negotiations. This promotes interesting possibilities for dynamic learning experiences through conflict and resolution. According to Xie's (2008) graphical and TUI comparison of jigsaw puzzles with school-aged children, learner motivation can be enhanced by the "direct physical manipulation" of tangibles and support face-to-face collaboration, and can support fun and novel experiences and more "playful learning tasks for children than desktop environments" (p.1). Researchers have also found that team member awareness with TUIs can also influence collaborative and co-dependent behaviour and can potentially delay responsive behaviour and encourage discussion before acting (such as Price et al., 2010). Another benefit according to Price et al. (2010) has to do with the shared display, responsiveness of the systems and coordinated awareness of learner actions: "Co-located designs seem to lead to a more straightforward interaction, allowing learners to keep their attention simultaneously focused on what they are doing and what the system is showing in response" (p.151).

Technologies which provide real time feedback can be used to initiate specific types of discussion and spark impromptu arguments and discussions of complex topics (Zancanaro et al., 2012). TUIs can also be designed to encourage learners to negotiate ideas through co-dependent access points (Antle & Wise, 2013) and engage in "enforced collaboration" or co-dependent tasks (Battocchi et al., 2010). Kafai (2006) claimed that designing technology for learning requires consideration for learners' 'fluency' (knowing how to use new tools), how to make things of significance with those tools, and most importantly, develop new ways of thinking based on use of those tools (p.39).

1.6. Examining Talk to Find Out How Learners Collaborate With Technology

Tabletop technologies have been found to leverage opportunities for collaborative learning by offering interactive objects which can work as tools to help persuade and support learners in working together (Zhang & Shi, 2012). Several types of qualitative studies on interactions around technology (computers, interactive whiteboards and tabletops) have offered new considerations for examining the relationship between speech and technology. For example, in Scott, Mandryk and Inkpen's (2003) and Wang and Ching's (2003) qualitative studies, researchers looked into the social interactions occurring around desktop computers. Both teams realised that children formed their own rules of use around fairness and monitoring around use of the technology. This indicated that there was a broader social order that was not considered prior to the design and implementation of the technology; highlighting there is an opportunity to examine how the rules of use are formed and how technology aids in these rules.

Kershner et al. (2010) looked at exploratory, cumulative, and disputational types of speech with an interactive whiteboard (IWB) with the aim of deciphering which of two project activities had elements that best encouraged collaboration with school-aged children. They found that enforcing talk rules in a turn-taking activity seemed to encourage rule-related conflicts, while another activity with open dialogue encouraged learners to take their conversation away from the IWB to focus on the problem (Kershner et al., 2010, p.379). This method of analysis was insightful, but only began to reveal defining factors of what made these types of collaborative learning activities successful. The study did not go into details about how exploratory and cumulative speech was supported by the design. These examples present some preliminary insight into how examining speech can shed light on collaborative interactions, including: "talk, gaze, and gesture between the children," and the "complex interrelated systems of social interaction, communication, and cognition in classroom" (Kershner et al., 2010, p.381). Building on some of these benefits, TUIs can have additional opportunities to enhance opportunities for particular skills (e.g., argumentation or reasoning skills (Dillenbourg & Evans, 2011)).

Studies on TUIs have documented opportunities of meaning-making for: exploration, expression, and integration of representations (Marshall, 2007) and coupling and mapping of actions/responses to support representation (Antle, 2007). Speech has been explored as a useful way to understand more about learners' interactions. Falcão and Price's (2011) and Price, Sheridan and Falcão (2008) used a discourse analysis approach to look at tangible features, reflection and action of digital and physical tools, learner conflict (aged 11-14), and how argumentative processes supported collaboration from a design perspective. They did not however specifically address what aspects of the activity aided their participants' ability to use integration-oriented consensus building which involved reflection and participation from all members in their conflict resolution (Price et al., 2008, p.557). It was also not clear how best to support consensus-building or how avoid conflict that was deemed counter-productive.

In contrast to the work described above, quantitative studies of collaborative TUI systems have looked at: the monitoring of frequency and accuracy of tabletop system tangibles (e.g., Schneider et al., 2011; Antle & Wang, 2013), on-task conversation and playfulness (Jamil et al., 2011; Xie, 2008), turn-taking and equality of interactions, as well as use of questioning, suggesting and affirming to support decisions, goals and plans for future actions (Buisine et al., 2012), expression of opinions to support decision-making (Stock et al., 2009) and assessment of previous decisions (Price et al., 2008). Marshall (2007), Schneider et al. (2011) and Do-Lenh et al. (2010) also showed that TUI technology can help build concrete understandings of abstract concepts and support accommodation or assimilation of concepts when learners discuss their experiences in cause-and-effect environments. However, Marshall (2007) critically noted that simply designing technical tools that a group of learners could use does not guarantee socially rich learning experiences (p.164). Tse, Shen, Greenberg and Forlines (2005) also developed a tabletop application to track speech and actions with some findings on turn-taking and mapping actions within the learning of an activity, but they did not present future suggestions about transferable learning. Quantitative approaches have been useful in measuring if particular actions which contribute to learning are occurring; however these studies have limitations in explaining how tangibles can promote dialogue and information sharing, as well as how learners make sense of their efforts together over short periods of interaction.

What has not been studied enough is specifically how speech and tangibles can be used to enhance meaning-making and decision-making processes by looking at the use of tangibles supporting speech and/or speech enhancing how the tangibles are used. Researchers have looked at the use of TUIs and talk, but have not examined these in an in-depth way together. As new technology continues to develop, there is a need for TUI design to understand how different kinds of talk can be enabled or constrained with the systems in order to guide the kinds of conversations that learners have. The research goal is to understand how learners' interactions were supported with the Youtopia system in order to enhance or amplify the positive actions that work to engage learners in even more effective learning processes. Speech Act theory (Searle, 1969) has been used as a conceptual frame in this study to analyse learners' speech in their collaborative processes because of its focus on the indirect purposes of speech and how speech can inform the actions and interactions between people. From the above examination of some of the related studies we know that speech and behaviour (including tool use) can have an influence on what makes collaboration successful with mediating technology; however there is a large gap of understanding around how technology (and specifically tangibles) can specifically support beneficial types of social order, conversation and conflict resolution. This research profiles how characteristics of tangibles can support learners in their speech and interactions by examining the relationship and recommending ways to enhance and/or amplify them.

The next chapters will provide further context about TUIs and why this approach of studying learner interactions with tangibles and speech is worth researching. Chapter 2 provides an in-depth literature review of the current state of research regarding TUI systems and collaborative learning, along with the problem domain and research question. Chapter 3 describes the Youtopia system and its design features to support collaboration. Chapter 4 presents a methodology to better understand how learner interactions and knowledge processes can be explored using a discourse approach focused on speech acts. Chapter 5 describes the six thematic findings in detail, while Chapter 6 explores the implications of this study for design and final conclusions.

Chapter 2.

Literature Review

This literature review describes the body of previous research and the guidance it had for this research project; namely how the use of collaborative learning theories and Tangible User Interfaces (TUIs) and other collaborative tabletop systems (e.g. multi-touch (MT) systems) can provide opportunities to support learning. TUIs can involve a similar setup as MT systems in which learners can engage directly with a tabletop computer interface, but also with the enhanced use of physical tools (tangibles), such as: stylus pens or wands (Dillenbourg & Evans, 2011, p.493), blocks (Jermann, Zufferey & Dillenbourg; 2008), or in Youtopia's case, stamps (Antle et al., 2013; Wise et al., 2015). Researchers have explored learners' relationships with digital tools and how they have been used (Falcão & Price, 2011), but there are still gaps in our understanding about how specific designs for discussion and conflict can provide better learning experiences with TUIs. This literature review lays out research on tangibles, the use of language in relation to TUIs/tabletop technology from a Vygotskian perspective and targets specific opportunities to enrich understanding about the use of tangibles and talk in facilitating the learning process. The first section provides an overview of collaborative learning and the importance of talk and negotiation in meaning-making processes. The second section provides details about tangibles and the features of TUIs. The third section provides a basis for how the design features of TUI/MTs can support collaboration between learners generally. The fourth section provides more in-depth description about how TUIs can be used to support learners' dialogue and negotiation. The fifth section discusses the prior findings about how conversations can be supported with TUI technology, while the last section describes the purpose statement and research question.

2.1. Background on Collaborative Learning

This section provides a brief introduction to collaborative learning and what it can offer learning in a group context. By providing a background on how collaboration can support learning, it promotes a better understanding of the role that technology (specifically TUIs) can play to support social learning processes. The section begins with a definition of collaborative learning and is followed by sections on how the process of shared meaning-making happens with support from language, and the specific role that negotiation can play in supporting it.

2.1.1. Perspectives on collaborative learning

This research uses a social constructivist perspective, which considers the role that learners play in their learning experience through their interactions and speech to take part in meaning-making (Vygotsky, 1978). Vygotsky and Piaget have important theoretical stances on cognitive development based on the relationship that learners have to their contexts. Piaget focused on the individual's role in their development of knowledge, and Vygotsky focused more on the social context shaping the learning experience (Tudge & Rogoff, 1999). Piaget saw knowledge as something to be held by individual learners. By focusing on one's own schema, learners engage in situations with new sensorimotory elements and can accommodate (add to their current knowledge) or assimilate (modify/redirect) new understandings (Piaget, 1952). The individual learner and their knowledge are commonly referenced in educational concepts in the HCI (Human Computer Interaction) field. Dillenbourg (2006) wrote that the "difference of viewpoints raises socio-cognitive conflict" (p.157). In this role, specialized information held by individual learners can create a greater understanding of 'knowledge' as learners go through the process of assimilating or accommodating the conflicting knowledge "which leads to a richer understanding of the object" (p.157). Researchers such as Ishii (2008) referred to external representations with a more Piagetian perspective of using a physical or virtual artefact to represent or support a piece of information or knowledge. Schneider et al. (2011) explained that "social learning processes could be promoted and enhanced when using a tangible interface, because access to a shared representation of the problem facilitates interaction and reduces cognitive load" or capacity (p.223).

In contrast, according to Vygotsky (1978), speech plays a critical role in supporting collaboration. As learners talk about their environment, they develop increasingly sophisticated ways of thinking, describing and analysing their problems, developing plans to solve them, and talking through their thought processes (using inner speech) as they problem-solve with each other (using external speech) (p.25). This growing understanding shapes learners' behaviour and speech, as they form new ways of interacting and speaking, and find new uses for tools which "stimulates development" (Vygotsky, 1978, p.27). Based on Vygotsky, Dixon-Krauss (1996) described, "learning leads development with the gradual internalization of intellectual processes that are activated through social interaction" (p.11). In other words, learning involves participants engaging in dialogue that reflects their inner speech; which plays a role in shaping their thoughts and guiding their planning as they make decisions together. Vygotsky (1978) described that the use of tools (artifacts, language and gestures) help children to direct their attention to the same things, engage in the process of developing vocabulary and new representations, and enable children to talk through problems and attain goals. This perspective is important because it can inform how we design tangibles to facilitate the topics of conversations and support learners' knowledge processes.

Collaborative learning involves a complex process and environment in which learners are required to work together, with more focus on the team or group knowledge process rather than on the individual. This includes the potential limitations of considering the group size and ability to dialogue and contribute (Suthers, Vatrapu, Medina, Joseph. & Dwyer, 2006), as well as the challenge of being able to infer meaning behind actions and dialogue of learners (Soller & Lesgold, 2007, p.64). According to Dillenbourg (1999), part of supporting the learning experience is providing a context that supports dialogue and authentic communication, or, "*situation*(s) in which particular forms of interaction among people are expected to occur" (p.5). These situations or experiences must be intentionally designed for. Stahl et al. (2006) specified that computer-supported collaborative learning (CSCL) "is an emerging branch of the learning sciences concerned with studying how people can learn together with the help of computers" (p.409). In these environments, the process of collaboration is said to be is dynamic, interactive, and processes which can involve shared goals and the use of language (Stahl et al., 2006, p.410).

There are also important similarities and distinctions between cooperative learning and collaborative learning that need to be made apparent in order to better understand why collaborative learning is worth examining (Dillenbourg, 1999). Collaborative learning has several qualities in common with cooperative learning, such as: shared overarching goals, accountability, functioning social skills, and reflection or group processing (Johnson & Johnson, 2002). However, cooperation is more results-oriented, and may not require much interaction or maximize an individual's learning experience (Johnson & Johnson, 1996), while collaboration focuses on interactions, learning process and requires that decisions are made together as an ongoing "attempt to construct and maintain a shared conception of a problem" (Roschelle & Teasley, 1995).

In taking the perspective that development occurs through the use of language and other mediating tools during social interactions, this denotes a shift from cooperation where learners may engage in parallel play with less awareness and intervention of each other's actions, tasks and successes (Bakeman & Brownlee, 1980). Roschelle and Teasley (1995) also outline an imperative distinction between collaboration and cooperation in which cooperation is described as learners participating in parallel to other learners; the outcome of their efforts is seen as a summary of learning (p.70). Alternatively, collaboration can be attributed to combined effort, a shared problem space with shared meaning emerging throughout the learning process. The difference presented here looks at learning in two ways, one that regards the knowledge of an individual learner, and one that looks at knowing as a process between learners. This leads to the next section which describes the importance of the shared meaning-making process.

2.1.2. Shared meaning-making and its importance in collaboration

Shared meaning-making involves the communication and interactions that are used to form common understandings and experiences of significance that are held by a group of people in a coordinated and continuous way (Roschelle & Teasley, 1995). Stahl and colleagues also described these understandings as interactions that happen between people over time: "(c)ollaboration is primarily conceptualized as a process of shared meaning construction. The meaning-making is not assumed to be an expression of mental representations of the individual participants, but is an interactional achievement. Meaning-making can be analyzed as taking place across sequences of utterances or messages from multiple participants" (Stahl et al., 2006, p.416). This aligns with a social constructivist perspective that members within a group engage in knowledge processes over time in their interactions and this type of knowledge cannot be held by a single person at any given time. As part of the shared meaning-making, learners engage in ongoing dialogue that shapes learners' thoughts and continually guides planning work as they first describe what they will do and speak as they act. "Speech first accompanies and then represents action" and develop(s) into planning to describe a past or ongoing action (Levina, 1999, p.80). Engaging in shared environments and language aids learners in planning and actions (Vygotsky, 1986), and thus shared meaning-making is a core process of collaborative learning.

Vygotsky (1978) argued that tools can work as mediators to aid learners in understanding cultural contexts (e.g., artifacts, as well as language and gestures), and support the planning of future actions: "The tool's function is to serve as the conductor of human influence on the object of activity" (p.21). By using these tools "the child acquires a device that allows them to develop plans before actually performing an action" (Levina, 1999, p.80). Vygotsky (1978) described how the use of tools helped children direct their attention to the same things, engage in the process of developing a shared vocabulary around the same items and enable children to talk through problems in spontaneous conversations as they "solve practical tasks with the help of their speech, as well as (with) their eyes and hands" in order to internalize experiences into knowledge (p. 26). As learners form understanding and develop language around the tools, the tools (whether language or physical tools) help shape the perception of the world as part of

their knowledge processes (Vygotsky, 1978, p.21). When learners negotiate shared words, explicitly or implicitly, the meaning that these words have within their contexts is shaped. With the perspective that shared meaning is created through the language and interactions of learners, negotiation between them can play a role in determining what is shared and agreed upon.

2.1.3. What role does negotiation play in collaborative learning?

Negotiation supports the process by which learners develop meaning-making (Jin & Geslin, 2010). Negotiation facilitates a common context in which learners can share information, learn about and address problems, and make "associations that relate goals to the current problem state and decid(e) on available actions" (Rochelle & Teasley, 1995, p.70). Negotiation can also deepen the understanding of terms, support conflict resolution and support shared ways of interacting. According to Stahl (2003), negotiation is defined as "a process by which a group of people who are working together arrive at a group decision" (p.13). Conflict is also an important part of the negotiation process because in conflict, learners explain their inner speech, while resolution of conflict requires the consideration of new ideas. According to Jin and Geslin (2010), learners "verbalize contradictory demands and then move towards an agreement through both trade-offs and searching for new alternatives" (p.35). This process helps move learners to develop new and internalized experiences which they can later refer to in their problem-solving. Kirschner, Beers, Boshuizen and Gijselaers (2008) explained that "negotiation of common ground is intrinsic to solving complex problems because common ground is needed to afford sharing knowledge and the subsequent constructing of a shared problem representation", as well as a "explicitly verify their understanding of each other's contributions to the discussion" (p.343).

As part of negotiation in meaning-making, new goals, rules of engagement and solutions are continually developed with compromises to clarify terms, compare "alternative related statements", and refine and "scrutinize linguistic expressions" (Stahl, 2003, p.5). Stahl (2003) claimed that negotiation is part of a shared process in which agreement is reached about objects and artifacts as it is "internalized by children based on what they are capable of understanding" (p. 4). As part of this process, particular pieces of information are socially agreed upon, a working consensus is ongoing, and common understandings concerning the meaning of expressions and terms are accepted (Stahl, 2003, p.5). According to Stahl (2003), information and understanding are linked to cultural tools or artifacts "such as a text or slogan" to provide some "basis for the meaning that the artifact encapsulates" by the learners (p.5). A main argument for this study is that there needs to be support for experiences for conflict and also opportunities for reasoning and resolution by creating tools and technology that support the negotiation process to happen. These views align with Vygotsky's views that development occurs during social interactions in the environment.

A difficulty in designing the learning environment is how to make informed considerations for how learners will dialogue within that space. "The challenge is to take the step from affordances defined in terms of features of representations to the social level and make predictions of the opportunities the technology provides for discovering affinities with others, orienting attention, expressing viewpoints, exposing conflict and consensus, and supporting debate and negotiation" (Suthers et al., 2006, p.332). To address this challenge, the next section introduces tangibles and looks at how they can be used to provide opportunities which encourage learners to work through negotiation and conflict as learners verbalize their shared experiences.

2.2. Introducing Tangibles

This section aims to provide readers with a short history and overview of tangibles and why they are worth exploring for their potential to support collaborative learning. This background will provide a foundational understanding which will heighten potential possibilities for future design for TUI system development and listing considerations for potential designs and limitations.

2.2.1. What are tangibles?

The first “tangibles” were developed at Massachusetts Institute of Technology as physical objects which held digital information and interacted with a computer system: “Tangible interfaces give physical form to digital information, employing physical artifacts both as representations and controls for computational media” (Ishii & Ullmer, 2000, p.916). Tangibles were initially developed from a Human Computer Interaction perspective as they focused on user experience and technical possibilities of having enhanced, sensory features and processing power outside of a typical computer system. Tangibles themselves can be stand-alone objects (e.g., Zuckerman, Arida and Resnick’s (2005) digitally-embedded FlowBlocks which allow learners to assemble and view mathematical concepts such as counting or probability), or can interact with other digital components (e.g., tabletops). There are also several other descriptive terms for tangibles: embedded artefacts (Dourish, 2001), graspable user interfaces (Fitzmaurice, Ishii & Buxton, 1995) and physical manipulatives (Resnick, Martin, Berg, Borovoy, Colella, Kramer & Silverman, 1998). Embedded artefacts or cooperative artefacts (Strohbach, Gellersen, Gerdkortuem & Kray, 2004) referred to physical objects with engrained information and enhanced function from the physical objects. For example, a cooperative artefact can “assess their situation in the world, without requirement for supporting infrastructure” (Stohbach et al., 2004, p.251). Graspable user interfaces referred to the physicality of an object that a learner could hold and control “which require(d) manipulation of finite data using hands, body or gestures” (Keck, Lapczyna, & Groh, 2014, p.130). Physical manipulatives referred to the interaction qualities (e.g., level of responsiveness or combinable parts) of the objects. Specifically, tools which had “computational power embedded inside” were also “designed to expand the range of

concepts that children (could) explore through direct manipulation, enabling children to learn concepts that were previously considered “too advanced” for children” (Resnick et al., 1998, p.281). For example, some activities have included physics or spatially-based problems (Schneider et al., 2011), or meta-cognition on problem-solving (Kharrufa et al., 2010). The development of tangibles and tabletop technology enables a broad range of software, interactions and physical objects to be designed and modified to interact with technological systems.

In this research, TUIs are referred to as complete systems with an interactive screen and the infrastructure to support the developed software. Ishii & Ullmer (1997) described a TUI system as a visual information and display surface that can interact with digitally augmented physical tools. While “an interactive tabletop is a computer interface that, as its name indicates, resembles a table: it is usually a horizontal (sometimes oblique) surface and usually is large enough to allow several users to interact simultaneously” (Dillenbourg & Evans, 2011, p.491). In the following section explores the potential of TUI/tabletop technology to enhance collaborative environments.

2.2.2. What are some considerations about tabletops/TUIs?

There is an assumption that tabletop technologies inherently facilitate collaboration if many people can interact with them, but Dillenbourg and Evans (2011) criticized this mentality in citing the overgeneralization and inflated expectations for CSCL and tabletop technology in supporting shared learning environments. An important part of designing for collaboration is in understanding how learners will engage with and talk about their tasks and experiences. One limitation is parallel play, which can sometimes result in learners engaging in their individual tasks without common experiences or decisions. This limits the opportunities that learners could have in verbalizing their interpretations and trying out different problem-solving approaches. Do-Lehn et al. (2010) also found that parallel work provides a shallow level of shared understanding where the college-aged learners could benefit from coordinated discussion and action on a tangible warehouse tabletop activity. Constant awareness of group members’ actions limits the amount of cooperative behaviour and influences co-dependent behaviour. Chan et al. (2012) and Kershner et al. (2010) indicated that

facilitation of discussion and mediation tasks are key requirements of collaboration which occur during the dialogue of learners and in the monitoring of other learners' tasks.

As peers share and explore the experiences, they also actively negotiate rules, reasoning and concepts (Kreijns et al., 2003). Johnson and Johnson (1999) argued that a deeper level of thinking and an advancement of communication skills take place when learners work collaboratively. Bachour, Kaplan and Dillenbourg (2010) outlined some additional benefits to collaborative dialogue with technology, such as: "elaborated explanation, argumentation, mutual regulation, conflict resolution, as well as seeking and providing help" (p. 203).

2.3. How TUIs Can Support Collaborative Learning

Tabletop systems can offer many exciting opportunities to support collaborative learning, by providing venues for negotiation, information sharing and decision-making within the activities (Dillenbourg & Evans, 2011). Tangibles that interact with these systems can also be designed to carry out certain kinds of functions (acting as tools) and have the potential to facilitate particular types of experiences between learners. Dillenbourg and Evans (2011) reviewed and listed several benefits for tabletops such as designs for co-location, multiple users, hands-on activities, and which can allow learners to capitalize on nuances of communication such as gaze, gesture and tone (p.500). Zaman, Abeele, Markopoulos and Marshall (2009) also suggested that the physicality of tangibles can influence engagement and learning opportunities, through the: manipulat(ion) of physical objects which provide "links between concrete manipulations and cognition," providing "shared and equal access to interacting" and "increased visibility" and a more fun interface for learners to engage with (p.2). Antle (2014) also described that tangibles can support "heads up" interaction in a more effective way than multi-touch interfaces (p. 66), which can engage learners' attention to focus on the same items.

Dillenbourg and Evans (2011) have listed several features which can play a role in supporting learning processes by reviewing several TUI designs (e.g., movement tracking, manipulation of virtual/tangible objects, visual feedback and timing and invisible tags). There are also several other learning benefits of tabletop activities which can support opportunities for collaborative learning. One of the important characteristics engages the intrinsic motivation of learners to participate. Another includes the support of external representations for discussion and exploration. A third characteristic involves harnessing gaze and awareness to develop language for learners to describe their peers' activities. Additional characteristics include monitoring learners' progress to inform future decisions, just-in-time feedback, and multiple access points for increased learner participation and interdependence.

2.3.1. Enhancing prolonged engagement with intrinsic motivation

Well-designed TUIs can provide visually attractive and exploratory experiences which employ learners' curiosity and directly address the concern of learner engagement (Xie, et al., 2008). In comparative studies with low fidelity and digital tabletop activities and university students and staff, Buisine et al. (2012) found that TUIs can boost the intrinsic motivation of learners to use the systems, while encouraging learners to engage in focused interaction for a prolonged period of time. Ryan (2000) described intrinsic motivation as "natural inclination toward spontaneous interest and exploration that is essential to cognitive and social development, and represents a principal source of enjoyment" (p.192). Seeing value in tracking this kind of persistent behavior, Ryan (2000) created a self-measuring tool for intrinsic motivation related to engagement. Stahl (2006) similarly described that "interactive learning environments promise to enrich the experience of students in classrooms by allowing them to explore information under their own intrinsic motivation and to use what they discover to construct knowledge in their own words" (p.46). Drawing on intrinsic motivation, participation in play and exploration enhances learners' autonomy over their priorities. This keeps learners invested in the outcomes of their actions and supports collaborative learning as it can enhance learners' investment in the process. As seen by Sugimoto (2009), activities which offer a "sense of play" can lead to "authentic learning experience(s)" (p.17), in their research with elementary school students with several tabletop activities.

2.3.2. Using external representations in shared meaning-making

Meaning-making can be enhanced through learners' ability to manipulate physical forms and digital information to develop reference points of understanding and next steps as they work towards solving a problem. Woolfolk (2005) writes that tools and external representation can shape the learning: "children do not just receive the tools, however. They transform the tools as they construct their own representations, symbols, patterns, and understandings" (p.45). In these cases, the tools can be an integral part of the meaning-making process, can act as reference points for previous approaches, as well as act as the means to solving a future problem.

Price and Falcão (2010) described how tangibles helped some learners connect digital information and physical components to build an understanding of what a tool could do, such as. "offer(ing) opportunities for meaning-making and non-verbal expression through links between action and digital representations" (p.146). According to Dillenbourg (2011), meaning-making can also be supported through the input-output coupling of actions and feedback which provide opportunities to form group working memory in reference back to items and experiences. Visible actions and uses of tangibles which are accepted by learners contribute to a working representation of their decisions, becoming a model of their current task which is continually adjusted or improved, based on their trials and findings. This links the importance of actions and tools to develop a working solution to a problem which is continually redefined.

2.3.3. Engaging learners' awareness and monitoring progress

Shared awareness of peer activities supports learners to be engaged and accustomed to their partner's and own actions (Phielix et al., 2009). This category holds both a benefit of physicality and enhanced computation. Although the benefits of gaze and awareness of learners are not limited to TUI activities (e.g., Scott, Mandryk and Inkpen's (2003) study showing social learning benefits using shared computers), the spatial layouts of TUIs on tabletop systems can allow learners to capitalize on the face to face interactions. Antle and Wise (2013) described how TUIs provide "configurations in which participants can monitor each other's activity and gaze…support(ing) the development of shared understandings" (Antle & Wise, 2013, p.13). The tabletop design

includes considerations of where learners stand (e.g., beside each other or across from each other) and what can be seen in their periphery (i.e., game objects and information). Some benefits of using TUIs in a shared space can include opportunities to interpret facial expressions, intonation, gesture, and other non-verbal cues to better understand learners' intentions. States of confusion, frustration, and celebration are also easier to perceive and respond to in these types of face to face contexts. The ability to gesture and point to objects can assist with the planning of actions before these occurrences take place. Jamil et al. (2011) found that with an interactive tabletop revealing talk patterns to 11-13 year olds, group communication of awareness includes three mechanisms for interaction; feedthrough, consequential communication and territoriality (p.3044). Feedthrough enables observers to watch tangibles as they interact with the system. Consequential communication involves the bodily responses and acting on decisions that occur in the group process. Territoriality enables a feeling of ownership and sharing of space on the tabletop. Speelpenning, Antle, Doering, and van den Hoven (2011) also described that ownership is recognizable in learner interactions: "The physicality of the tool enables the action of picking it up and holding it, which may in turn cause a feeling of ownership" (p.616), and that more research is needed to look at how this encourages or limits learner's use of the same tangibles and how these interactions can influence team dynamics and decision-making.

Tracking actions through the TUI technology's system and presenting feedback (such as results in a game) allows learners to be aware of their decisions, enhances collaborative learning opportunities for syncing learner awareness and can support shared meaning as learners reflect on the effectiveness and outcome of their decisions. As learner actions can be tracked in both virtual and physical environments with tabletop systems and software, tracked actions can also be used to support and display learner contributions. Dillenbourg and Evans (2011) suggested that when learners become aware of the consequences of their actions, they can better monitor decisions participation levels, and develop longer-term group strategies. This further enhances learners' awareness of their peers' actions via gaze with the use of tangibles. In the comparative study between digital and non-digital tabletop activities of Buisine et al. (2012), the researchers found that when learners were aware of each other's participation, this resulted in more equal participation from more members and a

decrease in “social loafing” (p.54), where a member relied on other team members to take on their work. The combination of physical actions, visible awareness of each other’s territory, and participation-tracking, provided learners an environment where users actively engaged, questioned, and discussed other member’s interactions. This phenomenon supports collaborative learning as learners become aware of, reflect on, and refer back to their decisions with a heightened awareness of actions and progress.

2.3.4. Learning from just-in-time feedback

When problems arise in learning situations, uniting just-in-time feedback with relevant information can help learners to clarify concepts to build shared understanding and can be used to address conflict. Just-in-time feedback presents itself as a benefit of computation (rather than only physical objects) and a benefit of physicality (which is added to a computing environment). As a benefit with computation, some tangibles that have representational and associated information properties can allow learners to support transferable relationships of the issues and relationships between the digital and the physical world. In Schneider et al.’s (2011) tangible shelving activity, researchers were able to monitor the errors of the college learners and provide them with the necessary information needed to make a decision to complete a task in order to try an increased possibility of options to solve a space-based problem.

As an added benefit of computation, the effectiveness of this learning feedback also relates to the ability to predict learners’ misunderstandings. Antle and Wise (2013) specified the need for positive feedback and confirmation of appropriate actions. In support of scaffolding, the feedback of some TUIs can address specific misconceptions, and can provide learners with prompts to explore and deliberate information. Just-in-time feedback can be used to support learner processes to try out ideas and consequences, and predict or demonstrate the effects of a decision (such as Suchman’s (1987) situated action work on making and adjusting plans and decisions in the moment).

2.3.5. Enhancing participation through multiple entry points

Research has found that when multiple learners engage with an interactive activity at the same time, the learners have increased access to actions and can achieve more equitable participation (Buisine et al., 2012), and potentially limit parallel-play (Wise et al., 2015). Multiple access points or simultaneous interaction through entry points can offer added benefit for computation and, with computation (as seen in Hornecker, Marshall and Rogers's (2007) museum installation study). "Entry points invite and entice people into engagement, providing an advance overview, minimal barriers, and a honeypot effect that draws observers into the activity" and a "fluidity of sharing" (Hornecker et al., 2007, p.22). Designing multiple access and entry points allows for more equal opportunities to contribute to work and planning as learners can direct each other to distribute the workload. Sugimoto (2009) also described that physical tools promote more equal participation for learners who are not confident or familiar with other types of technical systems and can lower the barrier for interaction (p.16). Marshall (2007) also suggested that offering several objects that can engage with a TUI system simultaneously can lower the participation barrier and increase opportunities for learners to explore, share and demonstrate understandings to each other. Enhancing opportunities for participation can support collaboration by allowing learners to: contribute to shared actions and have more shared/coordinated experiences together. This can lead to more opportunities for points of reference for discussion, such as debriefing what actions they took and what they observed.

2.3.6. Supporting interdependence in a joint problem space

Interdependence is an important aspect of a collaborative learning activity (Kreijns et al., 2003). Antle and Wise (2015) made the case for the need for positive interdependence as creating a reliance of learners in a joint problem space supports collaborative processes. "Each team member cannot succeed unless the others succeed and/or that each member's work benefits the others (and vice versa)" (Antle & Wise, 2013, p.339). Wise et al. (2015) also described that "interdependence can be employed on its own" (using colors to differentiate members' pieces) "or in concert with social interdependence (i.e. tools are distributed in alignment with particular duties)" (p.236).

For example, Kreijns et al. (2003) noted that learning situations can give learners a different but shared stake in the success of the task. Antle and Wise (2013) also discussed that "constrained or co-dependent access point schemes can compel learners to negotiate with each other" (p.13). This design feature supports the described goal because it necessitates communication between learners to make their needs and wishes known and that pre-determined actions and decisions need to be made together. Successes and obstacles thereby become part of a shared learning experience. The goal of designing for positive interdependence causes learners to be reliant on each other's contributions and enhances opportunities for dialogue and negotiation around goals and problems. Roles can also emerge as each learner encounters conflicting or complementary experiences (Antle & Wise, 2013) and information that learners share with each other help them to gain a deeper understanding of a problem. In order to learn more about how learners negotiate and how they use talk to support their interactions, the following section will explore some of the findings around learner's discussions with similar learning environments.

2.4. Supports and Challenges for TUIs/Tabletops and Negotiation

TUIs offer several opportunities to support negotiation, particularly in the way that they provide opportunities for learners to share information and accomplish tasks. This section provides a thorough look at useful benefits within a collaborative learning paradigm; specifically how TUIs can encourage and support negotiation and shared decision-making. By shifting focus from results-oriented to more process-oriented projects, researchers can learn how the learners engage with each other in these social environments and which design features can support these learning opportunities.

TUI design can encourage certain types of discussion that can promote and mediate collaborative behaviours (Stahl, 2000). As cultural tools (Vygotsky, 1978), (e.g. artifacts and language which are tied to some shared understanding) tangibles can serve as both a reference point and a support to: direct children's attention to the same things, initiate conversation, develop shared vocabulary, and settle arguments. Price et al. (2008) comment that tabletops allow learners to dispute objects and engage in "high

levels of interference with one another's arrangements and actions leading to interesting pedagogical implications, such as co-construction of ideas through resolving emerging conflicts" (p.150). Conflict allows learners to engage in a shared problem and language that aids learners in "planning the solution of a problem" (Vygotsky, 1986, p.87). This requires negotiation, and is based in and is shaped by a learner in their context (Suchman, 1987), as they prepare for and use skills to manoeuvre plans and reactions for changing situated actions. In the example of Zancarano et al.'s (2012) tabletop, learners relied on the visual display of their progress; consensus-building was enforced to address conflicts so that learners had to work through disagreements. Higgins (2012) saw joint solutions were a key aspect of collaboration: "Pupils should be encouraged to reach a consensus about what they have to do and how they are going to do it as well as encouraged to produce a joint solution" (p.1042). The next section discusses opportunities with technology from learners' conversations with similar projects, ways to encourage group interactions, and other approaches of discourse analysis in examining the learning environment.

2.4.1. Previous findings on learners' conversations around tabletop interfaces

The research below has explored learners' relationships with TUI/ MT tabletop systems to facilitate complex conversations and provide a research context in which discussion can be supported through the use of the systems. The design of the tangibles and systems can also give learners information sources to support their reasoning processes. Several of these research projects have identified how TUIs/MTs can encourage certain types of speech and joint actions, particularly projects which can encourage episodes of negotiation. Challenges for negotiation have also been described.

2.4.1.1. Promoting participation via reflection

Learner's personalities, abilities, knowledge, and increased access points can allow for dominance or one sided decision-making to occur (to the detriment of both learners) (Bachour et al., 2010). Participation equality was addressed in the *Reflect table* (Bachour et al., 2010), which integrated a visual display of lights related to the amount of speech learners contributed to a conversation and compared the participation to learners using a topic-based visualization. Although these lights could not be physically manipulated, these visualizations based on speech, made learners more aware of their own contributions and other learners were able to view the evidence of this through visual feedback. This in turn supported learners in regulating their behaviour (e.g., encouraging quieter learners to speak more). This presents an interesting way for learners to co-regulate their level of speech while encouraging learners to respond and address their participation levels; however there were limits to the ways learners could actively participate with the system.

2.4.1.2. Encouraging turn-taking

Olson, Leong, Wilensky and Horn (2011) looked at the communication of children engaging with four different types of digital interface toolbars with tabletop platforms. A fixed multi-touch interface, a computer and a mouse, a multi-touch with a floating toolbar, and a tangible controlled toolbar were all used in the examination of speech. Science-related talk was categorized as positive type of conversation as language was used to explore the task at hand, while control-related talk was labeled to be related to instructions, arguing, and power dynamics of decision-making. The study found that tangible "ownership" helped support a turn-taking protocol between learners and became a successful way for learners to share decision-making over the activity. The tangible was suggested to have helped some learners' decision-making and social order due to the physicality of it as learners took turns with the scripts, "asking to participate, passing the control, and complaining when those scripts were not applied" (Olson et al., 2011, p.34). This study suggests that a TUI helped to moderate control and encourage on-task language as a tangible helped mitigate conflict by supporting turn-taking. However, the only design qualities described for the tangible was its physicality which seems to support "passing the baton" or turn-taking protocols (Olson et al., 2011, p.34).

2.4.1.3. Access points and interference

Falcão and Price (2011) explored the use of tangibles, interference, and consensus-building to find that arguing could support learning if there was ample time to reflect on suggestions from all learners. By considering each other's ideas and gaining support for convincing others, the learners were able to make shared decisions. (This meant that both learners could contribute or accept a decision, as opposed to unilateral actions made without the agreement of the other). This study found that the tabletop hosted the space for conflict, but the learner's strategies and attitudes mainly supported the learning opportunities (e.g. reasoning and gaining consensus on decisions). The authors noted several design qualities which influenced interference and presented opportunities for negotiation in the activity, namely: multiple controls and access points, shared visual fields, responsive digital feedback, and dependency on a shared control/tangible. Having access to multiple tools/inputs influenced learners to "actively contribute to and engage in the activity, as opposed to merely observing and talking about what they see" (Falcão & Price, 2011, p.555). Simultaneous multiple inputs allowed learners to engage at the same time, offering more potential for conflict with each other's goals and actions without the need for turn-taking. Dependency on a single tool (a flashlight) became the central focus for controlling the use of physical objects. This served to encourage all children to be actively included in the activity and work through their conflict. The digital feedback demonstrated cause and effect and "enable(d) the students to test out their ideas, to see conflicting ideas taking place, and support(ed) the undoing and redoing of actions" (Falcão & Price, 2011, p.555). However, the study did not describe how key design qualities or functions of the tangibles helped to support integrated-oriented consensus building, other than that they resembled the real life objects that may have supported the understanding of their use. This study highlighted that designing for conflict and promoting learners' argumentation processes was more beneficial to learning than allowing learners to delete each other's work without discussion. The researchers also addressed a need for developing tangibles that support consensus-building which limit or constrict the ability for one learner to make decisions unilaterally.

2.4.1.4. Encouraging conflict resolution through restrictive access

Stock et al. (2009) and Zancarano et al. (2012), designed conflict into a Narration and Negotiation multi-touch tabletop activity for young adults by introducing images that triggered emotions about historical/cultural events. Through the use of multi-touch tools which selected images and labeled points of disagreement, learners were encouraged to explain their interpretation of event pictures to co-develop a narrative timeline. Additions to the timeline could be done independently, but points of disagreement could be labeled digitally, and would pause their ability to complete the timeline (fading out a 'done' button). The pair would then decide whether or not to keep the picture, and would "jointly perform some key actions, such as removal of contributions from the story" (Stock et al., 2009, p. 58), and would continue the construction of the timeline. The restrictive tools in this study influenced negotiation and provided learners with a broader understanding of the others' experiences. Learners also acknowledged that the system encouraged understanding "because if one disagree(d)" they didn't have to "interrupt the other, but (they) can present (their) view later" (Stock et al., 2009, p. 58). The moderator was also able to focus attention on the interface elements to mediate conflict; encouraging the learners to refer to the system to describe what they saw in pictures instead of including emotional attachment or interpretation. Learners said it was "difficult to disagree about a description, although it is possible to disagree with an interpretation" (Stock et al., 2009, p. 57). Learners were prompted to discuss conflicting events about Palestine/Israel in non-confrontational ways in order to get their partner to accept the description of the events and add them to the multi-touch timeline. The three qualities worth noting were: the ability to co-construct an artefact or representation of experience, restricting actions until a conflict-resolving or joint action was undertaken, and being aware of values and being able to separate them from specific tasks in a high-level way.

2.4.1.5. Supporting verbalization

Kharrufa et al. (2010) developed a digital tabletop to encourage externalization of thinking in a digital remake of a "paper-based higher-level thinking learning system called Mysteries" (p.197). Learners used the activity to discuss and make notes about the relationships of mysteries, while considering their own reflective processes. They looked at ways that interaction influenced learners' use of tools to support dialogue, externalize their thinking-processes and reflect on actions and make improvements through repetition (Kharrufa et al., 2010, p.203). Some of Kharrufa et al.'s (2010) design recommendations included providing and promoting: "a variety of cognitive tool[s] to express decision(s)" in a visible way, representations that show feedback via reflective tools, strategy and progress evaluation, mistake identification, reflection on alternative solutions, the adjustment of "the level of feedback provided according to students performance" (p.204). Several tools which supported dialogue included: a grouping tool which paused the activity to "focus all the students' attention on the activity of creating a new group," a drag-able "slip" which could be resized, moved and rotated for partner viewing, a "relation tool allows a student to mark tightly related slips or to build a sequence" and a "post-it note tool" which encouraged "students to record their thoughts for themselves and for others" (p.201). According to Kharrufa et al. (2010) the tools supported visualizations of learner's thinking and "a space for discussion, explanation, and disagreement" (p.201).

2.4.1.6. Speedy reaction times

One issue with TUIs can occur when learners do not consider the affects and effectiveness of their actions. Schneider et al. (2011) found that learners attempted many trial and error actions to build maximum shelf space within a warehouse in one TUI activity, but that the learners reacted so quickly (to the feedback) that they were not able to adequately reflect on why their decisions worked or not. Although the activity gave feedback which allowed learners to test out moves, the physicality of the tangibles permitted learners to speed up the rate in which they acted and reacted. They did not instinctively engage in discussion, which presented the need to slow down the learner's operations to have time for reflection. The challenge for design is to find ways to balance

action and information with opportunities for idea sharing, debriefing decisions and coordinating plans.

Ackermann (1996) noted the importance of learners' reflection: "There comes a time when they need to step back, and reconsider what has happened to them from a distance" (Ackermann, 1996, p.29). Rogers, Price and Fitzpatrick (2004) also mentioned the importance of encouraging learners to "step in to learn from their physical experiences and step out to reflect upon these at higher levels" (p.8). Antle (2014) described that the Youtopia system was specifically able to facilitate this "by halting the ability to build new developments and providing world state information, this stamp provides a referential anchor that both provides time and content to support analysis of the current situation and evaluation against task goals, and enables learners to modify or formulate new plans" (p.68). The ability to step in and step out of activities provides space for learners to view direct results, but also to consider the impacts of decisions.

2.4.1.7. Opportunities for sharing behaviour

Marshall et al. (2009) discussed how children fight for and maintain control of physical and digital objects on a tabletop and that this should influence "designing collaborative applications for shareable interfaces" (p.2149). When comparing digital and physical objects, they found that interaction with physical objects tended to use their bodies in their goals to obstruct other's actions (for example, "to move the materials out of reach" or "prevent access by closing their fingers around them"). However sometimes they "resorted to more forceful mechanisms such as pushing or pulling others away" and "shielding off an area of the tabletop with their hands" (Marshall et al., 2009, p.2152). Their main finding about this behaviour was that in accessing shared tangibles "while children might always try to find a way to limit others' access, they tend to choose less aggressive mechanisms first" (Marshall et al., 2009, p.2152). This study brings up interesting features in how both physical and digital objects have an influence in how conflict and resolution is impacted by the learner's ability to control and share items, and having joint or shared access to the technology limits how learners pursue individual goals and promotes team decisions.

In some cases, having multiple points of access in an activity can allow learners to act individually, in competition, and without talking to their peers (Schneider et al., 2011). This is a problem because independent goals or actions can limit supportive communication between learners and minimize opportunity for positive and shared learning experiences. Johnson and Johnson (2009) described that "when working toward competitive goals, individuals tend to engage in self-protective strategies such as self-worth protection, self-handicapping behaviors, and defensive pessimism" (p.370). To limit the competition between learners, goals and roles can be distributed amongst the learners and progress/results should be shared so that there is a sense of positive interdependence (partner-reliant relationships for success) (Wise et al., 2015).

2.4.1.8. Opportunities for roles

Different responsibilities and roles can bring out diverse experiences and interpretations of learners which can cause conflict. Group conflict or interference is a normal occurrence for learners working together. In some cases interference can be seen as a deterrent to learning, however arguments and conflicts also present beneficial learning opportunities if learners discuss options and ideas and can come to consensus on actions (as seen in Falcão & Price, 2011). Johnson and Johnson (2006) explained that conflict is to be expected in group-based activities with "potential positive outcomes" that must integrate useful mediation techniques and procedures (p.101). Stahl (2006) presented a few opportunities for using roles in decision-making, where there can be an "approval of decisions" where someone proposes an idea and it's agreed with or not, or provide "access permission" to resources or entry access to promote dialogue (p. 181).

Each of the above projects highlight valuable attributes of communication which provided insight into certain types of dialogue and interaction, such as: joint attention and shared awareness, co-regulation of actions, opportunities for consensus building, sharing of values and joint agreement, opportunities to slow down actions and engage in verbalized reflection. However, based on the review of literature, there seems to be a gap in the depth of research about how learners engage in learning processes together with the use of the systems' afforded tools, particularly negotiation and meaning-making. This presents some particularly interesting opportunities to explore how learners use speech and tangibles to gain and maintain each other's attention, coordinate and

monitor their actions, reason and negotiate in a way that encourages information-sharing, expression of values and active decision-making.

2.4.2. Discourse analysis approaches with tabletops

Tangible and other technological studies using discourse analysis were reviewed early in the process for their findings about group learning processes, as this would be most suitable to answer the research question about how learners interact in Youtopia with their speech and tangibles. Kershner et al. (2010) used Mercer's (2004) sociocultural discourse analysis to show how learners spoke collectively around interactive whiteboards and how this could be useful for teachers. The researchers were able to determine that "exploratory talk visibly indicates that speakers have internalised ways of talking to each other constructively about the problem-at-hand" (p.365), to support their learning with particular features such as a "page sorter" function (providing visible icons of pages available in the given activity) served as an "external memory" for the children (p.381). The approach looked at the positive learning potentials of collective thinking and knowledge constantly being developed (Mercer, 2004, p.140), but did not account for multiple functions of speech within the same utterances. For example learners could instruct and share information in the same sentence, and focus on the summary of learner's speech rather than the intentions of each contribution. Kershner et al. (2010) used the analysis to look at what the language was doing, but not on the relationships between aspects of the activity and speech. Knowledge processes in this study only examined collective language as something that makes collaboration successful, but did not look at potential benefits from arguments or how learners move towards collective thinking using the technology.

Jamil et al. (2011) looked at how design influences communication styles by examining two different tabletop learning activities (physical/low fidelity and multi-touch) and compared the effects on patterns of conversations (p.3044). They looked at eight conversation categories in utterances using: plural pronouns, teamwork and collaboration, directives, planning, topic-specific, reflection, accessing and manipulating objects, and playfulness (Jamil et al., 2011, p. 3047). They found that the digital tabletop activity was as good at promoting "interdependence and (a) reflective form of topic-

based conversation" (Jamil et al., 2011, p. 3047). The non-digital (physical) activity was found to encourage playful language and directives but not interdependence, topic-orientated talk, or reflection (Jamil et al., 2011, p. 3051). Limiting learners' ability to carry out a task alone also increased learners' reliance on each other (e.g., having items out of reach for one learner, pushes the learner to ask for help). The findings indicate that having both digital and physical parts can potentially offer more opportunities for interdependence, reflection, and topic-oriented conversation where a need for collaboration exists.

Buisine et al. (2012) also studied learners' conflicting perspectives and how they used tools to influence other learners in decision-making in low-fidelity and multi-touch versions of a digital card activity. They collected a quantitative count of interactional data and speech acts between the two conditions to see which encouraged more: providing of information, turn requests, action requests, providing answers to questions, expressing opinions, engaging in off-task talk, gestures/pointing, as well as moving items and interrupting. The researchers found system attractiveness could to lead to a "decrease in collaboration (as individuals focus(ed) on the system rather than on their partners)" (p.58), which was a risk worth noting for new designs. They found that spatial configuration around a table (vs. around a smaller device) improved groups' recognition of the other learners' actions, and engagement in discussions together, but the findings did not share much else about dialogue or negotiation.

2.5. Purpose Statement and Research Question

Currently there is a gap in research about how features of tangibles can support different types of speech which can shape how learners interact in an activity, and how speech can be used with tangibles to support meaning-making in TUI activities. The sustainable land planning activity, Youtopia, was an ideal technology for this exploration because it was designed to support collaboration through co-dependent access points and limit challenges such as parallel-play, competition, and provide adequate reflection time, and its tangibles function as tools in the activity. By examining previously recorded videos of children interacting with the system; this study explores how learners can use TUI systems in conjunction with language in their reasoning, negotiations, and decision-

making, and the implications of these findings for design. The primary **research question** was**:** *How were speech and tools used together by students in their interactions with Youtopia?* The answers to this question were then used to address the **design question**: *What guidance and new ideas for the design of TUI systems for collaborative learning can be generated from these observations?* The overall research goal is to both deepen understanding of and propose enhancements for TUI educational designs.

Chapter 3.

Using Youtopia for TUI Investigation

This research uses the tangible tabletop activity, Youtopia, as the vessel in which to explore the interactions of learners and how they engage with each other in a TUI environment. This section provides an overview of the Youtopia activity and its design, including particular features to support collaboration by initiating and enhancing opportunities for dialogue and negotiation.

Youtopia, a sustainable land planning activity, was designed by Dr. Antle and Dr. Wise at Simon Fraser University to support the exploration and collaborative negotiation of natural resource usage and decision-making to maintain and address the needs of a healthy population. The core goal of Youtopia was for participants to learn about the environmental complexities and the consequences of meeting the needs of a changing society. Targeted at the British Columbian Prescribed Learning Outcomes (PLOs) for fifth-grade material on Social Studies, Earth and Space Science about environment and sustainability, this tangible tabletop activity offered space for two learners at a time to engage, negotiate, and sustain a digital world. Videos on the Youtopia project are available on: www.antle.iat.sfu.ca/Youtopia.

The activity began with an undeveloped landscape on a digital tabletop as two learners stand across the table from each other with tangibles (wooden stamps). The learners are encouraged to first pick a population size (large or small), choose one of four landscapes, and cultivate a community using their stamps to designate land uses to produce food, energy and shelter for a human population. The natural resources (trees, water and coal) are limited and any energy creating developments contribute pollution. The tangibles in this activity consisted of 15 stamps and a donut-shaped tool. In this research, the tangibles as well as tabletop functions are referred to as tools as they both

instantiate important design features of the system and help answer the design question relating to other TUI systems. There were 13 co-dependent stamps divided into two main roles, resource tools and development tools which had interrelated dependencies. Resource tools had the ability to allocate resources towards: hydro dams, river reserves, nature reserves, lumber, coal mines and mountain reserves, and could create food for gardens and farms. Development tools could create: houses, townhouses, apartments, coal plants and river irrigation.

Each basic need (food, shelter or energy) had the option of using two or three tools to meet it, with environmental trade-offs. For example, water could be allocated to provide hydropower (as an alternative to coal plants) to supply energy or used to irrigate farms to provide food. A farm could be used to meet food requirements; however the trade-off was that the farms required more water and more land space than gardens. While the use of hydro dam supplied energy, the dam also detracted water for potential food and flooded the surrounding area (rendering the land unusable). In most cases, a resource stamp was required to be played first before a development stamp which supported interdependence and communication between learners. For example, if learners wanted to create housing for their population, they would need to first allocate trees for lumber via pushing down the lumber stamp on a forest, and then a second stamp would need to be used on a grassy area to designate a house. Learners received different levels of information and feedback (explained in *Table 3.1*: *Description of Tools)* to inform what actions to take with their partner. The impact tool and info ring were additional tools which paused the activity, and provided information about Youtopia. The impact tool provided a current assessment of food, housing, energy and pollution levels, and the donut-shaped info ring could be used (with a stamp inside it) to view information about the needs and contributions of a digital representation or eraser or impact tools. The last tool was the eraser tool which permitted the learners to remove digital land use representations. The affordances of these tools are described in more detail from in section *3.3: The system design of Youtopia*. The author's involvement in the early stages of the project contributes to reflections on some of the conscious design decisions which are referenced throughout the methodology and the findings. The section below describes the Youtopia learning goals, followed by the technical specifications of the system and the design features that were incorporated to support collaboration.

3.1. Design Decisions About Learning Goals

The British Columbian Prescribed Learning Outcomes (PLO) influenced the learning goals and game affordances designed in Youtopia. Affordances refer to opportunities that an object or tool provides in its form/function or, “the perceived and actual properties” (Norman, 1990, p.9). The content standards included focus on the benefits, challenges and limitations of resources and technology, specifically to understand the interrelationships and purposes between natural resources, technology and the complexity of sustaining a human population and healthy environment. To address these standards, Youtopia was given several constraints to support the learning goals for two players engaging in the activity together. The following table (see Table 3.1) describes the learning goals. Additionally, the design also aimed to promote negotiation, interdependence between learners, and the sharing of values and reflections. To encourage the exploration of complex trade-offs and sustainability, multiple options for energy, housing and food were offered with varying effects on pollution in Youtopia.

Table 3.1. Educational Goals (adapted from B.C. Fifth Grade Prescribed Learning Outcomes (PLOs) (2006) on Social Studies, Earth and Space Science)

1. PLOs	2. Guidelines	3. Learning Goals	4. Youtopia Features
Social Studies: Economy and Technology: D1- analyze the relationship between the economic development of communities and their available resources **Social Studies: Human and Physical Environment** E2- describe the location of natural resources within BC and Canada, including: • fish and marine resources • forests • minerals • energy resources E3- explain why sustainability is important **Science: Earth and Space Science:** • A) analyze how BC's living and non-living resources are used • B) analyse how the Aboriginal concept of interconnectedness of the environment is reflected in responsibility for and caretaking of resources • C) describe potential environmental impacts of using BC's living and non-living resources	A) Provide distinguishing traits between natural objects and objects made by humans B) Make learners aware that some objects (resources) occur in nature; others have been designed (technology) and made by people to solve human problems and enhance the quality of life C) Imply that the supply of many resources is limited D) Provide opportunities to analyze how BC's living and non-living resources are used (renewable or non-renewable) E) Provide opportunities to speculate on the consequences of non-sustainable practices in resource use (e.g. won't be there for future, effects on wildlife, global effects)	Make informed decisions and reflect on sustainability/ environmental responsibility, the complexity of resource management, development and interconnectedness and trade-offs of these choices Recognize the inherent constraints in the environment, the limited amount of natural resources and the impact of meeting human needs Identify BC examples of renewable (hydro power) and non-renewable (coal) energy sources, and potential impact of their use on the environment and people	Introduce limited natural resources and demonstrate consequences of running out of these resources *Learners can use Youtopia to:* Negotiate values and trade-offs of making environmental/ development decisions to support a (growing) population base Receive feedback on how individual/ collective actions can affect the world's state Reflect on decision-making, revise decisions and learn about the relationships between resource use, development and environment health Use discussion to reach a main objective to sustain a shared Youtopia that both players are satisfied with

Note: Adapted from B.C. Prescribed Learning Outcomes (2006) on Fifth-Grade Social Studies, Earth and Space Science Curriculum

3.2. TUI Guidelines for Supporting Collaboration

As part of the development, guidelines for TUI development for learning were also integrated to support specific collaborative behaviours. This section explores three main design features of the Youtopia system based on guidelines provided in Antle and Wise's (2013) *Getting Down to Details: Using Theories of Cognition and Learning to Inform Tangible User Interface Design*. A table describing how the design guidelines were implemented in the activity is found in the table below.

Table 3.2. TUI Implementation Guidelines in Youtopia

TUI design guidelines	Implementation in Youtopia
(Antle & Wise, 2013)	Goals were supported in the design, via the following considerations:
10. Creating configurations in which participants can monitor each other's activity and gaze can support the development of shared understandings	• Learners stand across each other in order to maximize monitoring activities • Shared information (via impact tool) appears between them • Actions are coupled together as much as possible (e.g., where one learner's move enable the actions of the other) • Info cards and feedback tabs can be resized and rotated to show partner
11. Distributing roles, information and controls across the TUI learning environment can promote negotiation and collaboration	• The tools can be divided in two roles: natural resources and manmade (technology) to enhance need for information-sharing • Role relationships and prerequisite stamp relationships are visually present using colours and icons • The alternative to developing land for basic needs can support environmental health
13. Creating constrained or codependent access point schemes can compel learners to negotiate with each other	• A natural resource piece must be played first, then a manmade piece (making clear the necessity of natural resources and how development impacts the environment) • Results are dependent on actions from both learners and appear as one set of results • Decisions have trade-offs and potential environmental damage • The shared info ring and impact tool can find out what caused new problems and the eraser tool allow learners to undo and play out decisions in a different manner

3.3. The System Design of Youtopia

This section describes the key design features and technical make-up of the hybrid tangible/multi-touch Youtopia system. To implement the educational and design goals in Youtopia, learners used two categories of stamps (resource-use and technology-use land development tools) to "design their own world, exploring how different land-use decisions affect the amount of food, housing and energy provided to the population; and the impact these decisions have on the level of pollution in the environment" (Wise et al., 2015, p.238). Many of the land development tools required the action of two tools to accomplish a development (e.g., a farm would initially need irrigation). Natural resource tools (lumber, coal mine, river irrigation, river reserve, nature reserve and mountain reserve) were labeled with a tree icon and development tools (power plant, hydro dam, farm, garden, house, townhome and apartment) were labeled with a wrench icon, with the interrelationships between them indicated by colour (e.g., lumber and houses were coded pink). Each basic need could be met in several ways to provide for a small or large population (e.g., houses, townhouses and apartments could supply housing). Section *3.3.7.1: Tools to support awareness* lists the relationships between the tools in a diagram.

Environmentally-sustainable options provided a smaller amount of assets, which made the goal to sustain a large population difficult. Purposefully, the options that easily met human needs posed a greater threat of rising pollution levels and influenced where populations could live and reduced the availability of water (consequently influencing food production) to encourage learners discuss and reconsider the trade-offs. When stamps were used on the tabletop, learners could work towards goals by accessing information and feedback while assessing their progress through multi-touch capabilities in the system. The following section provides more information about the Youtopia tools, including details about the impact tool, info ring, feedback tabs and eraser tool.

3.3.1. Technical description of Youtopia

In order to meet the learning and technical system goals, Youtopia was programmed in C# using the XNA framework and the standard Microsoft Surface 2.0 SDK for the Microsoft Surface table (a.k.a. PixelSense or the Samsung SUR40). The Surface had built-in infrared sensors and recognized fingers, system default 'tags' on the stamps, and the information ring (which was registered as a large mass). The system tracked and logged the stamp uses of the learners for analysis. The main tools that interacted with the system were traditional wooden stamps with tags and a large donut-shaped tool that had prescribed attributes, information and rules. The two learners stood on opposing ends (widthwise) to maximize the visibility/awareness of each other's actions. The stamps offered the first point of contact for learners. When a stamp was placed on the tabletop system; it would either stamp a digital representation of a land use type (e.g. a house) if it was successful, or it would provide error feedback if an action was unsuccessful. All of the information and feedback was touch-enabled and could be rotated in a circular direction and scaled to be larger or smaller.

3.3.2. Description of tools and terms

A description of tools is presented below in order to provide background understanding about the tools which will be referred to in future sections.

Table 3.3. Taxonomy of tools

Term	Description	Refers to:
Tools	Generalized term for any and all digital and tangible items with affordances in the activity	Land development stamps, impact tool, info ring, eraser tool
Stamps/ land development tools	The wooden stamps have corresponding digital qualities and relationships with other stamps, and can be used to adjust decisions in the activity.	Garden, farm, house, townhouse, apartment, lumber, hydro dam, coal plant, coal mine, nature reserve, river reserve, mountain reserve
Digital (land use) representations	When a land use tool was used, a digital land use representation was left behind to indicate its representation/use in the activity.	Digital representation of:: garden, farm, house, townhouse, apartment, lumber, hydro dam, coal plant, coal mine, nature reserve, river reserve, mountain reserve
Feedback tabs	Errors/issues for tool use prompt a digital hint about one of four possible improvements: proximity to water, resource requirements, terrain placement, or the existence of a digital land use representation in the same place.	All stamps can have potential error messages (including eraser and impact tool)
Greying Out	When a prerequisite stamp is in use by a development, this digital land use representation turns grey.	Irrigation, lumber, coal mine digital land use representations which are in use by gardens, housing or coal plants
Impact tool	The tool measures food, housing, shelter, pollution levels of Youtopia and displace the results with impact circle displays.	Impact tool only
Impact tool circles	The results are displayed during use of the impact tool and appear as four rings that can be interacted with to light up the contributing digital land use representations.	Food circle, shelter circle, energy circle and pollution graphic
Info ring	The only non-stamp, circular tool displays digital information cards (info cards) when individual stamps are placed inside.	Info ring, must be used in conjunction with stamps
Info card	The info card provides a full description of a digital land use representation's characteristics when a stamp is placed inside the info ring. The info card is rotatable and can be enlarged.	All stamps and tools have an info card
Receding River	When the water from the river is used to a certain threshold, it recedes from the river bed in two stages to indicate the water is limited.	Receding river/water

3.3.3. Evaluating results with the impact tool

To prompt learners to reflect on their choices, an impact tool provided status updates on the levels of food, shelter, and energy in relation to the population size. The information was provided in circular ring results which incrementally filled-in to 100%. The results of the activity were dependent on actions from both learners (e.g., an unhealthy environment and/or the world lacking basic necessities collectively affected both players). To provide consequences to human needs, an overall pollution description was also presented in snapshots; the pollution indicator at default was shown with the image of a pleasant looking world, but became more covered with smog. This imagery made the world less visible and less visually interesting. By touching any of the four impact tool indicators on the tabletop, any digital land use representations influencing those levels lit up to attract attention with white rings (indicating environmental benefits) or black/grey rings (indicating pollution).

Before starting, learners were verbally encouraged to discuss their progress and results together. They were also asked to reflect on the decisions they wanted to make when they used the impact tool, as the question 'is this the kind of world that you want to live in?' was displayed to prompt discussions and arguments about incremental and major changes. This design feature also allowed learners to reflect on their decision-making and to view the relationship to the health of the people and environment.

3.3.4. Learning in-depth about an item and previewing trade-offs with the info ring

The other tool in the activity that had the ability to pause actions was the info ring. When put on the table, this donut-shaped tool had a message to encourage participants to put a stamp on the inside. When this occurred, an info card appeared, providing information and pictures with explanations of: the digital land use representation needs (e.g., a house stamp needing lumber first), any geographical constraints (e.g., coal mine to be placed on a mountain) and how it contributed to the results (e.g., providing a small amount of housing). Learners could also place multiple stamps one after another in the info ring in order to compare the characteristics of tools.

3.3.5. Receiving advice from feedback tabs

Feedback tabs (although non-tangible items, but part of the TUI system) were designed to provide timely and specific advice for various logic errors and provide relevant information about why the land use could not be designated. For instance, if a development was stamped without a required resource allocated previously (e.g. lumber for a house), a feedback message appeared to tell the learner that the particular action could not be completed. These colour-coded error messages were linked to the use of the land development tools and appeared when: 1. an action requested was on the wrong land terrain and could not be completed for practical reasons, 2. if a learner tried to build on a development on a location where another already existed, 3. if the water resources had been depleted, or 4. if they required resources from another tool/digital land use representation. The last three error messages were designed as tools for negotiation as they necessitated a more in-depth discussion between partners and required use of the eraser tool to take adjustments. Each of the feedback tabs could be enlarged to provide more specific information about why the feedback tab appeared, and rotated to show their partner. When a stamp was used, a visual hint of the feedback would appear (e.g., a prerequisite resource). When touched and dragged, learners could pull the feedback tab to reveal additional text-based information about what was needed.

3.3.6. Making modifications with the eraser tool

The eraser tool was developed to support the trial-and-error aspect of the planning activity. Although not intentionally designed as a tool to explicitly support dialogue, the function of the tool aimed to support learners in undoing previous actions and in the decision-making of future actions. Using this tool on a digital land use representation caused the graphic image to delete and adjust the display results from the impact tool.

3.3.7. Tools to support awareness

Antle and Wise's (2013) Guideline 10 informed opportunities for gaze and awareness in the technical design. The goal was to encourage learners to discuss and engage in information in order to make sense of the current events, so students "monitor each other's activity and gaze to support the development of shared understandings" (Antle & Wise, 2013, p. 13). Deliberate viewpoints and positioning of learners were considered in order to maximize opportunities for learners to directly monitor each other's actions and view the digital information being displayed. Several of the tools also supported awareness as they contrasted in colour from elements on the screen activity, and provided enlargeable and rotatable feedback for both learners to see. Shared tools could also pause the activity to encourage learners to slow down their actions and reflect on and discuss their decisions.

3.3.7.1. Interdependent relationships of tools and resources

In order to support "creating constrained or co-dependent access points schemes (which) compel learners to negotiate with each other" (Antle & Wise, 2013, Guideline 12, p. 13), the interconnected tools used two-step actions to make learners reliant on each other. Limited resources of each tool required learners to have to make trade-off decisions. For example, use of water, trees and coal were in limited supply. Water could be allocated to provide hydropower (as an alternative to coal plants) to supply energy or to provide various allocations of food. River reserves provided very little food for a small group of people, gardens provided enough food for a small group of people and farms provided enough food for a medium group of people. Use of farms allowed the population's needs to be met faster; however, the trade-off was that the farms required more water and more land space. While the use of hydro dam supplied energy, the dam also detracted water from the food suppliers and flooded the surrounding area (rendering the land unusable for other developments). In most cases, a resource-reliant stamp was required to be played first before a development stamp. These designs supported a space where learners were encouraged to discuss trade-offs and potential damage (e.g., where to put the homes, and how to use the resources). The diagram below lists the relationships between the tools.

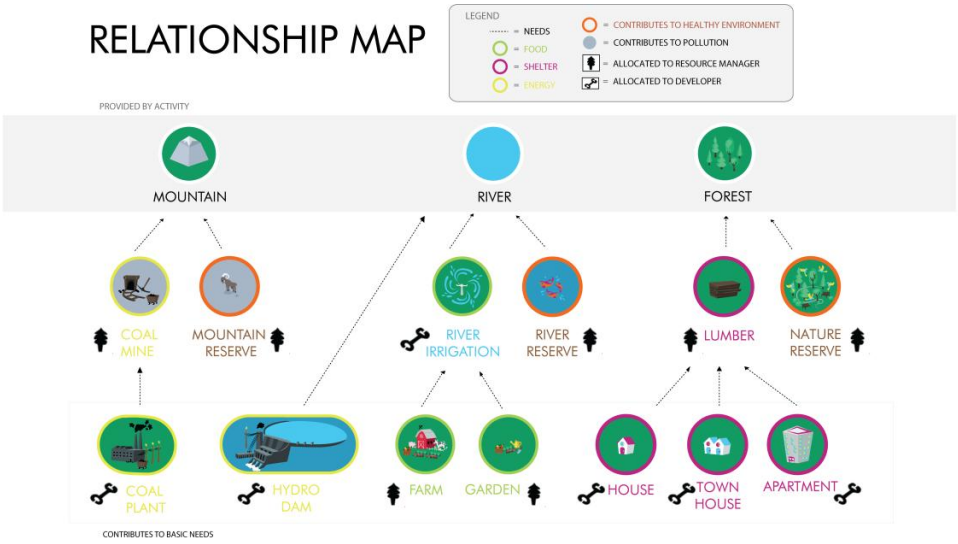

Figure 1. Relationship map between tools

3.3.7.2. (Optional) use of two roles

Antle and Wise (2013) also placed an importance on how information and actions are delegated: "distributing roles, information and controls across the TUI learning environment can promote negotiation and collaboration" (Guideline 11, p.13). The goal of introducing assigned roles was to enhance learners' reliance on each other and the need to consult each other to buy into decisions (relating to an aforementioned literature review on roles supporting positive interdependence. This supported negotiation because learners were situated in contexts which needed them to discuss what they needed with their partners and to share their differencing experiences to gain a full understanding of their responsibilities, abilities and limitations in order to carry out actions. This was an optional decision that could be used by reading a script which emphasized the responsibilities between a developer and resource manager and divvying up the land use stamps into two categories technology/developments and natural resources. The responsibilities over these items were implied; e.g., a developer would have ownership (Speelpenning et al., 2011) over technical developments such as: river irrigation, coal plants, hydro dams, houses and apartments.

The purpose behind the implied roles was to enforce learners' responsibilities regarding the tools which they could use. For example, a developer may develop land rather than conserve it; but the overuse of their tools would pollute the world and make it difficult to attain adequate levels of food and shelter. For the resource manager, complete conservation efforts kept the environment free of pollution, but food, energy and housing needs could not be met. The optional division of the responsibilities of these tools helped to reinforce the need for dialogue and negotiation in their decisions.

Figure 2. Photo of resource manager tools
(From left to right: mountain reserve, garden, lumber, farm, river reserve, coal mine, nature reserve). The impact tool is being used to display progress.

3.3.8. Summary of important TUI characteristics

The previous section described several features about the learning design and technical specifications which have been designed to support negotiation and information sharing. The particular designs for supporting collaboration and encouraging learners to dialogue include the interdependence/division of tools between two roles (developer and resource manager). To support awareness and gaze, features such as the feedback tabs and info cards were developed to be rotated and resized. The impact tool and info ring were developed to create opportunities for learners to reflect on their progress and options. The impact tool was also designed to display an unbiased view of the world with a question to prompt learners to discuss their values and interpretations about the results. The info ring was also created to support the exploration of information and learning about trade-offs.

3.4. Previous Research on Youtopia: Summary of Findings

In a quantitative study of Youtopia, the learners were generally found to work together (Wise et al., 2015). Several additional results were discovered about learners' interactions in regards to time spent on negotiation and roles, and positive engagement of learners in collaborative play (vs. cooperative/parallel play). Some highlights of the results included:

1. Only a small amount of time was spent engaging in in-depth talk. Differences in the length of time engaging (better chance for learning) only occurred in a small amount of cases, but when it happened it was valuable (p. 7)

2. More time was spent on learners explaining their reasoning than on negotiation itself (p.7), and learners did not negotiate more if given roles (p.8).

3. When roles and tools were not assigned, learners engaged in more conflict with both joint and unilaterally resolved decisions. When roles and tools were assigned, learners engaged in jointly-resolved conflict over longer periods of time (perhaps leading towards more opportunities for rich conversation (p.7).

4. There is a need for continued exploration into analysing the "golden moments" in collaborative learning" of valuable, in-depth conversation (p.7). The time of extended dialogue was found to involve a deeper negotiation around values, and this seemed to be an important area for investigation.

In reviewing the results, it became clear that by studying the dialogue of learners in conjunction with their actions could lead to some new discoveries about what supports the 'golden moments' in conversation. By examining how learners used tangibles which were designed for collaboration and negotiation, there would be potential to better understand how they could shape language, and enhance opportunities for dialogue. To further explore learners' speech and tools in their interactions in Youtopia, the next section describes the study's approach to find out more about the roles that tools and speech played in the learning process.

Chapter 4.

Methods

4.1. Research Question and Approach

This study seeks to answer the question: **How were speech and tools used together by students in their interactions with Youtopia?** To address this question, a discourse analysis study of archived video recordings of children using the system was conducted, using Speech Act theory as a conceptual lens to understand the details of learners' dialogue and how their dialogue shaped their interactions with tools.

This approach used discourse analysis because it allows for the review of "linguistic structure" to study the interaction processes and for the "meaning, interdisciplinary, social roles and relations, communication and identity" between speakers to be examined, and more importantly, examines the "the structure and the function of language in use" (Johnstone, 2008, p.4). Discourse analysis permits researchers to "focus on what the members make relevant in their talk" (Ziegler, Paulus & Woodside, 2013), and this is particularly important because by understanding more about speech, we can discover more about the role of language in learning processes. Discourse analysis methodology also aligns with a social constructivist perspective in that knowledge and truth is a construct of the discourse (Jorgenson & Phillips, 2002, p.13). Speech is a key part to understanding collaboration, or as Falcão and Price (2011) described "analysing the combination of verbal discussion and physical action is fundamental for understanding collaborative learning around tabletop computers" (p.550).

4.2. Use of Discourse Analysis to Explore the Context

Stahl developed a knowledge-building model to explain the relationships of personal understanding, in relationship to shared understanding through interactions with people. This model considered several aspects important to the social learning process: negotiation of perspectives, describing argumentation and rationale to clarify meanings and use of cultural artifacts, and experiences which play roles in shaping the understanding of the people engaging in processes together (Stahl, 2000, p.71). Stahl described that, in verbally explaining understanding, learners are forced to resolve differences "by reinterpreting our meaning structures– to arrive at a new comprehension. This typically involves some feedback from: "artifacts such as our tools and symbolic representations" (Stahl, 2000, p.72). When learners accept new understandings, they become reference points and comparison models for new experiences.

Discourse analysis permits the analysis of speech at the micro level, in order to draw wider perspectives about what the language means in context and how it shapes the context of use. Employing a discourse analysis lens on learners using Youtopia helps to explore answers of how speech and tools could shape their experiences, interactions and learning opportunities. This encompasses opportunities to focus on the "wider picture" of utterances and meaning and offers flexibility on the analytical structure, as well as more opportunity for inferences (Wooffitt, 2005, p.88). Conversation analysis was an alternative approach that could have been used (Psathas & Anderson, 1990), which, similar to discourse analysis, examines speech, but according to Wooffitt (2005) focuses more on the analytical framing and structure of routine activities (p.86) with the goal of examining repeatable instances of the same phenomenon (e.g., turn taking and sequence organization (p.88).

This study included many unpredictable features of children's conversations (e.g., rapidly changing topics, referring to non-descript items, gesturing in place of speech) and did not follow regular conversation patterns. Thus, an approach with a less restrictive methodology (discourse analysis) was required to draw larger findings about what was spoken about, how tools were used to facilitate their goals, and how learners communicated and how their interactions informed their knowledge processes.

4.3. Speech Acts Theory in the Analysis of Youtopia Interactions

Uses of discourse analysis in tangible and interactive technology studies were reviewed for their approaches to studying about group learning processes, as this would be most suitable to answer the research question. A method that allowed for both structure and room for interpretation about the language and the actions was needed. As a form of discourse analysis, Speech Acts theory (Searle, 1969; Searle, 1979) was used to analyse the relationship between speech and action because of its ability to examine speech as an action, allowing researchers "to make useful guesses about what the utterance is meant to accomplish" (Johnstone, 2008, p.231). Speech Acts was seen as a unique lens because of its opportunity to examine and consider language and actions between learners together, whereas other frameworks focus on either speech or actions. For example, researchers such as Heidegger (1978), could allow for focus on the availability of tools and how they are used, or other approaches such as Fairclough (2013) could be used to critically examine language related to social implications or examine meta-functions of language about the world (Halliday, 1978). Although each of these lenses looks at either speech or actions, Speech Act theory allowed this author to examine both of these simultaneously.

Speech Act theory provided a useful perspective to study learners' intentions through their requests, actions, questions, and directions by focusing on the meaning of language (pragmatics) instead of the exact words and utterances (semantics). Searle's (1969) Speech Act theory includes three parts to speech; the speaker's intended meaning or purpose (illocutionary act), the actual words (locutionary), and the hearer's reaction (the perlocutionary 'force' of which the speech has on the listener to respond or act). According to Searle (1969), speaking "is engaging in a rule-governed form of behavior" and linguistic communication has symbolic meaning, and is "performance of the Speech Act" (p. 16), or a goal that the language seeks to perform. Although there are many avenues to interpret or break apart the individual speech acts of language, there are five overarching illocutionary (speaker's purpose) categories (Searle, 1979) which have been adopted in order to explore the learner's use of tools in conjunction with language). The categories include:

- assertives (the provision or sharing of truthful information);
- directives (ordering or providing instructions, often in reference to a tool);
- expressives (sharing information about one's psychological state, personal values or opinions);
- commissives (providing utterances which commit themselves or their team to actions);
- declaratives (redefining the reality of their actions (often with some level of abstraction)).

Speech acts presupposes several factors about the speech in context, particularly truthfulness/sincerity and what can be reasonably taken from the speech. This theory has guided thinking about the use of language and tool use to analyze the actions of the learners, and provide a lens to describe how learners worked through their collaborative processes through the above five categories. For example, opportunities for negotiation may occur when one learner announces a directive (e.g., can you stamp a tree?), while the other learner follows up with a directive bid of their own (e.g., can you stamp river irrigation first?) for the other to perform an action. A directive could also be followed up with an expressive or assertive comment where the other learner describes their reasoning why they disagree (e.g., we actually need more food than we do housing). This may be followed up with a new directive request or committing to a goal (e.g., Okay, let's build some houses). The use of tools could also support their negotiation if learners: held, pointed with, or used stamps, or showed the impact tool to reveal the results to support their cause, or the info ring and stamps to explain why their idea might be a good one.

The table below outlines some examples of how the Speech Act theory was used in the Youtopia context with possible uses for the acts, the implications on the listener and examples of how these were used. Declaratives were rarely used by learners, and were only visible in only a handful of examples.

Table 4.1. Speech Act Lens for Youtopia Analysis

Speech Act	Explanation	Possible uses	Implications	Examples
Assertive	Verbalizing information about the world	-share information -prove/disprove a concept -provide evidence/ convince - use a tool or refer to tool's information -distract with irrelevant information	-This causes the other learner to agree or disagree - Can be collaborative when information is shared for the purpose of explaining/ understanding or opening conversation - Can also be used to shut down conversation – to make a point and get the other to accept	Assertive with impact tool: A:"Many people have energy, many people have shelter" B: "everyone has food" Both learners holding the impact tool or touching impact tool circles as they speak
Directive	Instructing the other to perform particular action, via direct/indirect language	-to plan/discuss possible ideas -to get other learner to do what they want -to test what happens when they stamp something - to move the activity forward	-This may be followed up with a rejection, alternative suggestion, agreement or follow-up action. - Can be collaborative when used to plan, sometimes in incremental steps -Can be used to dominate partner and control activity	Directive about a stamp: A: "put it... near a river" B: (silence) stamps river reserve
Expressive	Led by emotions, learners express why they want/ don't want to do an action (expressing attitudes)	- to share values/ perspectives -to provide personal reasoning	-This helps the other learner to understand their thoughts or give alternate information -Can be used to convince other of a plan (get buy in) - Can be collaborative in sharing personal information to start a dialogue	Expressive to provide reasoning while pointing: A: "you know, farm's look alone" B: "yeah" A: "should add a house then"
Commissive	Committing learners to act on some goal	-to aim to get both to agree to a plan/action -to make the other aware of their action without letting the other intervene	- If given time – allows other learner to intervene - If not given time – the learner has no choice but to watch partner act, and then question the action	Committing as they stamp: A: "get the info ring again...see this..." as learner uses the info ring B reads: "Small... population"
Declarative (Were not commonly used in Youtopia's context)	Changing the reality of their actions by stating something	-stating something with intent to change the state of affairs	- This may cause the partner to agree or disagree (if they think it's valid or not), ignore, or silently accept - Can be used to distract their partner/change topics - Can be used to address activity rules/dynamics	Stating a change in affairs: A: stamps near their partner and the partner declares which side is theirs, "not on my side. This is my side, that's your side."

4.4. Using Speech Act Theory to Examine Learner's Interactions With TUIs and Other Technologies

Speech Acts theory was used as a framework to focus on the use of tools with speech, because this study places a dualistic importance on the role that communication plays with interactions. In this study, the tools are operational in the activity, and as well, language itself functions as a tool. Speech in this way was examined for its function to support learner's interactions. In recent years Speech Acts theory has been used in the technology field to: develop game and language protocols (Zhang, 1990), study the differences in interaction between paper prototypes and tabletops (Buisine et al., 2012), and look at how potential actions can support decision-making (Rogers et al. (2004). In Buisine et al.'s (2012) study, they looked at interaction analysis with a Speech Acts lens but focused on the counts of particular criteria happening by looking at the number of speech acts, the communicative gestures and inequities between a paper-based and digital tabletop activity. They looked for assertions, information requests, action requests, answers to questions, expression of opinions and off-task talk (p.53) from a quantitative lens.

The study with the closest perspective to this one is from Rogers et al. (2004) who provided the most relevant research involving speech acts in coordination with actions and tabletops. Rogers et al. (2004) looked at how decision-making could be supported with a multi-touch tabletop, looking at "talk as decision-making components." These examples included "suggesting an option, asserting, rejecting, suggesting an alternative and justifying" and "classif(ying) the actions and interactions that took place at the table in terms of finger movements (e.g., spinning the calendar, moving an image to the workspace)" (p.3). Rogers et al. (2004) found that learners "manipulated and moved the images around on the tabletop in a way that supported them" using with five normal interactions: "asking a question," "instructing another," "making a suggestion and inviting," "requesting confirmation and inviting" and "offering and inviting" (p.3). However the transcription and analysis methods were unclear and only minor examples were provided to show what the dialogue and interactions looked like as Rogers et al. (2004) described actions with dialogue.

4.5. Data Source

The data source made available was a set of video recordings of 20 pairs of children engaging with Youtopia. The video data of 20 pairs of fifth grade children (10-11 years old) was collected in a prior study where learners used Youtopia to build a world "they would want to live in" over a 25-minute period, following a tutorial. The pairs knew each other and were organized by the teachers who chose pairs who worked well together and were mixed genders except for two girl-girl pairs. The sessions took place during regular school hours, but in a separate room from their regular classroom, across the span of a week in May, 2013.

Half of the pairs were given scenarios describing the roles and tools of a resource manager and a developer (the tools labeled with a tree and a wrench respectively), while the other half of the pairs were not given specific roles, and the tools were grouped together for both learners to decide how to share. As the difference between roles and non-roles categories were not being compared in this study, all of the videos were reviewed and examined as a complete set. The videos were reviewed on a secure server in an SFU lab.

4.5.1. Selection criteria

The original research team was consulted about their methods (including coding strategy, observations, and findings) prior to the episode selection. Episodes were targeted to find the best examples of collaboration in which tools were used to support learners' interactions and opportunities for dialogue. Initially, the original quantitative study coded for *"conflict"* events and "*in-depth"* events. Events in which one or both children explained their thinking or reasoning, these were coded as In-Depth Events. The researchers in the original study noted that the coding may have restricted some findings: "(i)n future work it may be necessary to relax these requirements to include a larger swath of relevant talk" (Wise et al., 2015, p.7). Examining the identified episodes from the pre-existing coding scheme would have limited the number of viewable videos significantly (e.g., in-depth coding was observed in only 5% of the video).

Therefore, rather than using the pre-coded episodes, this study started anew in identifying more liberal instances of in-depth thinking and conflict. In addition, two new ways to identify episodes were added to further develop the scope for findings that might be considered 'collaborative' or lead towards talk or actions that could be considered 'collaborative'. *Same-page thinking* was added to further develop the scope. This was a heuristic developed from Roschelle and Teasley's (1995) definition of collaboration, viewing learner's attempts to maintain a shared understanding of the problem space. Additionally, the research remained open to identifying episodes that captured particularly interesting forms of collaboration, even if they did not fit into one of the three pre-identified categories.

Upon discussion about coding for conflict and resolution and in-depth conversation with members of the research team, the categories did not include the *how* and *why* behind how conflict was solved or how learners shared information. Findings about how learners shared and dialogued information that led to same-page thinking or interesting forms of collaboration with the use of tools and language had not yet been addressed. For example, one person could discuss their thinking and the other person could completed their sentence, or come to a similar conclusion while their partner was contemplating an idea out loud. With the addition of two additional episode identification categories, the study was better equipped to look at the variety of interactions and the kinds of opportunities that led to shared moments of learning. The parameters were expanded to the below categories.

4.5.1.1. Conflict

Conflict was defined as learners verbalizing disagreement to another person's action or utterance in context of sustainability, particularly if learners had a difference of opinion on a decision that was made or was the process of being made. Conflict could end in compromise, abandonment, or a unilateral decision. In this study, episodes of conflict were extended to describe situations of verbal or non-verbal disagreement occurred between the partners, often where one learner took an action that prompted their partner to protest. This was apparent through some of the following examples:

Types of examples	Real examples
Having a disagreement about information/ purpose of a tool	A: "Why are the reserves making pollution?" B: "No they're not, they're helping." A:"Oh"
Raising their voices/cutting each other's sentences off	A: "Oh! A [large population]! B: "[we don't need that much]. A: "[we can...] B: "[there's a little pollution] so I think that…
Blocking/holding tools away/ trying to force stamping/ acquiring other's stamps	A:"let's just put like, a salmon, a salmon a salmon" - as she reaches for the stamp he holds it away while also holding impact tool
Having misunderstandings about plans (or what was agreed upon/or not)	A: "let's get some wood B: "Oh that's the…no] A: "No that's your job. You're the resource [extortioner]"
Completing actions without partner's input, to which the partner protests	A: laughs and stamps mountain reserves B: "no that's too many" A: "That's a little" - stamps impact tool

4.5.1.2. In-depth

"In-depth' coding from the first study included learners using reasoning or justification for actions which reflected the learners' values (not just preferences) and whether this happened separately or together. In-depth reasoning was expanded in this study to explore examples where one or both learners described why they should complete a particular action based on some facts or opinions. Some examples included:

Types of examples	Real examples
Reflecting about cause/effect in the activity	A: holding the impact tool and reading the display- "so I think we need more food... That's good, that's good. Not that much pollution. So I need food"
Expressing what they want to change and why/ arguments about something	A: "let's add one more nature reserve" B: "no" A: "just one " B: "no" A: "because ... [there's still a lot of...]" B: "[but there's so much] population" -"then there'd be people sitting on the streets. We should add another house"
Planning based on a prediction, based on previous experience	A: "Let's make a coal plant thing, if we use. if we do too many dams we're gonna run out of water" B: "Okay"

This category was used to understand how tools and associated information were used in Youtopia to support their reasoning and provide evidence to take a particular approach. This also addressed how negotiation/decision-making occurred by the sharing and compromise of information as learners increased their abilities to talk about their experiences.

4.5.1.3. Same-page thinking

The new category, same-page thinking was used to describe examples where learners' efforts and/or dialogue appeared to be focused on a shared objective. This appeared to be supportive in nature and dialogue often built on each other on a shared topic. The process where two learners work together towards same-page thinking seemed to be visible in examples such as:

Types of examples	Real examples
Talking through proposed next steps/ providing pauses and opportunities for the other learner to engage or provide feedback	A: "power comes from this" - points at dam B: "and that..." -pointing at coal A: "this is getting used up at least" -points at hydro in her corner
Discussing the state of affairs	A: "let's put a few more parks"- pointing at the impact tool B: "ah that's good" - looking at impact tool A: "and the goats are good."

4.5.1.4. Miscellaneous

Interesting forms of collaboration were created as a final category as an additional catch-all if an example did not fit into the first three categories. This criterion was meant to include any other episodes that provided unique or typical forms of interactions with tools. For example, when learners used tools and/or language to:

Types of examples	Real examples
Ways maintain/distract the attention of their partner (e.g., pointing with, initiating actions, compare before and after results)	Distracting: A: "That could create… huh. that could create lots of pollution" B: picks up info ring- "is that just tape?" A: "um I dunno. Or I think it's just …" Maintaining attention: A: "Is there any electrical lines you can put?" B: "No, this this is effective for electricity for people to have." - (hands coal plant to him)
Test an idea with the promise of undoing it if the desired outcome wasn't achieved	A: "let's see if 2 houses are the same or not" - erases townhouse B: "Let's try for 2 houses." A: "yeah that'll work. House. One. two impact" - stamps two houses and impact tool
Influence activity domination or trying to stop domination	A: "where's the- do we need number?" - reaching for the garden tool in B's hand B: "ahhh just put it down and see what we need"- pushes A's hand/tool on the table

4.5.2. Selection process

After these types of conceptual categories were identified, the videos were examined for episodes that fit into any of the criteria. This entailed a rigorous process of reviewing each of the 20 videos multiple times. The initial viewing included watching the video from start to finish, with occasional pauses to note time of interesting moments. The next pass required a viewing while frequently pausing the video to examine dialogue and actions while also noticing specific times and transcribing example segments of speech with notes on why this was interesting. Of the 20 videos, between zero to nine episodes were chosen and transcribed from each pair's videos (with most of them ranging between two to seven episodes), examining multiple back and forth utterances. Two videos involved quiet learners who engaged in very little collaborative dialogue; therefore no episodes from these two videos were transcribed. The final pass involved transcribing utterance and action details in-depth from multiple episodes when a major contribution was spoken until the train of thought or conversation topic changed or concluded. The start of the episodes was determined by a topic changing statement (such as explicit information sharing assertives, expressives or new direction) in combination with or shortly after use of the impact tool, info ring, eraser tool, or a stamp, followed by several turn-taking statements. Episodes ranged from five to 120 seconds (with most of them being between 30 to 45 seconds). Episodes ended with a conclusive statement or summary of learner's discoveries/actions or a statement about a new topic direction.

A total of 100 episodes fitting within at least one of the four criteria were transcribed. The amount of time transcribed was approximately 60 minutes over the 20 videos (roughly 8% of total data available).The fact that the number of episodes was exactly 100 was coincidental. The 100 episodes allowed for a diverse set of opportunities to examine how learners engaged in various decision-making and verbalized thought processes, how they explored, what negotiation could look like under certain pretenses, and how they used tools and language in ways that enhanced their information sharing and learning experiences. Details about the transcription method are described in the next section.

4.6. Transcription and Analysis Method

This section describes the simultaneous transcription and analysis approach, and addresses how Speech Acts theory was used in the analysis. Using Speech Acts as a conceptual framework, the transcription and analysis process considered how Youtopia tools were used in conjunction with language and actions (i.e., how the tools supported speech and how learners spoke around the tools). The work of Stahl et al. (2015) and Ziegler, Paulus and Woodside (2013) influenced the transcription and analysis template as they examined how language could support tasks. Stahl et al. (2015) presented an effective way of describing speech and actions by reviewing how tools were used (e.g., to explain current events) and documenting aspects of conversations and actions in easy-to-read transcripts to paint clear pictures of the events. However Stahl et al.'s (2015) study involved digital actions and lacked the subtleties of face to face interaction. Ziegler et al.'s (2013) transcription method was descriptive and concise and looked at how speech acts could inform online posts, they did not have to transcribe data, nor were there corresponding actions to the speech. Therefore, a modified transcription method had to be developed in order to fit the needs of this study.

Based on a review of the above papers and early video viewings, a new transcription and analysis method was revised to include a Speech Acts lens in the line by line analysis. Originally, the transcription method for Child Language Data Exchange System (MacWhinney, 2000) was utilized because of its ability to capture actions as well as dialogue and easily run through a transcription system. However, the transcription method itself was more appropriate for quantitative analysis and would not allow for much interpretation using qualitative analysis. Instead, a working transcription and analysis template was developed to capture as much as possible about what the learners were talking about and how their interactions were important. This included documentation of: utterances, actions, Speech Acts and ways these could influence the design of TUIs. (See the below table). In order to increase readability, transcription notes were also included; "[ ]" for overlapping speech between learners, "xx" for inaudible sounds, "..." for trailing off, (.) for long pauses or silences, and "//" for being interrupted (adapted from Psathas and Anderson, 1990's guidelines for conversation analysis).

Table 4.2. Transcription and analysis template

Video identification #					
#: High level theme(e.g., using tools in interesting ways)					
Time	**ID**	**Dialogue**	**Action**	**Speech acts to interpret events**	**What are we learning about TUI design?**
					High-level reflections: Design questions: Validation of design decisions:

This template was piloted on the first two video passes to see if this information could be captured and if it could produce an appropriate level of detail with preliminary thoughts on how the episode could inform design. The approach was modified to fill out this template as each episode was transcribed and analysed. The final step in the transcription phase was to iteratively review and compare the documented dialogue and actions, interrogate the differences and revise the transcripts where the utterances were unclear (e.g., any initial misunderstanding of words would be noted as 'XX', after 5-7 repeat plays of the utterance, 'XX' placeholders were ideally replaced by improved documentation of an utterance).

4.7. Thematic Analysis and Consolidation

This section describes how the thematic analysis of transcribed episodes was conducted. With an overall focus on how tools and speech supported learners' interactions, four analytic approaches were used to initially develop the themes. The approaches to analysis examined the themes from the various angles, and these were later compared and compiled to highlight opportunities and barriers for collaboration. This resulted in a final list of six overarching themes with 16 subthemes, which were consolidated to include repeating themes from the categories. The first approach included a broad look across high level themes. The second approach looked at intuitive themes which arose from across the episodes. A third approach examined multiple interactional/tool use micro themes within each episode, and a fourth approach had a particular focus on speech acts and use of language within the episodes. In the investigation of the 100 episodes, high-level and intuitive (first impression) themes in the first pass of thematic analysis were generated, however, these did not provide a deep

enough level of exploration. Micro-themes and Speech Act themes were added in order to retrieve more elaborate and varied descriptions of speech and tool use in each episode.

4.7.1. High level thematic analysis

As transcription took place, high-level themes were also documented with the episodes. The high level themes were chosen to capture reflections about interesting interactions, such as deciding what goal to pursue when human needs were equal or handing a partner a tool to do something. These 100 high level themes (one per episode) were thematically grouped together in nine categories and 19 sub-categories. However, the themes didn't succinctly capture all of the activities that happened in the episodes and several themes were difficult to map together.

4.7.2. Intuitive thematic analysis

The intuitive theme list was completed next by reviewing the high level themes and generating a list of several themes that stood out after the analysis without grouping the episodes together. One example of an early theme that was identified was: *Dominant personality forcing an action.* This list helped to reinforce noteworthy patterns of tool use and/or speech, and captured about 30 themes. The intuitive theme list was useful as a starting point for looking at themes, but did not capture a fulsome range of examples.

4.7.3. Micro themes and Speech Act thematic analysis

The last stage of generating new themes included the development of a larger and more detailed micro theme list. This involved reviewing and documenting one-to-five interesting observations in each episode for relationships into the use of tools and language (e.g., how a tool was used to achieve a goal, or tools being used to dominate a conversation). Speech Act themes were added in order to provide additional focus on the analysis of speech, examining the use of the five identified speech acts. This

generated a list of 18 major themes to examine the combinations of tool and language used, while noting the episode numbers where these occurred.

4.7.4. Consolidation and expanding on themes and examples

The final step of analysis was consolidating the themes to guide the writing. The transcripts were used to talk through the episodes and provide interpretations for speech and interactions. The episodes were examined to see how the thematic patterns were characteristically initiated, what the themes involved, and view variations of ways learners used tools and speech within the particular categories. With an overall focus on supporting collaboration, the four approaches to analysis were used to develop new themes. The last step was to compare and consolidate the initial themes to create a final set of themes and subthemes drawing from all four analytic approaches. This resulted in a final list of six main themes with two to three variations of how the related findings occurred, with concrete examples of each. The findings were presented similar to Ziegler et al. (2013) and Stahl's (2011) findings by presenting an interpretation of each theme, and using excerpts from episodes while describing language and use of tools, what the episode described, and how it affected decision-making and collaboration. Two additional sub-themes were absorbed into the sub-themes: *5.1.3 Discussing activity relationships to inform future decisions*, and *5.3.3: Sharing values to influence their partner's decision,* because they were very similar in the expanded explanation. The final analysis included six overarching themes and 16 subthemes. The summary table references the themes and subthemes and links them to the episodes in which they can be found. The episode examples were chosen to include the clearest and/or most verbose examples in the subtheme category, or present the most interesting examples based on learners' combinations or use of tools.

Table 4.3. Evidence of subthemes with listed episodes

Theme	Subtheme	Episodes providing support	Episode from which excerpt was taken
1. Exploring the activity logic together	a. Finding out the purpose of a digital land use representation	1,19,20,21,22,32,41,48,59,61,64, 65,72,76,78	64
	b. Finding out about trade-offs to decide what digital land use representations to use	36,42,61,74,75,81	81
	c. Discussing activity relationships to inform future decisions	3,4,5,9,17,22,31,36,45,58,68,69,73, 87	58
2. Proposing plans and suggestions	a. Proposing plans to improve the results	3,4,9,18,23,29,37,40,47,54,66,69,10 0	69
	b. Proposing responses to feedback	5,6,13,21,30,40,51,58,59,71,78,84,9 0, 98	18
	c. Redirecting the course	10,11,12,14,44,56,90	90
3. Advocating for a position	a. Providing evidence	5,6,7,13,35,47,59,60,81,84,99	59
	b. Explaining rationale	2,8,14,18,31,33,42,45,50,56,57,62,7 2, 82	33
	c. Sharing values to influence their partner's decision	5,7,9,14,16,22,27,45,58,62,83,80	45
4. Testing a hypothesis	a. Predicting the use of a tool supports particular outcomes	22,41,62,83,84,99	22
	b. Testing before and after results	53,58,62,69,70,100	70
5. Working cohesively	a. Creating new language/ common plans	3,16,28,34,35,38,39,46,51,57,63,66, 88	46
	b. Turn-taking and providing permission	2,6,16,21,35,37,40,57, 73, 77, 78, 90, 91, 95,96	78
	c. Working with conflict	8,11,12,14,16,24,26,27,28,30,50, 52, 59, 66, 79, 85, 86, 97	86
6. Controlling decisions	a. Taking unilateral actions	5,10,28,29,33,34,55,68,92,94	34
	b. Engaging a non- attentive learner	7,28,43,66,93	43

4.8. Trustworthiness

This section explains considerations for reviewers to accept this study as trustworthy, based on the Lincoln & Guba (1985) approach to naturalistic studies of the qualitative nature. As this study used a qualitative approach, these four categories were more appropriate to measure the degree to which reviewers can be convinced of the research findings rather than reflections on empirical studies use of: internal validity, external validity, reliability, and objectivity. Therefore this section describes the approaches taken by this study to mitigate the threats to trustworthiness by reflecting on credibility, transferability, dependability and confirmability of this research.

4.8.1. Credibility

Credibility describes the degree to which a study can be perceived as truthful and accurate. According to Shenton (2004) “investigators attempt to demonstrate that a true picture of the phenomenon under scrutiny is being presented” (p.63). This study integrated considerations for several ways to address that the depiction of the findings were a reasonable interpretation of what happened. “Triangulation” (Lincoln & Guba, 1985, p.305) was one approached used; which included using the data sampling source, methods, and coding themes to see consistent views. In review of the data set, all 20 videos were considered in order to seek a wider variation of interactions in the development of the themes. Using these, the consistent or interesting patterns could be found amongst multiple sets of learners. Raw data, collected data and thematic descriptions were reviewed and revised over several months. Thematic descriptions cross-referenced the collected data. Where features of the actions were unclear, the author went back to the video data to review and clarify details as needed. As well, “referential adequacy” (Lincoln & Guba, 1985, p.324) could be traced back from the episodes matching the time sequences of the videos, themes/subthemes matching the episodes and back to videos.

This author's involvement with the literature review, development of the learning goals of the Youtopia system, and video data, transcription and analysis data was over a prolonged period of time (3 years), with the benefit and bias of knowing the intentions of design on the system, as well as a relationship with other researchers involved of the analysis of the data for different studies. This also provided the opportunity to discuss information and mitigate misinformation.

Regarding "Peer debriefing" (Lincoln & Guba, 1985, p.308), the research team had differing levels of participation in this study, as well as "frequent debriefing sessions between the researcher and his or her superiors" (Shenton, 2004, p.67). Some members of the research team were involved in the early shaping of the coding approach, and advisors on the project had also reviewed raw video data, and transcription and findings. However due to the lengthiness of the collection and analysis process, and limitations in access to the video data, it was not possible to have a second coder involved in the video transcription process.

Keeping in line with the recommendation of "negative case analysis" (Lincoln & Guba, 1985, p.309), the original research question and design question were adapted to the findings of the research rather than a hypothesis shaping the findings. Originally, the research question looked only at decision-making and negotiation processes, but was extended to look at other possible interactions as well (e.g., conflict, power struggles, physical uses of tools, supporting collaborative or unilateral actions, use of reasoning, combinations of tools being used in interesting ways, how learners were able to convince each other to buy-into a plan or convince someone else to do something for them, etc.). The research question which focused on all interactions of the learners allowed for the full findings to be accounted for. The design question was developed as a way to focus on the implications for design after a review of the findings was complete.

4.8.2. Dependability

"Dependability" (Lincoln & Guba, 1985) relates to the quality of the research and the ability to replicate the study and find similar findings (p.317). Due to this author's involvement with the design, an auditing researcher would not have the same level of insight about the goals and conversations the research team had. This might influence a bias to describe or not describe some features or interactions that other researchers may not have recognized in the video study. As described in the earlier sections, the methods undertook a rigorous process of reviewing and confirming multiple approaches to video review and coding in order to find a large and diverse set of interactions. However as the process was described in depth earlier in this chapter, an 'audit' (Lincoln & Guba, 1985, p.317) could be performed to find how the approaches framed the study, and make a strong case for why certain decisions for an emergent methodology were used. Several themes repeated across the coding and thematic analysis and several themes were viewed across episodes and students (as evidenced by thematic chart). As well, the transcription approach used review and comparison of transcripts and at later dates. This aligns with transcription approach of intrajudge assessment as it considers how a person agrees with themselves comparing responses from the same recording on separate occasions (Salazar, Crosby & DiClemente, 2015).

4.8.3. Transferability

"Transferability" (Lincoln & Guba, 1985) addresses the applicability to other contexts (p.316). The transferability of this research primarily extends to guide general design, and can be extended to other projects of a physical nature (specifically multi-touch and TUI systems). As claims for design considerations have been based in evidence of learner's interactions with the system and tools, a reasonable transferability can be reviewed from other collaborative systems with tools that have similar design features. This study also describes several of the below features to establish the context: descriptions about the participants (of the previous study), data collection methods, number and length of data sessions (Shenton, 2004, p.70). The findings show that this methodology may be worth exploring further as a starting point for other research and design approaches by examining the combination of speech and tool use with TUIs

(additional reflections are presented in the *6.6: Limitations*). More importantly, several of the recommendations in the design implications section describe qualities which would be useful to researchers developing TUIs for collaboration (based in the findings from the study).

4.8.4. Confirmability

Confirmability describes “the extent to which the data and interpretations of the study are grounded in events rather than the inquirer's personal constructions” (Lincoln & Guba, 1985, p.324). The transcription and analysis template was developed to capture as many details as possible in order for a reader to visualize the actions and speech as they happened, while also considering how the findings in the episodes could lead to future design. The detailed play-by-play descriptions and the level of interpretation were described in order for readers to see the links and determine that the claims were reasonable.

Chapter 5.

Findings

In response to the research question: "*How were speech and tools used together by students in their interactions with Youtopia?"* six themes characterizing the ways in which learners used the Youtopia system in combination with language were found. Each of the six themes includes a general description with two to three subthemes and examples using excerpts from the episodes to describe how the collaborative activities were carried out using tools and talk. (In addition to the tangibles, other design elements of the Youtopia system will also be described). For reference, Chapter 3: *Using Youtopia for TUI investigation* provides a description of Youtopia system, Table 4.1 in the *Methodology* section provides a description of the speech acts used to analyze the transcripts. The six themes were laid out to describe distinct (though in some cases overlapping) uses of the tools in combination with language, and are identified by speech acts in order to better understand how both the tools and speech supported the interactions. The section is followed by an overview table of the relationships between speech acts and tool use and the tool qualities which supported the different types of exchanges. These findings will be used in Chapter 6 to address the design question: "*What guidance and new ideas for the design of TUI systems for collaborative learning can be generated from these observations?"*

5.1. Theme 1: Exploring the Activity Logic Together

One of the main ways that learners used speech and tools in their interactions was to explore the Youtopia system together. Learners navigated the relationships of the rules, resources and developments by using tools (i.e., stamps, info ring and impact tool) to explore and talk through the information from the info cards, impact tool display and feedback tabs. The subthemes included: finding out about land use representations, learning about trade-offs and relationships of resource and development uses, and discussing activity relationships to inform future decisions.

5.1.1. Finding out the purpose of a digital land use representation

Many learners asked their partner for advice or support in learning about Youtopia by finding out what capabilities a land use representation had. This subtheme is related to *Theme 6: Testing a hypothesis* in that a learner could find out what a land use representation did, but Theme 6 also includes demonstrating a land use representation's qualities by testing a prediction about it. This category provides a wider generalization to explore an answer without a learner trying to prove or demonstrate a concept. For example, this could begin with one learner providing a directive to their partner to help them answer a question about a particular land use representation. If their partner was not sure of the answer, they could find out by using a stamp themselves or direct their partner to perform actions; this could occur in one of two ways. The first way involved placing a stamp inside the info ring and asserting some information. For example: a learner could assert what a land use representation needed (e.g., pointing out that a farm needed river irrigation), how it contributed to the basic needs or affected pollution, or what it looked like in its two stages of use. A land use representation such as lumber, river irrigation or coal mine could be marked "in use" by appearing as a grey image when another development relied on the resource that had also been stamped (such as housing, farm or coal plant). Or, once allocated, the land use representation would be available for resource use. In the second way, one or both learners used a stamp or tool and then assessed its effect. Often, the impact tool was used following the stamp to assert information on how their choice affected their results, seen in the example (see Table 5.1) below.

Table 5.1. Episode in which learners discovered that river reserve contributes to food and pollution using a stamp and impact tool

Time	ID	Dialogue	Action	Speech acts to interpret events
6:07	Barry	What does a river reserve do?	Picks up the river reserve	Barry *directs* Kate to answer to a question
6:08	Kate	put it like near a river		Kate not having an answer, provides a *directive* to help him find out the answer
6:09	Barry	(.)	Stamps river reserve	Barry follows *directive*
6:11	Kate	oh that puts fish there (.) so let's go to impact	Uses impact tool	Kate *asserts* what happened and *commits* to using the impact tool
6:15	Barry	I think it's our food		Barry *asserts* result of adding the river reserve digital land use representation to the system
6:17	Kate	oh it lowers down the pollution		Kate *asserts* result as she reviews information

In the example, the learners used a stamp and impact tool to find out information about the river reserve representation. At 6:07 Barry asked "what does a river reserve do?" as he picked up the stamp to get Kate's attention. Not having an answer, Kate directed him to "put it like near a river" as she expected a response from the system (such as a land use representation appearing, or a feedback tab to provide hints). After Barry stamped the river reserve, Kate asserted "that puts fish there" and directed Barry to use the impact tool at 6:11 to find out its consequences. Between 6:15 and 6:17, Barry shared "it's our food" and Kate described "it lowers down the pollution" after looking at the impact tool display.

Directives were used with stamps to draw attention to the tools and ask questions. A commissive was used to report that the impact tool would be used, while assertives were used to reference the impact tool's visual information as learners discussed their findings about the food and pollution levels. This example showcased one way in which learners used speech and tools in the system to find out the purpose of a digital land use representation through use of the impact tool and stamps. Digital features of the impact tool supported the pausing of the activity and helped map the results of the impact tool to their previous decisions. The physicality of the tool drew the partner's attention to explain new contributions, and the combination of the physical and digital features supported new understandings, as evidenced by learners' speech. This reveals that learners discovered and explained characteristics of a tool by vocalizing what they noticed in the context, and that the tool supported information sharing by allowing learners to pause the activity, point out information and describe their findings.

5.1.2. Finding out about trade-offs to decide which digital land use representations to use

Learners were also able to learn more about trade-offs in their decisions by exploring their options before taking action. This subtheme is similar to *Theme 4: Testing a hypothesis* in that it includes a presumption about the land use representation characteristics, but focuses on the evaluation of which land use representation would be more effective to meet a described goal or support their decisions in a way that seemed satisfactory. Learners did this by comparing information between the info cards when the used the info ring or by touching the impact tool circles. This usually occurred when one learner directed the other to use a stamp, and the other learner tested the stamp in the info ring before agreeing. They would then use assertives and expressives while touching the info cards or impact circles to reflect on the information and decisions, and use directives or commissives to plan their next steps. The example below (see Table 5.2) describes an episode where learners evaluated the trade-offs for the food options.

Table 5.2. Episode in which learner switched back and forth between farm and garden in the info ring to determine the better option

Time	ID	Dialogue	Action	Speech acts to interpret events
15:30	Zack	So we could just have a bunch of gardens		Zack *directs* Ava to the suggestion to create gardens, then *asserts* this would support meeting the food goal
15:35	Zack	Then that would help (improve food results)		
15:38	Ava	(.)	Holding several stamps	
15:41	Zack	Wait	Puts down info ring	Zack uses tool to *assert* information
15:42	Ava	(.)	Starts to put info ring inside, then pulls back and reads	
15:43	Zack	Garden	Uses garden in the info ring	Zack *commits* himself to putting the garden stamp in info ring and *asserts* information about its use
15:47	Zack	A small group (supplies food for a small population)		
15:48	Ava	Farm?		Ava *directs* Zack to check on the farm option
15:50	Zack	[Medium group] (Supplies food for a medium population size)	Takes out the garden and uses the farm	Zack *asserts* his findings
15:51	Ava	[xx medium xx]		Ava *asserts* her findings
15:54	Zack	Let's do these because it took three (farm uses three river irrigations) and this [beats the medium] (and provides more food)	Showing farm, taking off info ring pointing at her side	Zack *directs* Ava to stamp the farm based on the information that farm provides more food
16:00	Ava	[Could do one (farm) there]	Stamps the farm directly in front of him	Ava follows the *direction* and *commits* to stamp

In this example, learners used the info rings and stamps to determine the best option for their activities. Between 15:30-15:35, Zack directed Ava to stamp the garden: “we could just have a bunch of gardens. Then that would help” (improve food results). Seeing Ava’s hesitation to act, at 15:41 Zack first gained Ava’s attention “wait,” and put down the info ring, indicating he wanted her to put a stamp inside to check its information. Ava waited for explicit instructions before acting, so Zack stamped the garden himself (at 15:43) and asserted that it supplied food for a small population: “a small group” at 15:47. Ava then directed Zack to try the farm, and Zack stamped the farm in the info ring as well (at 15:50), asserting that it fed more people at the same time as Ava (indicating that they were both aware of the information). At 15:54 Zack next suggested the farm as a possibility as he reasoned that it supplied more food than the garden: “let’s do these (farm) because it (uses) three (river irrigation) and this beats the medium” (provides food for a large population instead of a smaller population). To support his directive, Ava committed to stamping the farm (at 16:00).

In the example, the first directive played a role in attempting to make a plan, but the use of an assertive without evidence did not convince their partner to participate. Commissives and the info ring were used to pause the activity, and later assert information about both of the food options. Learners were also able to use the info ring to look between the garden and farm to compare the information, and make a more informed decision about the potential benefits to the community. With both learners in agreement about the options, a learner was able to provide a directive as they removed the info ring before taking action. This analysis shows that learners were able to compare the trade-offs of two tools in a way that allowed one learner to show their partner of the benefits of the options before agreeing. Finding out about the trade-offs of land use representation helped learners to engage in discussion, make comparisons and negotiate plans. Using the info ring and stamps, learners drew attention to and shared information through the use of the tools, and used the removal of a tool to resume the activity. This presents validation that the design of the info ring supports the quick comparison of different stamps, and can help bring learners into a joint-attention space to talk about plans to support their progress.

5.1.3. Discussing activity relationships to inform future decisions

Learners were also able to explore the activity logic of Youtopia by using tools to take stock of their progress and discuss activity relationships to inform their future decisions. This subtheme involved one or both learners committing to using the impact tool to find out about the current status of the world (e.g., a lot of pollution), and both learners engaging with the information from the impact tool and stamps as they shared their assessments (via assertives and expressives). In some cases, this additionally led to directives and commissives about next actions. The example in Table 5.3 shows how learners used the impact tool circles to debrief each other about their decisions.

Table 5.3. Episode in which learners refer to the impact tool circles to discuss digital land use representation characteristics

Time	ID	Dialogue	Action	Speech acts to interpret events
6:44	Pete	How polluted is the environment? (Requests her to stamp the impact tool a second time)		Pete *directs* Lori to check the pollution
6:45	Lori	Um (.) [There's little pollution]	Uses impact tool	Lori complies, *asserting* information
6:47	Pete	[There's] little pollution because of//	Touches pollution circle	Pete tries to form an *assertive*
6:49	Lori	Does that even help? Cuz//	Still holding impact tool pointing at energy circle	Lori questions the effectiveness of stamps, *directing* Pete to provide information
6:52	Pete	Wait (.) um (.) oh it's because (.) it's because of (.) thee uh//	Holding pollution circle and looking at the black ringed hydro dam and coal mine	Pete and Lori try to form *assertives* based on what's highlighted in white or black
6:59	Lori	[That and] that	Points at energy developments	
7:00	Pete	[That]	Points at same developments	
7:02	Lori	Um wait I'm gonna see if this xx cuz (eraser tool can make) our energy thing can go higher (.) I mean yeah	Uses eraser tool and then impact tool	Lori *commits* to trying to increase energy
7:07	Pete	I think we should do another reserve		Pete *expresses* his preference and provides an alternative *directive* to work on pollution
7:10	Lori	Some people // do you wanna put one more hydro (dam) just to get [xx energy?]	Reads impact tool	Lori starts to *assert* info and again *directs* Pete's attention to energy
7:13	Pete	[Okay]... another hydro	Looking at impact tool reading	Pete *commits* to the idea
7:21	Lori	Put one	Stamps hydro dam	Lori *commits* herself to stamping hydro dam

7:23	Pete	'Kay now it makes more sense now		Pete *asserts* he's gained some new understanding
7:25	Pete	Um now	Uses impact tool and moves it down the screen	Pete *asserts* that hydro dam has not caused as much pollution as expected
7:33	Pete	There's still no pollution Lori (.) Wow.		
7:34	Lori	'Kay		Lori accepts the *assertive*

This example shows how two learners took stock of the pollution levels. At 6:44, Pete directed Lori to check pollution by using the impact tool: "how polluted is the environment?" Lori then asserted information about the pollution level: "There's little pollution," as she used the impact tool. At 6:47 Pete touched the pollution circle on the impact tool as he started to assert why there was pollution, but was cut off by Lori who asked, "does that even help?" questioning whether their energy level affected their pollution level or not. Between 6:52-7:00 Lori and Pete used assertives about pollution as they pointed to the hydro dam, coal mine and coal plant, and touched the pollution circle to highlight the digital representations in black (which contribute to pollution) as they identified: "it's because of" "that and that". At 7:02 Lori committed herself to testing a hypothesis ("I'm gonna see if... our energy thing can go higher") to find out how much energy a coal plant produced. At 7:07 Pete then expressed his preference to "do another reserve" (such as nature, river or mountain reserve) and directed Lori to reduce their pollution. Following this, at 7:10 Lori used the impact tool and suggested, "do you wanna put one more hydro?" to improve their energy because Pete had already pointed out that coal contributed to the pollution issue. At 7:13 Pete decided to commit to this plan: "ok. Another hydro." Lori committed to stamping the hydro dam at 7:21, and Pete expressed support with this action: "it makes more sense now" as he used the impact tool to assert that "there's still no pollution." This kept their pollution level at a lower level and still managed to supply energy, which Lori acknowledged approval.

This analysis shows how learners used the impact tool circles to assert which digital land use representations contributed to the results (energy and pollution) in a way that prompted learners to resolve the meaning of the relationships and consequences. Directives were used in the form of questions to request information, make suggestions with the info ring and stamp and read information from the impact tool. Learners used several assertives with the impact tool. Commissives were used to develop a plan of increasing their energy. The use of eraser tool, stamp and impact tool allowed learners

to map the direct cause and effect of their decisions to results and test their actions in a non-consequential way. (They were able to undo and repeat actions without a penalty). The impact tool circles were used to highlight how their actions influenced results, helped them to recognize consequences of their actions and prompt them to discuss and to decide what changes to make (the impact ring circles indicate how much results can also be improved). By physically moving the impact tool around, learners were able to quickly attain shared gaze. By directing each other to use certain tools, learners were able to keep each other invested in the results, through the information provided by the impact tool, learners read information aloud in their attempts to share meaning.

5.2. Theme 2: Proposing Plans and Suggestions

Learners also used tools to propose plans and other suggestions. This could be pursued from high level/strategic ways (setting broad goals), to tactical ways (responding to information or feedback), or could rely on tools in the activity to provide direction. Proposing plans and suggestions could be carried out in a variety of ways, but was often prompted when one learner used a tool or stamp, and one or both learners asserted information via stamp feedback tabs, info ring or impact tool. The learners then examined and referenced the information (via assertive) to propose an idea or plan (via directive or commissive) to their partner. These are described in three ways: proposing plans in response to the activity state, proposing responses based on feedback, and redirecting the current course.

5.2.1. Proposing plans to improve the results

In many episodes, learners used tools to propose plans based on the activity state during or shortly after use of the impact tool. Upon use of the impact tool, information about the food, energy, housing and pollution levels would be displayed. This theme is similar to subtheme *5.2.2*: *Proposing responses to activity feedback* in that a learner presented an idea based on information, but this focused on high-level issues rather than on trying to determine why they could not carry out a particular action. This subtheme involved one or both learners committing to check their progress, when one learner stamped the impact tool, and one or both learners reviewed the world results

aloud, using assertives or expressives to interpret the information. This would be followed by learners discussing which area (i.e., food, housing, energy or pollution) to focus on (via directives or commissives). The other learner would then accept this, disagree or ask for clarification. In many cases, the impact tool was used to take stock of their current status in a way that allowed the learners to agree to facts to direct their next steps. The actions taken after this involved: using stamps, using the info ring for advice, or erasing of some items and making some new decisions. Often it was easier for one learner to convince their partner to buy into a suggestion if the impact tool or info card information was visible. Other times, a tentative partner would stamp the impact tool again to view results to help them consider the suggestion. Incremental steps were often proposed by learners until learners developed more verbalized plans. Until then, much of their time was spent figuring out what their next steps would be, often with a great deal of erasing of digital land use representations. An important transition sometimes occurred when learners began to describe more strategic moves rather than single combination moves (e.g., deciding that learners should have 50% housing, instead of deciding they should create one house). The example below (see Table 5.4) describes how one learner proposed an idea in response to the results.

Table 5.4. Episode in which learner uses impact tool circles to propose a goal to increase shelter

Time	ID	Dialogue	Action	Speech acts to interpret events
7:51	Brian	Many people have food. Great	(impact tool is on the table) Brian gives a thumbs up	Brian *assert*s information and *expresses* his satisfaction with their food result using the impact tool
7:55	Fay	I think we// I think I wanna get it 'm like halfway there	Fay points at shelter circle	Fay *directs*/tries to *direct* Brian to an improvement goal
7:57	Fay	Or some people don't even have shelter	Fay touches shelter circle	Fay *asserts* that some people don't have housing, *expressing* this as a problem
7:59	Fay	Some people don't, not many people ha(ve) it		
8:02	Brian	Many people have food so food is not the issue…		Brian first e*xpresses* that he thinks food is ok for now, *asserts* that food is not the worst issue and considers Fay's a*ssertive* while looking at impact tool
8:07	Brian	Well actually no, we can add xx	removes impact tool	
8:09	Fay	Shelter		Fay *directs* Brian to assist with shelter
8:11	Brian	Okay let's get some shelter	Searches through tools, finds and stamps lumber	Brian agrees and *commits* himself to stamp lumber

The example describes how one learner used the impact tool to propose an idea which the other learner later agreed to after engaging with the impact tool circles. Prior to the episode excerpt, the impact tool was used. At 7:51 Brian read the information provided by the impact tool and expressed satisfaction with their progress: “Many people have food. Great.” Between 7:55-7:59 Fay directed Brian to pursue a goal to achieve 50% housing as she gestured to and then touched the impact tool’s housing circle: “I wanna get it ‘m like halfway there,” because “not many people ha(ve) it.” At 8:02 Brian assessed that food was not a main problem: “Many people have food so food is not the issue,” and continues “well actually, we can add...” The physical removal of the tool by Brian then allowed him to resume the activity. Fay then restated that shelter was the main issue at 8:09. Brian later agreed with the suggestion: “Okay let’s get some shelter,” and committed to the plan by stamping his (prerequisite lumber) tool.

This analysis shows that the learners were able to use the impact tool as an information resource to help both learners form an understanding about a specific issue, so that when Fay presented a new directive that was in line with their described plan, her partner could easily agree to it. This was a valuable part of the learner discussions because learners were able to use the impact tool and speech to recommend improvements for their world. A few features on the impact tool supported proposing plans and suggestions to improve the results and consider higher level plans, 1. The incremental filling of impact tool circle results prompted learners to look at possible improvements 2. Prompting text on the impact tool circles gave learners a chance to repeat the information aloud to interpret and make considerations about plans, and 3. Pausing the activity with the impact tool allowed learners to consider options before going back to the activity.

5.2.2. Proposing responses to feedback

Learners also relied on feedback tabs and the recession of the river to propose short-term responses to feedback as a way to carry out actions successfully. Youtopia had four types of feedback tabs (error messages) in the activity which appeared when some action was performed incorrectly. This was different to the previous sub-theme of *5.2.1*: *Proposing plans to improve the results* because this subtheme always focused on

the learner's steps to correct or improve previous actions that were unsuccessful, or created a limitation of water for any future development. Feedback tabs appeared when a land use stamp was used and had one of the following issues: 1. some other item already existed in the space (e.g., someone tried to stamp a house on an existing garden), 2. More resources were needed to complete the action (e.g., a coal mine was needed for a coal plant), 3. Water was located too far away (e.g., a farm requiring three river irrigation representations connected to the river) or 4. A stamp was placed on an incorrect land terrain (e.g., trying to stamp a river reserve on a mountain). This mainly occurred through the use of feedback messages as a stamp was used (e.g., when learners stamped in error and received feedback hints). Sometimes the info ring (and a stamp inside) or impact tool would be used to find out more information and sometimes a stamp or the eraser tool would be used to try to correct or successfully carry out the action. A receding river became apparent when an abundance of hydro dams, river irrigations or river reserves were used. The river would then become thinner and a dry river bed would become more obvious. An example of learners responding to feedback tabs is described below (see Table 5.5).

Table 5.5. Episode in which learners propose plans based on feedback tabs and info ring

Time	ID	Dialogue	Action	Speech acts to interpret events
9:27	Lori	That's uh [energy] its energy	Both hold info ring and stamp	Pete and Lori *assert* information about the stamp from info ring
9:28	Pete	[oh]		
9:30	Pete	It makes it even more polluted though		
9:32	Lori	Yeah I know but xx	Tries to remove coal plant stamp	
9:34	Pete	Wait (.) it needs to be grassland	Touches feedback tab message as she tries to remove	Pete *asserts* new information based on feedback message
9:37	Lori	Oh		
9:40	Pete	Yeah it needs grassland	Touches feedback message as she tries to remove	
9:43	Pete	So coal mine needs to be in the mountain	Picks up coal mine and stamps it	Pete *asserts* additional information based on new knowledge
9:47	Lori	And this	Stamps coal plant	Lori *commits* based on Pete's information

The example shows how learners used feedback tabs to propose actions. Previous to this excerpt, Pete and Lorie discussed whether or not to use coal as an energy source using the info ring and coal mine. Lori asserted at 9:27 that the coal plant provided “energy” and they both held onto the tools to see the results and take some control over how the tools were used. At 9:30 Pete described that using the coal plant would add to their pollution levels: “it makes it even more polluted.” At 9:32 Lori began to provide reasoning for why coal plant was a good option, but Pete saw a feedback message and touched the tab to reveal the hint about where it needed to be placed: “it needs to be grassland.” At 9:40 Pete reasserted that the coal plant “need(ed) grassland” and that coal mine required a “mountain” as he stamped the prerequisite coal mine. Responding to the current feedback, Lori stamped a coal plant at 9:47.

The feedback tabs in this case were used to reveal information about where the stamps needed to be placed. Assertives were used with tools (stamps and info ring) as they provided information about the feedback. A commissive was used to follow through with the hints from the feedback tabs, however a formal plan was never agreed on. This subtheme usually focused on direct (one or two step) changes, but also on timely suggestions, and trade-off decisions when water resources became scarcer. This example showed how learners used stamp feedback tabs to inform how to complete an action. Interestingly, learners ended up taking an action that they hadn’t fully discussed, but took as direction as they responded to the feedback tab.

5.2.3. Redirecting the course

Some learners used tools to redirect or restart the conversation away from the content of a previous decision, as a way to propose new plans and suggestions. This subtheme was distinct from subtheme *5.2.1: Proposing plans to improve the results,* in that the outcome of these actions could lead to new examination instead of specifically improving results or following through on previous plans. Using stamps, info ring or the impact tool, learners could request immediate direction to redirect or distract learners. This was seen when one learner tried to direct their partner to do something, but instead of uttering a response that agreed with or rejected the directive, the other learner would use the impact tool to pause and distract, or to gesture at tools which were not related to

the conversation with the purpose of steering the dialogue in a new direction. Restarting the conversation could also be seen in where dialogue or a plan between partners was exhausted without a satisfactory result. In these instances, the impact tool could be used to direct learners into a new conversation (see Table 5.6).

Table 5.6. Episode in which learner uses the impact tool to restart the conversation

Time	ID	Dialogue	Action	Speech acts to interpret events
15:25	Barb	Now what else do [you want?]	(using impact tool)	Barb asks for *direction*
15:26	Reg	[Shouldn't we] spread out the parks? So like some are here?	Points at nature reserve representations	Reg *directs* Barb to erase and move some of the nature reserves to new locations
15:30	Barb	I don't think we can spread out xx		Barb *expresses* concern about his *directive*
15:33	Reg	We can erase them and put some there	Points to a different area	Reg *directs* Barb to a new option
15:34	Barb	Oh yeah sure. Mm No we can't, cuz they (can) only be xx. Took (take) off lumber	Points at lumber used	Barb initially agrees, then *expresses* disagreement as she begins to *direct* him to look at a need for lumber
15:40	Reg	Okay		Reg verbally accepts Barb's *assertive*
15:43	Barb	See cuz they can't really go like see like. 'Kay yeah	Points around, tries to stamp lumber and shows a feedback message	Barb uses a feedback message to try to *assert* what lumber needs to be stamped
16:00	Reg	See what we still need	Uses impact tool	Reg *commits* himself to the use of impact tool

This example describes how the impact tool was used to begin a conversation and follow a new direction (at the end of the episode). At 15:21 Barb stamped the impact tool to get a general assessment about how their world was doing before inquiring, "what else do you want?" at 15:25. Reg then suggested scattering the nature parks as opposed to placing them all in one section at 15:26: "Shouldn't we spread out the parks? So like some are here?" The learners shared what they thought was possible between 15:30-15:33, when Barb said "I don't think we can spread out" (the nature reserves), and Reg responded, "we can erase them and put some there" while pointing around the table. Barb initially agreed with Reg's idea: "yeah sure," but later disagreed and suggested that they take "off lumber" (erase lumber) at 15:34. When the partners were unable to come to consensus, at 16:00, Reg used the impact tool to "see what we still need" in order to help specify what was needed and reset the conversation. This analysis shows specifically how Reg turned to the impact tool to when his ability to convince his partner to agree to a plan was not successful.

Commissives and directives were used with the impact tool in this episode as learners pointed at and described ideas. The impact tool in this case was especially useful in prompting a new route when learners couldn't agree on a direction. Unable to come to a satisfactory understanding, Reg used the impact tool to begin a new conversation to reengage his partner in new steps. The sub-theme was influential in maintaining positive working relationships but the conversation 'reset' of this tool was not always useful in encouraging learners to work through their differences in an integration-oriented way. As well, some conflicts about values or arguments may not have been fully addressed. A learner could use the impact tool to either propose a fresh plan with no invested interest, or propose a specific plan. The pausing capability of the tool however did provide time separate from the immediate activity for planning and reflection. A potential issue of the tool was that it might have played a role in limiting learners' own ideas as learners focused attention on the results rather than reflecting if they would actually live in their world.

5.3. Theme 3: Advocating for an Action

Another important pattern of learners' use of Youtopia was to use tools and talk to advocate for what they thought should be done in the activity. This could be at the tactical level of using a specific tool (e.g., "let's build more houses") or the strategic level of trying to set up a plan (e.g., "we need to focus on shelter"). The pattern generally began with use of one of the stamps or tools to engage their partner's attention (e.g., holding up a stamp for their partner to see) with a directive to use the stamp. If the partner hesitated or disagreed, the learner could use a tool to provide evidence why the tool should be used. In some cases, this strategy could convince the partner to: agree to an action, or point to a different piece of evidence with the same tool, or use another tool. The impact tool and info ring (with a stamp inside) were the most common elements used, but the eraser tool and stamps were also utilized for a learner to demonstrate an action which could support their position. Advocating for an action could be seen in three main ways: providing evidence, explaining their rationale for their actions, and sharing values to influence their partner.

5.3.1. Providing evidence

One important way learners advocated for themselves or an action (e.g., pursuing one basic need over another or focusing on reducing pollution) was by providing evidence to support their case. Evidence was primarily provided by using information from the impact tool or info ring (with a stamp inside). This would be initiated by one learner engaging their partner's attention with an assertive, paired with physical use of a tool (often the impact tool). This would be followed by a directive and/or discussion of next steps involving expressives or assertives. Often additional presentations of evidence (assertives with tools) were also used. An episode would conclude with a decisive action by one learner (based on consensus or taken unilaterally), sometimes accompanied with an assertive or expressive to assess their decisions, or using a commissive or directive while performing or planning their next steps. This pattern is outlined in the following example (see Table 5.7).

Table 5.7. Episode in which a learner provides evidence to focus on reducing pollution

Time	ID	Dialogue	Action	Speech acts to interpret events
9:52	Sai	There's some pollution	Uses impact tool	Sai *asserts* the pollution level
9:55	Ben	We need to cut down the pollution		Ben *directs* them to lower pollution
9:56	Sai	'Kay don't let anything else that might [xx pollution]	(Re) uses impact tool	Sai agrees with *directive*, *committing* to limit the pollution level
9:58	Ben	So do you think we should take out the hydro dam?	Removes impact tool	Ben asks Sai for *direction* to erase the hydro dam
10:00	Sai	No, cuz, then people wl'(will not) have energy		Sai *expresses* concern against Ben's suggestion
10:02	Ben	Now wait (.) check that	Uses eraser tool to delete hydro dam	Ben commits to erase dam and *directs* Sai to check the impact tool
10:06	Sai	Some [people have energy]	Uses impact tool	Sai *asserts* the energy level
10:11	Sai	[So] if we add one of this (hydro dam) then many people have energy (.) but there'll be pollution	Points at energy circle on impact tool	Sai *asserts* that adding energy sources will contribute to pollution
10:19	Ben	I think we should take out (.) the coal stuff	Removes impact tool, erases coal plant	Ben *commits* to erasing the coal plant as he acts on reducing pollution

This example presents an episode in which a learner presented evidence to advocate for their perspective as they both negotiated trade-offs between the needs energy and pollution. At 9:52, Sai used the impact tool to pause the activity and draw Ben's attention to the current pollution level, "there's some pollution." In response, at 9:55, Ben built on Sai's comment and suggested that they "need to cut down pollution."

Sai agreed at 9:56 and emphasized her concern about the pollution, reusing the impact tool to draw attention to the current pollution level. Between 9:58 and 10:02, Ben questioned if they should remove a hydro dam in order to lower the pollution, and Sai disagreed, saying “no then people (will not) have energy.” At 10:02 Ben erased an energy source (hydro dam) and directed Sai to use the impact tool to check on the difference this had made. She then used the impact tool and reported that only, “some people have energy,” indicating their population had lost some power. At 10:11 Sai recognized and described the trade-offs between providing energy and creating pollution. Ben considered her comment, removed the impact tool to resume the activity, and at 10:19 she suggested and committed to erasing the coal plant as an alternate strategy to reduce pollution.

The analysis showed how Sai repeatedly used the impact tool to generate evidence that helped stress her concerns about the pollution, which her partner considered and then took action to support her concern. The impact tool was used (with assertives) to indicate they had something to say on multiple occasions, to pause the activity and to point out the energy circle’s information. An expressive was used by one learner to convince their partner to consider their concern. Directives and commissions were used with removal of the impact tool to take planning steps and with the eraser tool to follow through on their partner’s plan. Through this sub-theme, learners realized that evidence-based decisions were more convincing to their partner. Evidence was always based in what a learner could show or demonstrate. In the aforementioned example a learner repeatedly used the impact tool to support providing evidence in a few steps: 1. Pause the activity 2. Point out information, and, 3. Stress their concerns and 4. Use the impact tool repeatedly to limit the actions of the other (and promote consideration of their ideas). The visual display of the four impact tool circles also encouraged learners to focus on what they thought was in greater need of work.

5.3.2. Explaining rationale

In advocating for a position, learners also used tools to provide or request reasoning for their actions. This usually happened after one learner suggested a plan that the other disagreed with, or used a stamp without buy-in from their partner (and their partner directed them to explain their actions). In cases where a learner took a unilateral action without buy-in, the first learner would explain the reasoning for their actions (using assertives or expressives) in combination with the impact tool or info ring as they referred to tool information. Learners spoke about the specific details of tools (e.g., about the pollution level), or gestured with, pointed at or used speech as a prompt to remind their partner of previous experiences (e.g., but remember...). Their partner would accept the information, or use the impact tool to pause the activity and check the results via impact tool or use the info ring to confirm key details. In some cases, assertives were used as they considered and touched the tools or their multi-touch information. An example of requesting and explaining rationale using the information from a tool is outlined below.

Table 5.8. Episode in which a learner requests reasoning using the impact tool and partner is prompted to explain rationale

Time	ID	Dialogue	Action	Speech Acts to interpret events
13:46	Jim	Alright irrigation, we need to build a little more um farms	Stamps river irrigation several times	Jim *commits* himself to begin stamping river irrigation
13:52	Sara	What's going on here?	Points at where river irrigation is using up water	Sara is unhappy about Jim's actions and *directs* him to answer a question about the receding water
13:54	Jim	Uh remember? It's kinda drying up on the [xx]		Jim *asserts* what happens when the water is used, reminding her that the water recedes
13:56	Sara	Uhh!		Sara utters frustrated sounds
13:57	Jim	It's okay. It's okay it's okay it's okay. It's for the farms	Shaking his hands	Jim tries to *express* his actions are acceptable, and convince Sara to accept his reasoning
14:03	Sara	Yeah but then the. Okay	Grabs impact tool	Sara tries to assert details about the water, but accepts that she understands his intentions
14:04	Jim	It's okay. Where's the farm?		Jim aims to follow through on his *commissive*
14:10	Sara	Most //	Stamps and reads impact tool	Sara tries to *assert* details about their current state
14:11	Jim	Most people have food, that's why I'm putting the food place		Jim tries to *assert* the results to support his actions

The example showed that Sara was able to use the impact tool to successfully request justification for Jim's actions, and Jim was able to refer to the information to explain himself. At 13:46, Jim stamped several river irrigations without consultation from his partner, and as a result, the river receded. Watching the river recede, at 13:52, Sara first showed concern about the river and directed him to respond: "what's going on here?" This prompted him to explain that in stamping the river irrigation he was trying to meet a need to supply more food: "it's for the farms" (as he tried to discount her concern) at 13:57. She acknowledged that she understood the purpose for his actions at 14:03, and then grabbed the impact tool. At 14:04, Jim again tried to reassure her of his intentions as he aimed to follow through on his goal: "It's okay. Where's the farm?" To point out their current state (and potentially request information about his idea), Sara stamped the impact tool at 14:10. However, Jim reasoned at 14:11 that his action to supply more food was justified as the result read 'most' instead of 'all' (indicating that there was room for improvement). The statement, "most people have food, that's why I'm putting the food place" supported his earlier commissive "we need to build...farms."

For the purpose of explaining rationale, in this case the impact tool was used to: 1. follow up from a previously disregarded request for an expected explanation, and 2. enhance their questioning process. By using the impact tool, the learner was able to request their partner to use evidence to explain how their actions benefited them. This analysis shows that the impact tool was used by an information-seeking partner to request explanation about their partner's activities. Unfortunately, when a learner announced their actions to their partner (using commissives), assertives and expressives were then used to explain their reasoning after the fact. This was problematic because there was not a high degree of buy-in from their partner to comment on before they acted. In the combination of speech acts, this suggests having assertives before commissives, or having harmonious commissives from both partners before acting may lead to more integration-oriented consensus-building. This also points out that there were limited options to stop a partner from stamping unwanted items or limit a partner from making unreasonable claims.

5.3.3. Sharing values to influence their partner's decision

Learners were also able to advocate for their perspective by expressing their values and interpretations to try to influence their partner's decisions. This subtheme was similar to *Theme 5.3.1*: *Providing evidence* to influence their partner's buy-in, but they tried to influence their partner was based on feelings rather than on fact. This involved one partner providing a directive about a next step, and their partner reflecting on the potential impact of a decision via expressive (sometimes additionally with assertive). This could be tied to use of any stamp or tool, and sometimes would not involve direct use of a stamp or tool. One or both partners would provide expressive language to provide additional insight, potentially modifying a previous idea statement and providing a new directive after the information was shown. This is interesting because of the opportunity for learners to develop shared values. The example below (see Table 5.9) provides an example of one learner's effort to express how they felt to influence a particular decision.

Table 5.9. Episode where learner expresses disproval about placing animals near coal plants

Time	ID	Dialogue	Action	Speech acts to interpret events
11:15	Ian	Is there any electrical lines you can put?		Ian *directs* Nora to stamp energy
11:22	Nora	No, this this is effective for electricity for people to have. But it create a lot//	Hands coal plant to Ian	Nora begins to *assert* pros and cons (pollution) to using the tool
11:36	Ian	Let's put, let's put the coal plant ...	Walks around table, moves to stamp	Ian tries to *commit* to stamping the coal plant
11:41	Nora	There's nothing over here		Nora *directs* Ian to place in an area by a mountain reserve
11:44	Ian	But you don't want to put it near a mountain goat because I think it'll kill the goats xx		Ian *expresses* his disapproval in putting a coal plant near animals
11:46	Nora	That'd be sad		Nora concurs with Ian's *expressive* and makes another *directive*
11:50	Nora	How about here? [cuz]	Points at a corner	
11:54	Ian	[Near] the city?		Ian aims to confirm Nora's *directive*
11:55	Nora	I guess cuz cities usually have [electricity]		Nora *asserts* information about electricity
11:58	Ian	[A coal plant] xx	Stamps coal plant	Ian takes Nora's understanding as a *direction* and *commits* to stamping coal plant

In this example, one learner expressed his disproval about placing animals near coal plants before his partner made a decision. At 11:15, Ian directed Nora to provide support in developing energy: “Is there any electrical lines you can put?” At 11:22 Nora then directed Ian to use the coal plant as she handed it to him “this is effective for electricity for people to have,” reasoning that it created more energy for a larger population. However she started to caution Ian about the effects of pollution: “but it (will) create a lot.” Cutting Nora off, at 11:36 Ian began to follow up, “let’s put the coal plant...” as he considered a place for it. At 11:41 Nora directed Ian to stamp the coal plant near a mountain reserve: “there’s nothing over here.” At 11:44 Ian disagreed and provided his own reasons to not place the coal plant next to a mountain reserve: “but you don’t want to put it near a mountain goat because I think it’ll kill the goats.” Nora agreed with his comments at 11:46 by showing empathy “that’d be sad,” and pointed to an alternative option (placing the plant by the city). At 11:54 when Ian questioned her directive, “near the city?” she reasoned that “cities usually have electricity.” This presented good enough reasoning for Ian who committed to stamping a coal plant at 11:58. This analysis shows that as learners began to form their own interpretations and attach emotional value to the animals in Youtopia, it influenced the decisions they made.

In the episode learners used reflection and personal values (based on how they felt about the goats) to shape their decisions. Assertives were used to help learners point out information. Commissives were used to announce next steps, while an expressive was used to emphasize concern with an assertive while referring to shared experiences. The impact tool supported a learner in understanding their partner’s values as they used the tool results to verify what their partner had expressed. They passed a stamp in order to prompt their partner to be more invested in the plan. A visual of healthy people were not included on the main interface of the activity, and this may have influenced how closely learners related to them, as the learners were more concerned about the health of goats near pollution than people. Youtopia characters were designed to be appealing to look at, and the health/care of digital beings seemed to have an impact on the decisions made about them. Learners were also able to learn more about the activity dynamics by summarizing their understanding of Youtopia and sharing their interpretations and values. Many conversations relied on pointing to stamps or digital land use representations and using the impact tool circles or info ring to talk about what

they observed. The pointing and talking strategy (building on each other's assertives and expressives) allowed learners to use the multi-touch features of impact tool, info ring, and stamp feedback to explain what had occurred, and how they felt about it.

5.4. Theme 4: Testing a Hypothesis

Another interesting theme of use for tools and language in Youtopia was to test a hypothesis to explore possible outcomes. This was different from *Theme 1: Exploring the activity logic* because there was some prediction or certainty about the outcomes of these hypotheses. Learners would discuss a plan and act it out with the understanding that the actions could be reversed with the eraser tool. In these situations, conversation between the two partners would lead to the development of a hypothesis (e.g., use of the farm would increase food levels) via a directive and support from their partner, followed by use of stamps and/or eraser tool and impact tool. Assertives and/or expressives would then be used about the results of their discovery. The impact tool and info ring (with a stamp inside) were commonly used together. The info ring was used to predict how something contributed to their current activities in order to reinforce details. The impact tool was used to pause the activity and show the results. The examples present how learners predicted how use of a tool could influence results, and how learners tested before and after results of a hypothesis.

5.4.1. Predicting the use of a tool supports particular outcomes

Some learners proposed hypotheses to predict that certain tools would contribute to a particular result. This often happened when one or both learners asserted information, followed by one learner directing their partner or committing themselves to test their hypothesis. This subtheme was different from *Theme 1.3: discussing activity relationships to inform future decisions* because in this subtheme tools could demonstrate/try out a concept using the eraser tool rather than advocating for what they want to happen. One or both learners would then make a move that followed through with the testing of that hypothesis. There were two main ways tools were used in this way by learners: using a stamp followed by the impact tool, or using the info ring to check if there was evidence to support their hypothesis. For example, a learner could

predict that stamping an apartment would increase the housing result. To do this, one learner could assert that they didn't have housing and could direct their partner to stamp an apartment. If their partner complied, then the first learner could use the impact tool to point out that housing had increased. See below for an example (Table 5.10).

Table 5.10. Episode in which learner predicts that use of a tool will contribute to the result

Time	ID	Dialogue	Action	Speech Acts to interpret events
20:58	Brian	Want a coal mine? And then a coal plant next to it?	Holds coal mine stamp	Brian proposes ideas (*directives)*
21:06	Fay	Mmm cuz I bet if we use like two there though. Then there'd be a larger impact watch		Fay tries to *assert* coal produces more energy
21:11	Fay	Watch. And coal mine	Stamps coal mine twice	Fay *commits* herself to stamping the coal mine and *directs* Brian to use the impact tool
21:21	Fay	Now watch impact tool		
21:21	Brian	(.)	Uses impact tool	Brian complies
21:23	Fay	See. Some pollution see? It's more impact. See, look	Touches pollution circle	Fay tries to *assert* an explanation Brian *asserts* information on pollution
21:26	Brian	But there's some pollution		
21:30	Fay	There's some pollution but...see	Touches pollution circle	
21:32	Brian	Oh that lowers the food?		Brian *directs* Fay to answer if she's talking about food
21:35	Fay	No because there's some pollution see?	Touches pollution circle	Fay uses the impact rings to *assert* her understanding about the trade-off of energy and pollution by touching them to indicate these are the things to which she's referring
21:39	Fay	We used like two of those and caused more pollution		
21:42	Brian	[Oh that's...xx]	Looks at pollution, takes impact tool	
21:43	Fay	[But it gives us] more energy!	Touches energy circle as he lifts the tool away	

In this episode a learner predicted that a tool would contribute to a particular result. At 20:58, when Brian suggested that they should create energy: "Want a coal mine? And then a coal plant next to it?" Fay predicted that if they used two coal mines, "there'd be a larger impact," as she expected an increased energy result. Between 21:11 and 21:21 Fay stamped two coal mines with Brian's help, and at 21:22 Fay used the impact tool to show that pollution had increased: "It's more impact. See, look." Brian showed confusion at 21:32 when he asked if coal mine "lowers the food?" but Fay explained between 21:35-21:43 that the coal mines caused pollution and contributed to energy as she engaged with the energy circle on the impact tool: "No because there's

some pollution see? We used like two of those and caused more pollution." Brian looked at the impact tool during the demonstration and began to agree. Fay concluded the episode by stating, "it gives us more energy!" which added to their understanding that coal mines had a role in contributing to both energy and pollution.

In this example, assertives were used while engaging with the impact tool and rings, while stamps were used with directives and commissives as part of a demonstration process. Learners were able to direct how to stamp (as a way to participate), and assert information while using impact rings to explain as they lit up. The analysis shows that by drawing their partner's attention and stamping a digital land use representation and the impact tool circles, the learners were able to test how coal contributes to energy and pollution, and share new interpretations about the outcomes. Learners were also able to engage in low-risk experiments by using stamps and the impact tool to draw attention, propose a hypothesis, test it and share their interpretations. Combinations of stamps and eraser tool were used to demonstrate a concept with use of the impact tool circles to light up and verify the information needed for discussion. Particularly, the eraser tool played a key role in encouraging learners to both try ideas, as well as form their own understanding of relationships based on previous information.

5.4.2. Testing before and after results

Some learners were able to develop sophisticated ways to test their hypotheses by comparing before and after results with the impact tool or by watching the river recede after use of a river irrigation stamp. In these examples, a learner looked at information (via info ring or impact tool) to suggest a hypothesis as part of a plan (via directive or commissive). They would then add a digital land use representation (with a stamp) or delete an existing digital land use representation with the eraser tool, and then use the impact tool while providing assertives or expressives. Both learners then decided if they were satisfied with their current world and move onto a different focus, or continued discussing and modifying the current focus. The example below (Table 5.11) outlines how learners tested before and after results to inform a decision.

Table 5.11. Episode in which learners test if erasing a house will impact the result

Time	ID	Dialogue	Action	Speech acts to interpret events
21:30	Barry	We can take away one nature reserve and build one house	Removes info ring	Barry provides a *directive* along with Kate's previous proposal about housing
21:35	Kate	But if you look at it. Our pollutions going to go higher by a lot	Uses impact tool	Kate *expresses* concern that Barry's *directive* will not change housing much and uses the impact tool to *assert* her point
21:38	Barry	Let's check	Points up like it's a great idea	Barry and Kate *commit* to checking if building a house is a good idea and
21:41	Kate	Yeah let's check. Where's the eraser?		Barry follows through
21:42	Barry	(.)	Erases two nature reserves	
21:46	Barry	[Barely.] Let's do it	Uses impact tool	Barry *asserts* that there's been a small change *commits* them to check the result
21:48	Kate	Okay lumber. Lumber. House [xx do it] Impact.	(Rushed) takes impact tool from his hand, stamps lumber and house, and uses impact tool	Kate considers what to stamp and *commits* to using impact. Kate *asserts* there's some pollution and a need for shelter
21:55	Kate	Pollution, yah. Just a little bit. More shelter		
22:03	Barry	Wait (.) it's about knee thumb length right?	Looks at shelter circle and measures the reading with his finger	Barry *commits* to testing a plan to measure the amount one house provides by *directing* her to erase
22:09	Barry	Okay take away the [house]	Removes impact tool	
22:10	Kate	[This this] house? House. House this house?	Looks for eraser tool and erases a house, uses impact tool	Kate follows his *directive* and *commits* herself to following through
22:15	Barry	Okay (.) Barely [does anything]	Measures difference with his thumb	Barry *asserts* there isn't much change
22:17	Kate	[Doesn't do anything]		Kate agrees

In the example, learners examined a specific way to test their hypothesis by measuring incremental changes. At 21:30 Barry suggested that they "take away one nature reserve and build one house" as he removed the info ring. Kate, at 21:35, next stated a hypothesis with the impact tool: "But if you look at it. Our pollutions going to go higher by a lot," verbalizing her suspicions that if they erased a reserve; their pollution level would rise (as reserves in Youtopia provided small amounts of protection from rising pollution levels). Barry, at 21:38, noted their current pollution result, and then they committed to testing out the idea between 21:41 and 21:46 by erasing some nature reserves and using the impact tool. Between 21:46-21:48, Barry commented that erasing the two reserves did not make a noticeable difference to the pollution levels and encouraged Kate to continue with their semi-developed plan to build more houses: "Let's

do it." Between 21:48-21:55 Kate announced the actions: "Lumber. Lumber. House...Impact" as she took the impact tool from Barry, used the lumber and house stamps, and impact tool to check that pollution was still the same. At 22:03, Barry pointed out the increase in shelter and suggested that they measure the difference with his thumb as he removed the impact tool and directed Kate to erase a house and check the impact tool again. Kate complied at 22:10, confirming which house to erase, following through and using the impact tool again. Following that, Barry and Kate expressed dissatisfaction that erasing a nature reserve wasn't worth the measured trade-off for houses, as it "barely does anything" when Barry measured the difference with his thumb.

The learners took advantage of the impact tool circles' ability to track and show instantaneous incremental changes and were able to use this to compare the differences. The eraser tool was used by learners to easily test this question without long term consequences. Learners were able to use commissives and directives to organize and carry out a test while both learners were explaining their moves. Assertives were used to make sense of what they were seeing and sharing their interpretations once they saw the results of their work. As evidenced by the excerpt, learners verbalized that they expected the nature reserve would have had a greater impact on pollution. By using the info ring to pause the activity to discuss an idea, and then the impact tool, eraser tool and stamps to test their prediction about consequences, learners were able to describe links between their past actions by focusing on the incremental increases linked to actions in the impact tool rings.

5.5. Theme 5: Working Cohesively

Another valuable way in which learners used their tools and speech in Youtopia was to support their communication and teamwork approaches. In combination with the tools and language, learners worked together to develop ways to better understand each other and perform tasks. These approaches used the impact tool, info ring, stamps and feedback tabs in a variety of different ways to support interesting and harmonious working conditions. The subthemes include: creating common terms and language, turn-taking, and permission-seeking, and working with conflict.

5.5.1. Creating new language/common plans

Some learners were able to create and use terms and ideas in Youtopia by using language and tools to describe and support their actions and plans. In this sub-theme, learners developed new names for digital land use representations or tools, or worked together to co-create a 'plan' (i.e., a jointly-agreed upon idea with follow up actions). For example, in the case of co-developing new terms, a learner often used an assertive about a digital land use representation while pointing at/with or gesturing at a location on the table followed by the other learner questioning what they were referring to. The first learner would point to, touch the digital land use representation, or pick up the stamp, while repeating themselves or adjusting their language before directing their partner to an action, or committing themselves to an action once their partner indicated they were aware of their intentions. Sometimes the second learner would repeat the new term or use a variation of the new term as they engaged with stamps. In a few cases, one learner would pass the stamp to their partner as they were clarifying which item they were talking about. This helped them to verbalize what particular stamps did (as they repeated each other's words). In co-creating plans, the process would be similar, but would result in both learners repeating a variation of the same words to direct or commit their next steps (e.g., both learners saying nature reserve as they identified that they would use this stamp next). The example (see Table 5.12) provides a description of regular behaviour around creating new terms.

Table 5.12. Episode in which learners develop new terms for river irrigation

Time	ID	Dialogue	Action	Speech acts to interpret events
13:23	Dan	Okay. Let's group all the stuff	Grouping stamps by colour	Dan *commits* (himself/both) to grouping the stamps
13:30	Ida	Electricity (.) erasing tool	Arranges tools	Ida follows Dan's *commissive* by grouping stamps according to the pattern colours on the stamp handles
13:35	Ida	Info rings (.) nature stuff		
13:40	Ida	Oh wait. Garden	Picks up and stamps garden	Ida *commit*s herself to stamping garden
13:43	Dan	Nature reserve over here	Continues grouping stamps	Dan is still focused on the sorting goal
13:44	Ida	It needs sprinkler	Looks at garden's feedback tab	Ida *asserts* what the tool needs, also *directing* Dan to use river irrigation
13:46	Dan	What's a sprinkler?		Dan *directs* Ida for clarifying information
13:50	Ida	That's it. Oh we already have it	Points to a grey irrigation	Ida *asserts* what digital land use representation she's referring to.
13:53	Dan	Ok we'll put an interrogation thing [there]	Stamps river irrigation	Dan uses the (more correct) word, and *commits* to Ida's *directive* to use river irrigation

In the example, Dan first committed them to "group all the stuff" as they announced the purpose of the tools while sorting them according to colour category (food/shelter/energy) at 13:23. At 13:37, Dan and Ida started to list several terms as they grouped stamps: "electricity," "erasing tool," "info rings," and "nature stuff." Once this was complete, at 13:40, Ida found the garden stamp she was interested in and stamped it, while Dan continued sorting: "nature reserve over here." At 13:44 Ida asserted that her garden stamp needed river irrigation as she read the hint from the feedback tab: "it needs sprinkler." At 13:46 Dan asked for clarification: "what's a sprinkler?" because he was unclear of what she was directing him to do. At 13:50 Ida pointed to an existing grey digital land use representation on the table and said, "We already have it" to explain that she was talking about river irrigation. At 13:53 Dan agreed to stamp river irrigation as he used his own term: "interrogation thing." This example shows how the organizing and use of stamps supported the formation of common terms and language of the digital land use representations.

In this example directives were used to ask questions, while commissives were used by learners to group the stamps together and announce actions when a learner found a stamp they wanted to use. Assertives were commonly used to label the tools names or functions. Learners also used assertives when they saw a feedback message to explain what it was to their partner by pointing out examples in the activity. Stamp feedback was also used to make connections to other digital land use representations (e.g., what 'in use' river irrigation looked like) and helped them to co-create shared terms for reference in their discussions. Colour codes and resource/developer symbols helped learners to visually organize the stamps' relationships and to be on the same page when discuss an unknown stamp.

5.5.2. Turn-taking and providing permission

Another important way that learners develop tactics to work cohesively was in the turn-taking and permission-seeking rhythm that learners engaged in as they carried out activities with tools and talk. Interdependent tools and roles were some of Youtopia's designs which were developed to encourage back and forth conversation, and input-seeking, and this was seen throughout many examples of learner's interactions in both the role and non-role uses of the activity. For example, a learner with development responsibilities could propose the idea to build a house to their partner with the natural resources, and both learners would need to stamp a digital land use representation in order for the house to appear. In many episodes, this happened as one learner provided a directive, and their partner would commit and/or comply with another directive or agreement. Alternatively, the responding partner could check the impact tool or info ring (with a stamp) and an assertive. Once the action was complete, the roles would often reverse and the other partner would propose a different idea (via directive or commissive if they followed through on an action themselves). In many cases a working approach would be developed where learners regularly began to ask for input before acting. The episode below (Table 5.13) outlines a common episode of turn-taking and permission-seeking.

Table 5.13. Episode in which Ava and Zack engage in shared dialogue and action based on equal participation

Time	ID	Dialogue	Action	Speech acts to interpret events
5:23	Zack	More garden? Or farm?		Zack looks for *direction* on the next move
5:27	Ava	How much does farm need?		Ava *directs* Zack to check what a farm needs
5:29	Zack	(.)	Checks farm stamp in info ring, spins info card	Zack complies and *asserts* information
5:36	Zack	Medium group of people	Takes out stamp and info card	
5:41	Ava	What about there?	Stamps farm	Ava *commits* herself to stamping farm
5:42	Zack	And then maybe another there	Points at a section of the table	Zack *directs* Ava to stamp a farm in an additional location and erase a garden
5:43	Zack	And then we can take out that one	Points generally toward garden	
5:46	Ava	Which one do we take out?	Hovers while holding eraser tool	Ava *directs* Zack to provide advice
5:47	Zack	That one, that ones being 'used?' So yeah		Zack *asserts* some information and
5:52	Zack	Now we take this and, take, yes	Erases garden icon	Zack commits and takes the action of erasing certain tools

In the example, the learners took turns using tools as part of their planning process in an egalitarian way. At 5:23 Zack asked for direction on whether they should stamp a garden or farm. Ava, in response, at 5:27 directed Zack to find out "how much (a) farm need(s)" (how many river irrigations were needed before a farm could be stamped). Before he responded, at 5:29, Zack put the farm inside the info ring and spun the info card so Ava could read it. At 5:36 Zack shared "a medium group of people." Ava then committed to stamp the farm at 5:41 when she said: "what about here?" Zack responded by directing Ava to stamp another farm at 5:42 ("maybe another here"), suggesting they could remove the existing garden. Ava, at 5:46 sought clarification as she was not sure if he was referring to garden or farm and while hovering over the table. At 5:47 Zack clarified he was speaking about a garden and erased it to demonstrate. This analysis shows the working process moves back and forth between learners and how interdependent tools support this permission-seeking and turn-taking behaviour after a verbalization of intent because tool use can signal the completion of a turn.

The example of turn-taking and permission-seeking used many directives, particularly in the form of questions, while using commissives to complete actions with a stamp or eraser tool. Only one assertive was used to provide an answer to a question. When learners were already engaged in the activity, the tools were used to make incremental decisions. The info ring's info card was also rotated and shown to their partner to answer a question. Hovering over the table also enhanced gaze and awareness of their partner's actions before making a decision. Decisions often involved a two-step process of interdependent tools (e.g. a resource stamp before a development stamp, or eraser tool before use of another stamp). Combining this with interdependent/ role relationships, learners were encouraged to seek buy-in, which required one person to make one move and then the other to take a turn. Taking a move or putting away a stamp often prompted the other partner to complete the direction with a follow up action, or suggest the next move. By dividing up the tasks (Antle & Wise, 2013) learners were encouraged to slow down and engage their partner's feedback in their decisions.

5.5.3. Working with conflict

Another way that tools and speech supported teamwork was in helping learners attain consensus or working agreement in order to move past conflict. Although in some cases, one partner would make a unilateral decision (without the consensus of their peer). Often these situations would begin with one learner or both learners trying to force decisions. This could be seen by interrupting or speaking over a partner, sometimes with forceful or preventative actions (e.g., blocking their partner's hands). As one directed or tried to commit their partner to plans, the other would redirect their partner or commit to alternative actions. In some cases resolution could be reached by providing more details or reasoning. In other cases, learners hesitantly agreed, or one learner would unilaterally take an action. The impact tool, info ring, eraser tool, or stamps could often be used to work with/through these conflicts. The impact tool and info ring were used to reach consensus and resolve conflict in this usual sequence: 1. pause the activity, 2. point to the issue being discussed, 3. provide explanation as to why something should be carried out in a certain way and come to a similar understanding, and 4. assess the information to help the pair consent to next steps. An example below illustrates how a minor conflict was resolved through use of tools and speech (see Table 5.14).

Table 5.14. Episode in which learner demonstrates a concept by erasing a digital land use representation and using the impact tool to settle a disagreement

Time	ID	Dialogue	Action	Speech acts to interpret events
7:24	Sam	There it's two of	Points at coal plant info card	Sam and Pia both try to *assert* information about the stamp and its usage
7:25	Pia	But//	Touches info card	
7:28	Sam	Polluted environment		
7:29	Pia	It gives us lots of energy so//	Removes coal plant from info ring	
7:31	Sam	So we take out that	Points away	Sam *directs* Pia to erase coal
7:35	Pia	What's giving us most of the pollution is that	General gesturing with coal plant stamp	Pia *asserts* the tool purpose
7:37	Sam	That	Picks up eraser tool and points at coal plant	Sam and Pia disagree about why the *assertive* is important
7:37	Pia	Yah		
7:38	Sam	yeah so//	Holds impact tool in his hand	
7:39	Pia	So why are you gonna take out that one?	Points at hydro dam	Pia *directs* Sam to provide reasoning
7:41	Sam	Because then it lowers it down	Puts down eraser tool after not using it	Sam aims to provide reasoning based on an *assertive*
7:43	Pia	Lowers what down?		Pia *directs* Sam for more information
7:44	Sam	Like look. If you erase that	Picks up eraser tool and erases hydro dam	Sam *asserts* clarifying information commits to a demonstration
7:48	Sam	And then you. There	Uses impact tool	
7:52	Sam	Erase. Some pollution	Points at pollution	
7:57	Pia	Oh. Okay	Removes tool	Pia accepts the *assertive*

In the example, Sam and Pia disagreed about what each other were saying, but were able to use the eraser tool and the impact tool to resolve disagreement about how the energy sources polluted the environment. Between 7:24 to 7:28 Sam and Pia cut each other off as they both pointed at the info card as Sam tried to point out information about the pollution "there it's two" and Pia touched the card to interrupt about energy trade-offs (before getting cut off). At 7:31 Sam suggested removing a coal plant to reduce pollution: "so we take out that." Pia explained "it gives us lots of energy" as she pointed with the tool, before asserting "what's giving us most of the pollution is that" as she referred to the coal plant. At 7:37 Sam picked up the eraser, pointed it towards the coal plant to indicate he planned to erase it, while Pia tried to clarify that the coal plant (energy resource) caused more (air) pollution than the hydro dam. Recognizing Sam intended to erase a coal plant, at 7:39 Pia questioned "why are you gonna take out that one?" Sam tried to explain that the pollution levels decreased (at 7:39) "then it lowers it

down," but Pia didn't understand Sam's assertive as she asked: "Lowers what down?" at 7:43. At 7:44, Sam demonstrated how the pollution result decreased to 'some pollution' as he described: "If you erase that" (using the eraser tool), "then you (erase). Some pollution," using the impact tool and pointing to the pollution result. At 7:57 Pia accepted this explanation and removed the impact tool to allow them to resume the activity. This analysis shows that combined tool use of eraser and impact tool was used in order to determine some information and end a disagreement.

Assertives were used frequently as learners tried to explain their understanding of the relationship between energy sources and pollution. When a directive was not successful, a learner used more tools to try to convince his partner of a concept and committed to using the eraser tool and impact tool to do a demonstration. In cases such as this, minor conflicts could be worked through if one learner demonstrated a finding or presented some reasoning. However, this was an issue when one of the learners did not understand or accept the assertives but agreed to them (or gave up) in order to move on. The eraser tool and impact tool was used together, as well as the info ring (specifically an info card), to support learners to move past this conflict. The info ring's ability to pause the activity helped learners focus attention together, touch and adjustment capabilities allowed both learners to read the information in order to agree to it. However some decisions were made unilaterally, which may have negatively affected the motivation of the other learner to engage or contribute, particularly when they did not agree with the unilateral decision.

5.6. Theme 6: Controlling decisions

Lastly, the last strategy of tool possession and speech was another interesting method of use by learners in how they tried to influence decisions in Youtopia. This theme is similar to the Theme 3: *Advocating for a position* theme in that a learner's goal was to get a point across to their partner, but this theme focused on a learner opportunities for control, by influencing or limiting their partner's participation (e.g., getting the other to comply by a more dominant partner) and finding ways to support their own participation (for a more reserved partner). These uses often occurred as learners realised that their tools could be used to: suspend the activity, distract their partner, and/or allow learners to control which stamps were used. The descriptions below provide details about how learners used tools to carry out a unilateral action, and engage a non-attentive learner.

5.6.1. Taking unilateral actions (as a resolution to conflict)

In some cases a more vocal and dominant partner used tool possession to follow through on unilateral actions and control the pace and decisions of the activity. Carrying out a unilateral action with stamps mainly involved a learner using both a resource and development tool in order to complete actions themselves, instead of trying to resolve conflict. In a few interesting cases the impact tool or info ring was used in quick combination with a stamp to accomplish this. A dominant learner could try to control decisions in the activity by: hoarding tools to assert/express opinions instead of engaging in conversations, committing to activities without endorsement from their partner, or directing their partner to engage in particular actions without understanding about why they should do so. In the example below (see Table 5.15), tools were used with language to carry out their unilateral actions.

Table 5.15. Episode in which learner uses the impact tool and info ring to make unilateral decisions

Time	ID	Dialogue	Action	Speech acts to interpret events
16:38	Jim	All people have energy, most people have shelter, most people have food. We're doing well so far	Points at each section and removes the impact tool while holding the river reserve stamp	Jim *asserts* information about their result, and *expresses* his interpretation of their progress. Jim then *commits* himself to putting a river reserve without requesting feedback
16:43	Jim	Let's just put like, a salmon, a salmon a salmon	As she reaches for the tool he holds it away holding impact tool down	
16:46	Sara	Wait what?	Grabs for his stamps	Sara tries to clarify his goals
16:48	Jim	Fish guys. Member?	holds stamps away as she yanks on one	Jim attempts to *assert* that he's referring to the river reserve stamp
16:50	Sara	But it's in one section so xx spread out	Grabs the river reserve stamp from his hand and pushes down	Sara *commits* herself to stamp the river reserve that Jim was about to stamp as she possesses the tool
16:52	Sara	There we go		
16:54	Jim	Bu//wa// wait a second. Uh produces an//	Takes stamp and puts it in info ring	Jim and Sara compete to *assert* information by reading aloud
16:58	Sara	Overall health and by reducing pollution [so it reduces pollution]		
17:01	Jim	[And] food for a small group of people	Holds info ring and river reserve stamp	
17:05	Jim	That's okay that's enough		Jim *directs* Sara to not stamp more
17:07	Sara	No because then that	Puts down impact tool	Sara starts to *assert* information
17:08	Jim	Little pollution. It's still good. It's still good		Jim *asserts* their pollution level, and *expresses* the world is 'good'
17:10	Sara	Okay		Sara agrees reluctantly
17:12	Jim	So (.) so far we have a pretty darn good world here		Jim *expresses* his assessment of their progress

This episode describes one learner's actions to gather and maintain possession of tools in order to dominate the decision-making. At 16:38 Jim provided information from the impact tool then indicated he was satisfied with their progress: "All people have energy, most people have shelter, most people have food. We're doing well so far." Without waiting for a response, at 16:43 Jim committed himself to stamping the river reserve, "let's just put like, a salmon, a salmon, a salmon" as he held the stamp and the impact tool away so Sara couldn't check the details or use them. Sara questioned Jim's actions at 16:46, "wait what?" as she continued to reach for the tools he was protecting. Between 16:48-16:49 Jim referred to the "Fish guys. 'Member?" to indicate that 'salmon' were river reserves. She used the opportunity to grab the river reserve stamp from him and announced "there we go" when she stamped it. At 16:54 Jim grabbed the tool back

from her and checked it in the info ring as he tried to explain what it did. At 16:58 Sara confirmed that it “reduce(d) pollution,” and at 17:01, Jim confirmed that it also provided food “for a small group of people” (while he held the info ring and stamp). Between 17:04 and 17:07 Sara tried to use the tool again but Jim disagreed and held onto the tools. Trying to argue, Sara stamped the impact tool at 17:07 as she said “no because then that,” (referring to the results). Jim however used the information to reason that their pollution was not a concern: “little pollution. It’s still good. It’s still good.” Sara reluctantly accepted this reason at 17:10: “okay” and Jim further expressed that they had a “pretty darn good world here.”

This analysis shows how tools can be used to amplify a dominant learner’s voice and make arguing with them difficult. Dominant learners used tools in the following ways: holding them away so their partner couldn’t stamp, removing the impact tool while holding the stamp, holding the impact tool down so their partner could not remove it, grabbing tools, and stopping their partner’s actions by using the info ring to pause the activity. Assertives, expressives, commissives and directives were used with these actions to limit the activity of partners. This poses a problem as learners did not solve the problems together and were left with unresolved conflict. Problematically, some tools could augment these decisions, which made negotiation processes more difficult for the partner who did not possess certain tools. The impact tool was used in combination with a stamp to pause the activity and immediately use another stamp. Tools were also held away from their partner for the same reason. However it was possible for the other partner to intervene in these actions by taking and using the impact tool. This leads to some considerations for tool design to control the pace of the activity and how use of physical tools by some learners can complicate fair decision-making.

5.6.2. Engaging a non-attentive partner

Similarly to the power struggle in (described in *5.6.1: Engaging a non-attentive partner*), some quieter learners were able to use tools and language to gain influence and control in the activity. Usually this started if a learner found that their partner was not listening to them or considering their ideas. This theme was similar to *Theme 3*: *Advocating for a position*, but focused more on the power imbalance. In a few interesting cases, the learner was able to impede the control of their more dominant partner by using the impact tool or info ring (usually with an assertive) that would pause the activity (usually the impact tool or to a much lesser extent the info ring) and give them a chance to gather their partner's full attention. They would then assert information, express concerns, participate through use of stamps, or direct their partner to do something. The example below (Table 5.16) illustrates how a learner used the info ring and a stamp to obtain her partner's attention.

Table 5.16. Episode in which learner uses info ring to share information to get partner's attention

Time	ID	Dialogue	Action	Speech acts to interpret events
4:05	Jen	How about garden?	Grabs garden stamp	Jen *directs* Tom to give input on stamping a garden
4:07	Tom	Xx tool hydro dam		(non responsive)
4:12	Jen	Food for small people	Puts garden tool in info ring	Jen *asserts* the information most valuable to her
4:13	Tom	Okay. What do you need for that?		Tom agrees and *directs* Jen to explain what is needed to follow the new plan for making a garden
4:16	Jen	One of these	Gestures and passes garden stamp to Tom	Jen responds and *directs* him to do so using the tool
4:18	Jen	So... you have to put some of these cuz those are in use	Shows Tom river irrigation and stamps it	Jen *asserts* information about how the plan will be carried through and *commits* herself to the plan by stamping irrigation first
:25	Tom	Ehh. Ehh	Uses the garden stamp	Tom utters sounds (acting as *commissives to announce actions)*

In this episode, Tom had his own interests and Jen was able to use tools to get her partner to follow her suggestions. At 4:05, Jen suggested to Tom, "How about garden?" when she picked up the stamp. However, at 4:07, Tom's focus was on the "hydro dam." Recognizing that Tom was not listening, Jen (at 4:12) put the garden tool in the info ring (pausing the activity) and asserted "food for small people." Tom's gaze was then averted to her tools and he questioned "What do you need for that?" at 4:13. Jen

replied, “One of these” as she handed him the garden stamp at 4:16, “Cuz those are in use” (referring to the river irrigation stamp as she used and pointed to it). At 4:25, Tom (understanding what she directed him to do) complied by stamping some gardens.

The analysis shows how a learner used the info ring and stamps to steer their partner (previously noncommittal) to contribute to her plan. A stamp was first used to draw attention by showing it and directing them to an activity and was put in the info ring to stop their actions. When engaged, the learner passed a stamp to her partner to help commit them to use it. As a quieter learner in collaborative learning activities, tools that can engage their partner to participate with them can help equalize participation. This highlights a need to consider other ways that quieter learners can be encouraged to lead discussions through support of tools that allow them to pause activities, engage with their partner’s tools, or put focus on issues which haven’t been addressed.

5.7. Overview of Speech and Tool Use

By reviewing these examples of tool use with speech acts, we can shed light on how tools in coordination with language can support learners in their conversations and in turn, support decision-making and knowledge processes. Additionally, several other interesting features about tool use in conjunction with language have been learned. Figure 5 presents a table of how tools and speech were used (together or separately). The table is divided by the subthemes and overview about which tools were used in relationship to assertives, directives, expressives and commissive acts. The last column describes the tool qualities which support learners’ speech and interactions. This table presents the overview of findings, implications and highlights of how the tools have been used with speech to support learner goals.

Table 5.17: Overview of Findings

Overview of Speech and Tool Findings			
Sub-theme	Overarching finding	Tools/ Representations supporting speech acts	Qualities of the tools to support speech and interactions
1. Exploring the activity logic together			
a. Finding out the purpose of a digital land use representation	Learners used impact tool to share information on interrelationships and form new understandings	Impact tool (assertive, commissive)	• Pauses the activity to draw attention • Maps results to previous decisions • Referentially used to remind learners of previous shared understandings • Physically signals learner to watch
		Stamp (directive)	• Holding a stamp draws attention to look at it • Can use stamp to find out what it does
b. Finding out about trade-offs to decide what digital land use representations to use	Learners used info ring to compare the benefits/differences of two stamps and make an informed decision about which to use	Info ring (assertive, directive, commissive)	• draws attention and share information • switch between stamps and observe differences • removing tool resumes activity and signals to follow through on a move
		Stamp (commissive)	• following through on a directive, learner announces their supportive move
c. Discussing activity relationships to inform future decisions	Learners used impact tool to resolve meaning and highlight which digital land use representations contribute to results	Impact tool (assertive/directive)	• answer to a question through using tool • rings light up and inform decisions
		Eraser + impact tool (commissive)	• combination of tools allow learners to improve (erase) and measure without lasting consequence
		Stamp+ impact tool (directive/commissive)	• tool held and moved down the screen to get a better look and more emphasis on information
2. Proposing plans and suggestions			
a. Proposing plans to improve the results	Learner used impact tool to share understanding to get partner to accept a plan	Impact tool (assertive, directive, expressive)	• having text makes learners repeat the information so they verbalize/interpret it • touching rings to engage with the information • pauses the activity, allows learners to decide on actions before going back to the activity
		Stamps (commissive)	• if impact tool used to discuss beforehand, decisions are made together before learner acts
b. Proposing responses to feedback	Learners used the info ring and stamps to propose a new plan.	Info ring (assertive)	• both learners held the physical tools down to claim some ownership over the items and confirm the information for themselves • tool can be used as a reference tool to answer a question (information the partner does not have) • text prompts learners to repeat information aloud
		Stamp/ feedback (assertive/ directive)	• feedback tabs hint how to carry out actions

c. Redirecting the course	Learners used impact tool to begin a conversation/ direction when unsuccessful	Impact tool (assertive/ directive)	• used to pause the activity and aid in planning/ reflection time • answers the question of what to do next • can be used to provide new focus/restart goal setting (as four levels are presented)
3. Advocating for an action			
a. Providing evidence	Learner repeatedly used impact tool to stress concerns, causing partner to contemplate and act	Impact tool (assertive /directive)	• pause activity/draw attention/emphasize • provides result information/finding the difference • remove to start plan/resume activity
		Eraser (directive/ commissive)	• non-consequential testing • using shared tool with other's approval • allows learners to continue from evidence-based understanding
b. Explaining rationale	Learners used impact tool to request and provide reasoning	Stamp (commissive)	• limited options of how a learner can stop partner from to stamping in no-roles scenarios
		Impact tool (assertive)	• helps accountability, learner points to the results to explain how actions are in line with needs
c. Sharing values to influence their partner's decision	Learner used reflection and passing a stamp in order to prompt partner to consider a direction/ be invested in the plan	Stamp (assertive/ commissive)	• physical stamp passed to use (in-hand) • used to present a case why to use it
		Digital land use representation: mountain reserve (expressive)	• learners made comments based on how they felt about the goats shaping their decisions (how they look influences actions) • lack of visual of people may influence how connected/ how they relate to the people
4. Testing a hypothesis			
a. Predicting the use of a tool supports particular outcomes	Learner used stamp and impact tool to draw attention, and test a hypothesis, share interpretations	Stamp + eraser tool (assertive, directive, commissive)	• used to demonstrate an idea with ability to erase if needed
		Impact tool (assertive)	• multi-touch ability to light up areas and use that information in discussion • tool removed when conversation ends
b. Testing before and after results	Learners used impact tool, eraser tool and stamps to observe progress	Impact tool (expressive, assertive, directive)	• imagery on impact tool made it visual easy to recognize change in levels when compared with previous action • tracking and display of activities allows learners to make predictions and take measurements
		Eraser tool + stamps (assertive, commissive, directive)	• allows testing of idea to be easily erased • multiple physical tools allows both learners to be involved (turn-taking)
		Info ring (directive)	• direct actions related to previous information (connections between past and new actions)

5. Working cohesively			
a. Creating new language/ common plans	Learners developed new language around the tools, engaging in unique discussions	Grouping stamps + using feedback tab (commissive, assertive)	• colour coding and symbol on the physical stamps help learners understand relationships • feedback tab symbol (without text) used to prompt new language for the digital land use representations
		Info ring (assertive)	• gather attention and show information
b. Turn-taking and providing permission	Learners used interdependent tools which support permission seeking/ turn-taking behaviour	Info ring (assertive)	• interdependent tools support a two-step process • acts as an external reference point for information • removal indicates completion of a turn
		Stamp, eraser (assertive/commissive)	• use of a tool signals other's next move • non-consequential (actions can be undone)
c. Working with conflict	Learners used eraser tool and impact tool to suspend/resolve misunderstandings.	Info ring/info card (assertive/directive)	• touch, adjust info card so both can read information • use pauses the activity, removal resumes
		Eraser + impact tool (assertive/ commissive)	• combination of tools used to demonstrate understanding so both can agree to a concept • physicality of tool helps signal to look
6. Controlling decisions			
a. Taking unilateral actions (as a resolution to conflict)	A dominant learner used possession of the impact tool, info ring and stamps to amplify their voice. This made it harder for the partner to argue	Impact tool + stamp (assertive/commissive)	• leveraged to pause the activity and stamp without consensus (partner cannot react quickly) • physical tools were hoarded/held away
		Impact tool (assertive)	• can pause/stop other learner's actions
		Info ring (assertive, expressive)	• used to redirect and carry out own wishes • can pause other learner's actions
b. Engaging a non-attentive learner	A quieter learner used impact tool and stamps to steer partner's attention and contribute to a new suggestion	Info ring (assertive, directive)	• used to pause activity, point out specific things while they have partner's focus
		Stamps (directive)	• physicality of passing partner a stamp focuses partner's attention of what's in their hand

In the analysis, there were varying combinations of how the design features were used as learners attempted to use different forms of evidence to support their goals. There were many interesting uses of Youtopia which involve the holding, blocking, stamping and referring to of stamps and tools, along with interaction with their special digital features. The tools used by learners in combination with speech acts include: the impact tool, stamps, info ring with stamps and eraser tool. Interestingly, combinations of tool and stamp use were also used to explore or provide increasingly convincing information as they advocated for ideas, deepened their understanding of the activity and progressed as they tested hypotheses, proposed plans and reasoning, learned more about activity dynamics, developed teamwork strategies, and gained control of decisions.

Tools were used to enhance their opportunities to: assert information, direct future steps, commit to plans and express learner's opinions in the decision-making, which created more opportunities for dialogue and topic exploration. The six findings help highlight some new considerations of tools and opportunities for how tools and learning experiences can be designed to support collaborative learning by supporting particular types of speech and discussion. The following section explores the design implications and conclusions of these findings and how these contribute to what we know about TUI design.

Chapter 6.

Design Implications and Conclusions

This final chapter describes the design implications and conclusions for this research. Described in the *Chapter 5: Findings* section, speech and tangibles were found to influence several interesting and important collaboration and learning processes, such as: 1. Exploring the activity logic together, 2. Proposing plans and suggestions, 3. Advocating for actions, 4. Testing hypothesises, 5. Working cohesively, and 6. Controlling decisions. Building on the findings, this chapter aims to answer the design question: **"*What guidance and new ideas for the design of TUI systems for collaborative learning can be generated from these observations?*"** The chapter will first describe a summary of the tool qualities which were shown to support collaboration, followed by reflections on transferable design principles and new ideas for design. Next, new understandings on the previous research will be described, followed by reflections on the use of speech acts in this research. The final sections will describe the limitations of the research, and implications for future development, followed by the conclusion.

6.1. Summary of Tool Qualities for Supporting Collaboration

The *5.7: Findings* section presents a new taxonomy of uses for combinations of speech acts and tool features which offer reflections on supports for experiences and discussions with the system. By learning more about how learners can contribute to their collective collaborative learning experiences, we are able to better design for opportunities for learners to explore, explain information, reason why they should take certain actions, negotiate terms and be aware of social cues that support their work. Of the system designs to promote learning, there was evidence that several of the tools' features offered overlapping benefits to support decision-making and negotiation.

6.1.1. Pausing quality encourages joint attention and reflection

The impact tool and info ring were used by learners to reflect on their decision-making and determine information about the relationships between resource use, development and environment health. The impact tool was used to pause the activity and help answer the question: 'is this the kind of world that you want to live in?' by describing what issues (housing, food, energy and/or pollution) learners were or weren't satisfied with. The info ring was used with stamps to identify relationships between digital land use representations and encourage talk about them while the activity was paused. The pausing feature of the two tools allowed learners to point out specific concerns or information while they had their partner's focus. It also allowed for time to decide on actions and develop plans before going back to the activity. Removal of the tool resumed their activity and signalled that some next steps would be followed as discussed. Based on their step in/step back discussions from the impact tool/info ring, often learners revised their decisions using the eraser tool and/or stamps.

6.1.2. Splitting information between tools supports information-sharing and explanation

Coupled information and actions of interdependent stamps, info ring and the impact tool supported learners in comparing the trade-offs for environmental/ development decisions. Using the info ring and stamps, learners were able to try out the digital land use representations of their different tools and explain/demonstrate concepts to their partners by showing how the use of a particular stamp would cause an outcome. Having access to divided tools, individual info cards and feedback tabs, learners were encouraged to share information with their partners via reading, repeating and interpreting the details. Learners were also able to negotiate meaning-making and values by verbalizing their understandings while using or pointing to stamps and feedback tabs, using the info ring, and tracking and reviewing activities. Using the multi-touch interactivity of the impact tool circles also made relationships between actions and consequences easier for learners to describe. Shared experiences and points of understanding were also linked to the tools as they pointed to stamps or digital land use representations.

6.1.3. Multi-step tools support buy-in and action-planning

Several of the learner's actions were coordinated with discussion due to the interdependent nature of the tools. A few features highlighted interesting opportunities to support buy-in processes and action-plan development. Learners were able to construct shared worlds through discussion and stamping of multiple interdependent tools, the eraser tool, and multiple uses of the impact tool to identify and/or agree about what a satisfactory world state was, and reach verbal approval about when they were finished. As the interdependent tools supported a two-step process for completing actions, verbalized suggestions or proposals were presented for learners to buy into coordinated actions. Use of multiple tools allowed both learners to be involved; removal indicated completion of a turn and use of a tool signaled other's next move. Turn-taking then became a natural process of accomplishing tasks and checking the changing results. Some of the more collaborative examples had frequent updates to each other on their next moves and what they found out. The impact tool and eraser tool were also used to support this multi-step process as learners discussed information and decisions before any digital representations were removed. Often the impact tool was used before and/or after the other stamps, making it a three to five step process which supported a deliberate set of decisions to be decided before any actions took place.

6.1.4. Tools supporting low-risk trials enhance informed decision-making

The eraser tool played a key role in supporting learners' ability to explore, learn about relationships and make increasingly-informed decisions about the environment and resource trade-offs. The combination of eraser tool, stamps and impact tool allowed learners to make improvements or adjustments and measure their results without lasting consequences. Other testing features such as info ring and feedback tabs allowed both learners to hold and engage with the tools to confirm the information without influencing results in the activity. By touching and referring to feedback tabs and impact tool information, pointing out the receding river, learners were able to identify how their collective actions and decisions affected the world's state.

6.1.5. Tools presenting information can be used to convince or advocate

In addition to tools supporting joint attention and explanation in Youtopia, they also supported learners in making recommendations for their actions. Learners used evidence (via impact tool, info ring and stamps) and value-based reflections to support their efforts in convincing their partner what actions they needed to take. Sometimes this was leveraged by learners who used the tangible form to influence their partner (e.g., passing partner a stamp so the partner's attention was focused on what was in their hand and presenting a case for why to use it). Combinations of tools were also used to provide demonstrations or show information to influence their partner's acceptance of an idea or suggestion. This also supported accountability where learners could point to the results to advocate why they should focus on a particular basic need, or to explain how certain actions are in line with the current needs.

6.2. Reflections on Design Principles

This section refers to three of Antle and Wise's (2013) TUI design guidelines for collaboration, with the goal to support future design with TUIs. Included below are reflections on how the guidelines supported collaboration in Youtopia, challenges which were presented, and ideas for how these guidelines could better support future projects. A reflection on a new guideline is also described.

6.2.1. Creating configurations in which participants can monitor each other's activity and gaze can support the development of shared understandings

This guideline (Guideline 10) supported the development of several design features such as: feedback tabs, impact tool and info ring. The design guideline was validated in the restrictions of independent actions as learners found that explaining their ideas was important to get partners to buy into their decisions. The form of stamps, visual appearance of stamp feedback, and pause actions of the impact tool and info ring increased their awareness of each other's activities and quickly draw attention to items worth discussing. Using tangibles, many dyads effectively monitored and discussed

activities using gaze and joint attention before acting. A challenge of this guideline is that 'shared understanding' of learners is difficult to identify, but can be looked at in terms of what both learners refer to and speak about. A recommendation for this guideline is that it should be modified to examine the language surrounding the learner's actions. This could be used to design activities which encourage speech from both learners around particular digital and tangible features. For example, creating configurations in which participants can monitor each other's activity can support learners to build on each other's explanations and contributions.

6.2.2. Distributing roles, information and controls across the TUI learning environment can promote negotiation and collaboration

Guideline 11 supported information-sharing and promoted learner contributions through distribution of tools, roles via the stamps, (through their physical labels and restrictive actions) info cards and feedback tabs. This guideline was validated as the design features supported learners in identifying tool ownership, requesting involvement from their partner and sought buy-in, which supported general negotiation processes. Relationships to roles and prerequisite stamp relationships were present (via the basic need colour-codes and resource/developer land use representations on the stamps). The shared info ring was used to find out the characteristics of their tools and played a role in evaluating trade-off decisions. In Youtopia, role distribution had some effect on how learners negotiated meaning-making based on the ability to use their own stamps, however reflections on individual contributions to outcomes were not described. There were some expressions of individual values but more scripting/ scaffolding around the roles or prompting reflection on individual contributions would be needed to encourage explicit discussion about values. A recommendation about this guideline is that it should be specific to what the learners can negotiate (e.g., distribution of roles, controls and information can promote negotiation of values/ideas/plans/points of disagreement and/or evaluation of trade-offs/decisions). Alternatively, distributing roles, controls and information can also promote discussion, information-sharing and more equitable contributions.

6.2.3. Creating constrained or codependent access point schemes can compel learners to negotiate with each other

Guideline 12 supported the development of interdependent stamps in role scenarios which required contributions from both learners to take actions and make decisions. Learners used several features to support their negotiation (see *5.7 Overview of findings*). For example: interdependent stamps and resource/development reliance required learners to consult each other and share information. Using the impact tool to discuss trade-offs and potential damage appeared to be the most informative discussions in negotiation of activities (e.g., where to put the homes, and how to use resources), however the developer role may have been in a better position to negotiate of dependency on resources. In some cases this role was not as compelled to support the resource role and moving forward, more complicated negotiation relationships should be experimented with. This design guideline was effective in promoting learners to speak to each other and make decisions together. One recommendation for enhancing this guideline for design could be to specify what learners will be negotiating (e.g., mutual-benefiting decisions, plans, buy-in, verbalizing concerns, points of disagreement, or power dynamics). However not every study will look at negotiation in the same way, so the guideline as it stands is applicable to any teamwork activity that aims to encourage balanced participation.

6.2.4. A new guideline

In addition to these guidelines for TUIs, there are additional opportunities to encourage deeper levels of negotiation and reflection. For example, based on how learners negotiated meaning and decisions with Youtopia, a guideline could encourage designers to consider how learners will bring in new information, learn from their experiences and make better informed decisions. Guideline 13: Create opportunities for learners to jointly reflect on their actions and make corrections to improve their decision-making. This guideline would promote the externalization of evidence, expression of values, reflection of contributions and accountability. The implication of this guideline could be in the tool design (such as an eraser tool), on the learning activity (question prompts) or actions on object relations (pausing the activity), but could also be transferred to another project which aims to support dialogue and reflection.

6.3. New Ideas for Design

This section presents some new ideas for design to influence the quality and frequency of meaningful interactions and dialogue in TUI activities. Based on Antle and Wise's (2013) TUI categorizations of physical and digital objects and actions on objects and informational relations and learning activities, this section aims to reflect on and highlight some new design considerations about future TUIs that will improve meaning-making, information-sharing and negotiation of ideas and actions and low-risk trials.

6.3.1. Physical and digital objects

Physical and digital objects describe the "set of materials through which learners interact with the TUI system" which "exist concretely in the world and have physical properties that must be designed" (Antle & Wise, 2013, p.4). In Youtopia, learners used the tangibles to signal to their partner to watch them or pay attention to what they had to say, to encourage/advocate for their use, remind partners of shared understandings and confirm information. In a few cases they were also organized by colour code and symbol to make sense of the tool relationships. In addition to these purposes, the digital and physical forms of the tools and information were explored for their function and representational meaning. New examples could include fresh tangible forms which hint at the tool's use (e.g., resources could be one shape or size and differ from the development tools), or visually/physically hint at the prerequisite tool/ representation that it needs, or at the results it provides (e.g., two stamps could fit together like a house for use). Alternatively, the tool form or imagery of info cards could hint at the benefits or damaging effects on pollution or resources (e.g., by image, size or colour).

The multi-touch features of tools also seemed to support learners in demonstrating and verbalizing how actions related to results (e.g., touching impact tool circles, feedback tabs or resizable info cards allowed both learners to see or read). The visual presentation of text with images also encouraged learners to repeat the text aloud. Results (via the impact tool) were also used to reset conversation, answer questions about how they were doing, advocate for world needs, provide accountability for actions, prompt discussions, and support evidence-based planning, prediction and hypothesis

testing. Other avenues for exploration about building meaning-making with the tools may involve developing spaces for shared plans or understanding away from the main activity. For example, offering more opportunities for reflecting and grouping ideas together (via digital notes), creating timelines, reflecting on major decisions, or enhancing the interactivity of the info cards to support reflection or negotiation about trade-offs if multiple tools are used at the same time.

6.3.2. Actions on objects and informational relations

This category included the relationship between the objects and abilities; through the "coupling of physical and digital objects through action (i.e., control) and information relation or association (i.e. representation coupling)" (p.5). A tool's ability to pause, emphasize points, support power dynamics and conflict was an important discovery in this study. The notion of stepping in and out of space (Ackermann, 1996; Rogers et al., 2004; Antle, 2014) to explore activity logic also has implications on team dynamics in addition to reflection. The ability to pause and resume the activity with tools aided learners in gaining a partner's full attention in order to advocate for a point (sometimes using several tools in sequence or repeatedly). Use of these tools also supported the start and stop of a discussion, often with the tool being removed when discussion was near completion. The pause function also magnified power struggles (e.g., with the ability to pause partner's actions, or leveraging own actions to carry out unilateral moves without consensus). Some other areas to explore could be how designers can influence power dynamics (e.g., restricting moves, time, or present visual feedback when one learner participates more than the other (such as in Bachour et al., 2012)). Supporting a designated space for agreements or plans, designers could develop opportunities for learners to highlight or write on digital representations (e.g., info cards).

Although the interdependent tools compelled learners to ask each other for support or permission, they could also use the tools to influence participation. Many decisions required a two-person process and this influenced a pattern of turn-taking behaviour (i.e., the completion of one person's action led to the other's turn). Pausing tools such as the info ring and impact tool were used to redirect conversations, and in unequal partnerships, this allowed learners to stop each other's actions, use tools in

succession to carry out their own wishes, and thus limited how many moves the partner could make. However, quieter learners were also seen to take efforts to improve their position by using pausing tools to enhance their speech by pointing to evidence, and passing tools to their partner to consider their requests. An area worth exploring would be critically looking at the benefits and downfalls of control-seeking and turn-taking to better understand how and why certain tools or features support argumentation or depth of conversation. Different kinds of destructive behaviour could also be examined (e.g., a learner who erases a partner's work) in order to find ways to promote learners' working strategies.

6.3.3. Learning activities

Learning activities refer to how "design can influence how learners take action on the system as well as how they interact with each other" (Antle & Wise, 2013, p.5). In this section, the framing of the activity set the tone for the learners' goals. The set-up of the activity (facilitators instructing learners) set the objective of developing a utopian world, and the freedom to let them formulate that visualization. The challenge was in creating a shared understanding of a satisfactory world, and the constant negotiation of what it looked like based on the existing version of Youtopia. The planning aspect of the activity (allowing learners to try out and remove ideas, and use non-committal demonstrations to learn about and explain concepts) allowed learners to engage and convince each other of what actions they should take and why. Future work around the learning activity could examine how the framing, objective, or instructions could be revised in order for learners to work towards different goals. For example, redistribution of tools, or prompting learners with questions about equality could support the learners in reflecting critically on the division of resources.

6.4. Building on Prior Understanding about TUIs and MTs

This section describes how the findings build on previous literature about how participation and reflection, conflict and verbalization can be enhanced through specific features of the systems. Several traits were broadly supportive of collaboration in TUI/MT tabletop design. For example, factors such as joint attention/awareness of activities, opportunities to co-regulate actions/support turn-taking, slow down actions, and promote verbalized reflection and equal participation (Jamil et al., 2011; Buisine et al., 2012) all had ties to successful collaboration which could be measured quantitatively. However few researchers described how and why collaborative interactions occurred or what intentional designs contributed to successful examples. Three categories of expanded understanding are described below.

6.4.1. Participation, turn-taking and reflection

Providing adequate time for reflection was a consideration when developing Youtopia and balance action and information with opportunities for idea sharing, debriefing decisions and coordinating plans. In the role scenarios with Youtopia, learners were given a set of tools and were aware of which tools and contributions were theirs. However there was expectation from the researchers that learners would be aware of their contributions (such as in Bachour et al., 2010) via impact tool circles which highlighted which digital representations contributed to which results. The learners did not however verbalize that their individual actions had contributed to a particular score. There was some co-regulation of actions (via the impact tool results and turn-taking/permission-seeking behaviour); however the co-regulation was often near the completion of the activity. For future reference, goals to promote verbalization of individual contributions should include a visual prompt or indication of one's efforts that can be visible while the activity is paused. This would enable learners to think about their contributions and consider how their actions could be improved.

The studies of Marshall et al. (2009) and Olson et al. (2011) described issues of conflict, participation and ownership over physical and digital objects, which were related to learner's ability to control and share items. In Youtopia, the goals and roles were distributed amongst the learners, and results were presented as "shared" so that there would be a sense of positive interdependence. The Olson et al.'s (2011) study about different kinds of toolbars highlighted that a tangible supported the social norms of turn-taking behaviour and sharing/passing of tools. This was confirmed, in that the visibility of partner's tools and interdependency encouraged turn-taking behaviour and permission-seeking, as partners in Youtopia often needed the buy-in from their partner to complete an action. In some episodes, learners relinquished a shared tool (e.g., impact tool, info ring, eraser tool) once they had used it, often to be followed up with an action from their partner. Olson et al. (2011) did not describe the qualities of the shared tool other than its physicality, but in this study the qualities that supported turn-taking behaviour included: joint-attention, visibility of the tools, and interdependency. For example, often one learner made a suggestion and waited for their partner to respond/comply before they took a turn. This also supported awareness of partner's actions as there was a relationship to their own ability to complete actions. Although there were some instances where a learner could hold or use multiple tools, this was not a regular occurrence. Regarding opportunities for reflection (Schneider et al., 2011; Ackermann, 1996; Rogers et al., 2004), suggestions about the pausing action of the Youtopia tools allowed for some important reflections and planning discussions to occur. In some cases, the removal of the pausing tool signalled that a conversation was complete and indicated that a partner could continue with a previously suggested action. Building on Antle's (2014) reflections on "referential anchor" and "evaluation against task goals" (p.68), this was also a key time to advocate for a basic need, or propose a new plan while results were in plain view.

6.4.2. Access, interference and verbalization

Falcão and Price (2011), Stock et al. (2009) and Zancarano et al. (2012) focused on the learning potential of conflict and consensus-building related to having access points, shared visual fields, digital feedback and dependency on shared tools. This study was able to build on the research of these authors by offering insight into how interdependent tools and access to multiple tools could encourage participation, but also limit and control the actions of others. Some of the ways that learners inhibited each other's actions were by seeking ownership over tools and using the stamps (or eraser tool) without discussion before acting. Building on the work of Falcão and Price (2011) about consensus-building, useful types of integration-oriented consensus building could be related to how learners proposed and accepted ideas, or resolved conflict by sharing values, providing evidence, testing hypothesises or presenting rationale for decisions, or by using reference tools such as the impact tool. The Zancarano et al. (2012) study was able to help learners provide clarity about their conflicting ideas and promote consensus-building (via the disabling/enabling of functions).

With Youtopia, learners were indirectly able to highlight and refer to points of disagreement but they were not able to necessarily limit/prevent future work from occurring. Learners were able to temporarily pause the activity, even though their partner could remove the tool. Also, not all actions or disagreements were as visible as in Zancarano et al. (2012) or Kharrufa et al. (2010) but this study did bring out some reinforcing ideas about enabling conflict (via differing roles) and supporting resolution (by supporting learners to explain and reason). Learners could point to the impact tool (results) for visual support to externalize their thinking (e.g., by reading the text aloud), but in some cases learners agreed with a suggestion or request without much explanation (potentially being passive or avoiding conflict). A potential limitation of the design was that the differing roles of developer or a resource manager were not taken advantage of, as learners were not explicitly encouraged to verbalize the concerns that their Youtopia citizens had. The next section reflects on the use of speech acts to inform knowledge processes and TUI design.

6.5. Reflection on Speech Acts in Knowledge Processes

Using a Speech Act lens helped to stress interesting findings on how speech aids the construction of knowledge processes. This categorization was useful in looking at a broad range of interactions and speech, but a follow up study would look at more specific and different aspects of speech in-depth. The sections below describe what was found with speech acts, as well as what potentially new information could be found using alternative ways of using speech acts.

6.5.1. What was found with speech acts

In supporting ways that learners could assert information, learners had more options to build new ways of meaning-making, communicating and informing each other of plans before they were carried out. Learners used directives and tools to ask for their partner's participation to share or find out information, or contribute to a course of action. Discussing results from the impact tool circles could lead to a new direction, or stamps being utilized with the info ring could be used before proceeding with a 'plan' or some next steps. In some cases when directives followed assertives, this improved explanation of ideas and supported buy-in from partners. Commissives had both individually-focused actions and group-benefiting actions. Learners often used commissives to announce what they were doing, sometimes with space to intervene, but in many cases they used them because they had already committed their actions to do something. Group commissives were interesting, because although they happened to a lesser extent, these would involve learners talking through what their next steps should be, sometimes with reasoning and shared agreement (shown by one person agreeing, and the other partner following through (sometimes also stating a commissive)). Learners provided expressives to guide each other's work and give feedback and evaluate how they thought about the world. The reflection question from the impact tool also helped prompt learners to express their thoughts about the world. The mountain reserve 'goats' were also mentioned in a few episodes which learners used to describe why they liked goats and describe some concern for their placement. Declaratives were not used very often in the examination of learners' speech in this study. In reviewing learners' interactions with speech acts, learners used speech to support their goals, in:

1. keeping learners abreast of actions in line with team decisions and developing agreed upon strategies via commissive acts.

2. teaching each other through use of assertives and tools to share information and promote evidence-based reasoning.

3. using expressives via personal reasoning to convince each other to make value-based decisions.

4. supporting exploration and planning using directives which consider the contributions and support of their partners.

6.5.2. What could have been done differently with speech acts

A limitation of using speech acts for this type of exploration was that this type discourse analysis was not intentionally designed to examine speech with technology. There are also multiple ways that this research could more deeply examine specific types of speech. If new types of specific research questions were asked such as: What leads to valuable moments of negotiation? What would be considered valuable examples of negotiation? It would make sense to look at in-depth planning through supporting multi-step actions when commissives were used after assertives/directives. Future researchers could also explore expressives and ways that they were prompted, and potential ways to encourage value-based utterances (related to human/animal well-being). Stricter use of speech acts within specific contexts could be used (any utterances that seem to redirect how terms are used, or seem to influence modes of actions). This may have helped identify turning points when realizations of concepts were newly described and adapted.

The findings could have also been possibly more specific, informative, or more direct and less descriptive if different categorizations of speech acts were used. Related to the work that Ziegler et al. (2013) did in their research, more descriptive terms could have been used to analyse how speech acts supported meaning-making, including: describing, extending/reinterpreting, refuting, finding commonalities/differences, evaluating, requesting/providing clarification, labeling, explaining, assuming, providing evidence about one's own assumption, and challenging the assumption of another (p.7). Using these categories would have provided more specific insight into the most frequent acts, and also provided deeper insight into which tools/functions best supported different

levels of meaning-making. Rogers et al. (2004) used findings of speech that categorized some overarching themes, documenting that learners used speech acts to: ask questions, instruct another, suggest and invite, request confirmation and invite, offer and invite (p.3) and encourage contributions (p.4). Both of these approaches used expanded subsets of speech acts that provided supplementary information to other findings, and use of either one from this study would have been simplified the criteria for the coding. Even though the study was open to a wider possibility of findings, categories such as *exploring the activity logic together,* or *advocating for an action,* could have easily used either of the two categorizations to look deeper into the episodes.

Alternatively, the order of how the episodes were transcribed also could have had an effect on how the interactions and speech were interpreted. If tool use was looked at initially and speech was the secondary focus, different categories of speech may have been linked to the tools (with no interest in looking at the speech that happened in between actions) or if learners decided against taking action. Some of the findings would have been the same; prominence would be put on the act of a tool and speech surrounding it, rather than several other possibilities for speech that could lead to the action. Although this method sufficed to gain a broad picture of events, speech and tool use, in future work it may be more constructive to look at important tool uses (e.g., eraser, impact tool, info ring) to look into interesting negotiations or discussions happening before or after usage.

6.6. Limitations

There are several limitations that could be considered in this study in regards to the implications that can be taken to other studies. The limitations which are described include challenges with the transcription and analysis of this study.

6.6.1. Transcription challenges

There were several transcription challenges in the manual form undertaken. In addition to being very time-consuming to watch and transcribe 100 episodes, the data was on a secure server and accessing the lab and transcribing onsite was a challenge. Additionally the available robust video software took a long time to load a single video. Given a limited amount of time to transcribe; each of the videos was viewed using the VideoLan Client (VLC) Media Program as it was the most flexible video program available that required the least amount of video loading time. However, VLC did not have a lot of capabilities to code sections of video, save any work, or do anything besides view video. A bird's-eye camera and front camera collected video for each of the sequences and the time codes on these videos did not match, so when the top camera needed to be viewed to verify which stamp was used, the video had to be manually reviewed to find the starting place of the sequence needed. As well, initially batches of segments were initially transcribed with the goal to save time, with analysis to happen away from the video lab, but this required several more reviews to verify and compare the analysis of what had actually occurred to clarify nuances or any missed actions.

6.6.2. Analysis challenges

It was difficult to model an existing template since there were not many examples of qualitative interpretative studies using Speech Acts and tools. Looking to a basic framework, the five main illocutionary acts were used as a framework for analysis of speech. Further distinctions of speech acts could have been used to pinpoint specific types of assertives, directives, expressives, commissives and declaratives of specific acts happening (such as Ziegler et al.'s (2013) online post analysis), but for the first attempt to analyse the speech and actions, a 13-point list would have been difficult to examine to capture the variety of possible interactions and many would not have mapped to the types of conversations that the children had.

Another limitation of the research was the difficulty in coordinating a second coder. Due to the lengthiness of the transcription, coding and analysis phases, the time commitment required from other researchers would have been quite extensive, however members of the research team were consulted with throughout this study's process. It was also not possible to do member checks with the children, as this study used secondary data. However, the focus on the analysis was to provide some generalizable design recommendations based on the conversations, interactions and decisions learners had, and not specifically their intentions.

6.7. Implications for Future Development

As a robust TUI system, Youtopia has efficiently integrated several design considerations to facilitate learners to work collaboratively together (Wise et al., 2015). However there are still several areas that could be improved in order to capitalize on particular kinds of discussions, explanations and reasoning. Identified potential outcomes of new ideas could influence motivation and exploration, reasoning and reflecting skills, and promote better awareness of group behaviours. This section reemphasizes the value of supporting affordances and guidelines for design in order to improve the depth of learners' conversations by creating more test spaces, visualizations on decisions, tangible forms for reflecting or supporting buy-in, as well as possibilities for scripting. Additional recommendations about future methodology are also provided.

6.7.1. Learner motivation and exploration

As motivation plays a key role in the enjoyment of an activity, prolonged participation or repeat uses would require modifications to keep learners engaged, exploring and trying new methods. Two possible suggestions include making space for test spaces or increasingly complex worlds. One possibility for the design of the activity would be to enhance the use of evidence to make better informed decisions. For example, although Youtopia has an impact and information tool which help in this way, a compare space or a space (to step out) could be used to compare two or three similar tools and their associated information and also see the effect on the environment (e.g., reflecting on pollution or water quality).

From the literature review, opportunities for testing out their ideas (Falcão & Price, 2011) played an important role in the collaborative learning process. Further developing test spaces could support learners in trying low-risk experiments and tracking their actions. Learners could use a tool to play out a scenario with the ability to stop or remove the tool when the learners are satisfied. This would allow them to take more testing opportunities without making any changes to their current state, and use the findings for evidence or to advocate for further decisions. Another consideration for engagement would be the consideration for complex tasks for experienced learners. Learners could be faced with issues such as having more limited resources; higher pollution levels in certain areas and migration of people which would encourage learners to reconsider their strategies and goals. However the implication could be that people may not make any decisions and the benefit of first making a decision and then testing its effectiveness may make learners less confident in their suggestions or assertions. Some of the richer conversations occurred when learners retraced their steps, explained reasoning or trade-offs of the options and had to make more difficult decisions.

6.7.2. Reasoning and reflecting skills

Developing opportunities to support reasoning and reflecting skills could also enhance learning objectives for Youtopia. Some suggestions into enhancing learning opportunities for these skills could include more tool designs which prompt verbalization, reflection and accountability. Shared spaces for developing new terms and interpretations seemed to be valuable in helping learners to work together and understanding more about each other's ideas and plans. Enhanced areas for shared discussion space or reflection could include sending or dragging information to the learner's side of the table to prompt discussion. As pausing was one of the most important aspects about the impact tool's ability to support focused discussions, additional question prompts for in-depth negotiation, recalling and interpreting information, or visually mapping the experiences could be used as a reflection space or help them explain their goals. A timeline tool could also help learners keep track of and reflect on their decisions and accountabilities. This could be done by showing a fast-forwarded time lapse or linear visualization of their changing world, so that learners could discuss the changes on the environment (during or after the activity). A challenge

or implication of these modifications is that learners may lose interest in reflecting on every decision, and these options might make decision-making more onerous.

6.7.3. Supporting collaborative team behaviours

Although there is a danger of over-scripting, there are some possibilities for encouraging helpful or consultative behaviours. This section describes a few ideas related to tangible forms, shared actions and interventions through mediators. It would be interesting to experiment with the forms of tangibles in relation to sharing and negotiation. Are there some forms or textures that are more promoting of sharing? (e.g. passing an item from person to person). Are there forms that are more convenient for two people to hold at the same time or can grab attention faster than other forms? For example, a tool with two handles, or a tool that shakes if it is held too long. However the tangible forms may also distract learners from the task if the tools command more attention than the activity. To improve the way that learners convince their partner to engage in particular actions, more elaborate buy-in processes could be explored in regards to tool/activity limitations. Potentially there could be some mechanisms to restrict how many actions one person could do alone, or how many suggestions a partner could agree with or disagree with to ensure participation from their partner. Alternatively, negotiation can also be encouraged through different kinds of goals and scripts. If learners were provided with specific goals (e.g., to reach 100% of all basic needs or use as little water as possible) would this have an impact on how learners work together? Perhaps if more time was spent discussing roles and values prior to the activity, this could prompt more discussion about individual values from learners within the activity. However, a danger of these ideas could the over-scripting and restriction of natural collaboration (Dillenbourg, 2002). As well, if the functionality of the tools are not intuitive, learners may also become frustrated and lose interest in the activity.

Method revision

Given the lengthiness of this analysis process, if this research question was to be investigated again, limiting the scope of viewable data could offer a few new benefits to the study. Potentially two videos (with 'rich' discussions) or particularly interesting themes could be looked at in-depth for more exploration into the circumstances leading up to/or following interesting tangible uses. This would improve the opportunity to involve other researchers in member checks, as well as present potentially deeper findings about which kinds of conversations or tangibles were most supportive of information-sharing, negotiation, or other kinds of collaborative behaviours. However, it was valuable to learn about the barriers to collaboration, as well as what learners used the tangibles for, even when their efforts did not directly support collaboration.

6.8. Conclusion

This research contributes to both CSCL and HCI fields in future designs for collaborative learning with TUIs. By studying learners' interactions, a new taxonomy of learners' speech and tools has been developed, along with some considerations for enhancing opportunities for sharing and dialogue. The six themes of how learners use tools and speech to support their interactions were found: 1. exploring the activity, 2. proposing plans, 3. advocating for a position, 4. hypothesis testing, 5. working cohesively, and, 6. controlling decisions. By studying how learners engaged with each other with Youtopia, new ideas of designing collaborative features were brought forward, such as: developing tangibles or digital assets to support specific types of collaboration or negotiation, and supporting spaces and opportunities to: discuss trade-off options, share notes and ideas, develop plans and explore complex relationships in the activities.

For optimal collaboration with TUIs, learners should be able to access tangibles (controls and/or representations) which support articulation of inner speech and can help to develop external representations. Some reflections about tool qualities for supporting collaboration include: pausing activities to encourage joint attention and reflection, splitting information between learners to support information-sharing and explanation, encouraging partner support and action-planning through multi-step tools, supporting

low-risk trials in order to enhance decision-making skills, and providing learners with tools to present information that can be used to advocate for actions.

A main implication for the design guidelines is to modify recommendations and expectations about ‘collaboration’ by specifying the expected form of negotiation (e.g., building on each other’s explanations and contributions, negotiating values or plans, or evaluating trade-offs and decisions). As well, designing for collaboration can include designs for supporting mutual-benefiting decisions and buy-in from team members. A new guideline also recommends designing opportunities for learners to jointly reflect on their actions and make adjustments to their deeds to improve their decision-making. Future development may also have an impact on learner motivation and exploration, developing reasoning and reflecting skills, and supporting certain kinds of supportive team behaviours. These include creating more test spaces, providing visualizations which prompt learners’ reflection on decisions, experimenting with tangible forms for opportunities to support discussion and buy-in, and promoting possibilities for supporting team accountabilities in the activities. Through the use of this study, readers will have some new understanding about some interesting relationships between speech and tool use, and how these considerations and ideas can potentially enhance conversations and interactions with TUI systems.

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