Exploring Context in Primary Education Classrooms: Implications for Tangibles Methodology and Design

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1. Introduction
In this abstract we will first discuss the general research topic and motivation for our work. We will then give an overview to the current research being conducted, including research questions and methodology. We will then discuss how the proposed PhD research will extend our current exploratory investigation. This work explores the contextual factors that can impact the design, evaluation and use of TUIs for learning by conducting preliminary research in an actual Canadian primary school classroom. This study is intended to not only create design knowledge for these systems based on real teacher/classroom needs, but will also contribute methodological knowledge that can be used for future in-the-wild classroom studies.

2. Research Topic and Motivation
Current research in tangible user interface (TUI) design investigates ways that digital technology, combined with tactile and gestural interaction, can not only enhance our ability to learn [2, 4, 8, 16, 17, 19, 20], but can also make learning more fun [13]. The conversation about the potential of TUIs for learning is growing and has been of particular interest within the IDC community (e.g. [6, 7, 14, 22]) – partly driven by technical developments and lowering costs. It seems more possible than ever to think about deployments of tangible systems within everyday environments like the classroom.

Much of the research on TUIs' potential in learning aims to understand how system affordances complement learning processes within individuals. Several recent studies concerned with learning on (non-TUI) tabletops failed to find significant positive effects [8]. Reflecting on this problem, Marshall argues, "where tangible interfaces are used to promote an activity like learning" that "a more empirically grounded framework is necessary to facilitate design" [16]. Recently, researchers within in the field have focused on creating more systematic and formalized approaches to the design of TUIs for learning, like frameworks informed by theory (e.g. [3]) or classes of activities that may be better learned or explored through tangible interaction (e.g. [1, 9]). These contribute towards more concrete, systematic bridges between theory and application for educational TUI development, but they do not address contextual sensitivities that can influence a systems' (un)successful integration into actual contexts such as classrooms.

Though efforts to gain an understanding of the co-located, social TUI experience have been made for users in real-world contexts [10, 21], these studies neither explicitly address the constraints and expectations of varying educational stakeholders nor do they provide insight about actual TUI integration within classroom culture. Additionally, little focus is put on how TUIs, integrated into actual classrooms, can play a role in the holistic development of interconnected competencies outside of explicit curriculum learning. Chapman et al. point out that primary school education extends beyond curricula and therefore needs to also facilitate aesthetic and artistic development, emotional and social development, intellectual development, physical development and well being, and development of social responsibility [5].

Reflecting on these problems, Zaman et al. caution researchers about "an a priori assumed superiority of tangibility" and that "the field of tangible interaction would benefit from more empirically grounded demonstrations of benefits and from studies that explain what these benefits might imply for young users" [23].

3. Current Research
Through our prototype exploratory qualitative study, we use The Activity Checklist as a guide for structuring interviews in an effort to formalize our understanding of how and in what ways tangible tabletop technologies mediate classroom collaborative learning activities. This work contributes contextual design sensitivities – from our emergent *themes* – in the form of design questions. This work also introduces the potential for Activity Theory (AT) and The Activity Checklist as a way to more formally structure future contextual inquiries – particularly in the area of 'educational' technologies.

3.1 Research Questions
RQ 1. What underlying contextual themes or concerns arise, from a teacher's perspective, when considering the integration of a collaborative learning TUI-touch tabletop within a primary school classroom environment?

RQ 2. In what ways, if any, can these themes inform sensitivities for the design, evaluation, and/or in situ practices of (tangible) user interfaces intended for collaborative learning activities in primary education?

RQ 3. In what ways can 'contextual' theoretical tools, particularly The Activity Checklist, help inform or be integrated into existing methodologies for designing and evaluating collaborative learning technologies for in situ (educational) activities or practices?

3.2 Methodology
We conducted our study with 21 pairs of 5th grade (aged 10–11) students from a local primary school. Children used a TUI-touch land use planning application implemented on a Microsoft PixelSense digital tabletop for up to 30 minutes to create 'the

world they would want to live in'. Two teachers familiar with the students and the 5th grade sustainability curriculum were asked to observe a pair of children using the system and were then interviewed with questions guided by The Activity Checklist. The teachers were tasked with playing the land use planning activity together. Teachers were also tasked with creating the student pairs based on similar curriculum/technology competencies (equal playing field between partners), mixed gender (minimize effects of gender by having all pairs boy/girl partnerships), and track record for working together (equal opportunity for collaboration distributed across all pairs). Five researchers took observational notes, which were later compared with the observational video data to find common patterns of interaction as well as 'confirm' conversations and actions. The video data was captured using two HD cameras: one gave an aerial view from its hanging position on the ceiling and the other, positioned on a tripod, provided a view of the children, the facilitator and the tabletop.

3.2.1 The Activity Checklist

AT has gone through many adaptations over the years, particularly as each new field of inquiry brings with it new socio-cultural factors and mediating artifacts for examination. As part of AT's HCI-specific transformation, many tools have emerged to bring AT down from a high-level framework to 'tools' that can be used for technology design and evaluation, many of which come in the form of a checklist to help guide attention to the aspects of human activity that are most pertinent [11]. Quek and Shah [18] point to these tools as support for "asking the right questions" when analyzing, designing and evaluating interactive systems – particularly when human behavior is tied to socio-cultural or contextual concerns.

One of these tools, The Activity Checklist [13], "is a guide to the specific areas to which a researcher or practitioner should be paying attention when trying to understand the context in which a tool will be used." Though the checklist is not intended to produce "ready-made solutions" it touches on all of the main precepts important to AT and is best used by researchers and designers to frame meaningful questions [13]. The checklist provides focus in the following four areas:

1. *Means and Ends*: In what ways does the target technology impact the ability for a user to reach their goals? And what role does the technology play in conflicts between different goals?
2. *Social and Physical Aspect of the Environment*: What are important considerations for how the target technology can be integrated with existing requirements, resources, tools, and social rules?
3. *Learning, Cognition and Articulation*: In what ways does the target technology support both internal and external components of the activity?
4. *Development*: In what ways does the target technology facilitate the development of activities over time?

This checklist was chosen because it allows us to explore the space of the primary classroom context for designing and evaluating educational interactive technologies [11]. Additionally, this checklist is beneficial because the concept of tool mediation, central to AT, spans the questions in all four checklist categories [18] – providing a way to understand technology concerns *spanning* categories as well as ones that may be *unique* to a particular area.

With the 'evaluation' section of the checklist as a guide, we adapted our interview questions to explicitly reflect the TUI as our target technology[1]. Since the checklist questions provide 'generic' or 'abstracted' technology and context as its focus, it was important for us to understand the main point of each category (as noted in the previous list), how this mapped to our classroom context (target actions, users, goals, rules, etc), and how the system (target technology) fit, or didn't, into each question. Understanding each of these allowed us to choose and adapt the questions that were most pertinent to address RQ 1. Note that as a result we did not adapt questions for all the evaluation checklist questions provided. Two questions were adapted from areas 1 and 4. Three questions were adapted from areas 2 and 3. For example in area 3 of the evaluation checklist the question provided reads "Is the whole 'action lifecycle' from goal setting to the final outcome, taken into account and/or supported?" We adapted our interview question to read "In your view, does the system take into account the whole cycle of learning as you understand it?" This allowed us to gain an understanding 1) of *their* opinion on the whole cycle of learning 2) how *they* teach (sustainability) or what models/pedagogy *they* follow and 3) how *they* do or don't see the system fitting into this vision or practice.

These interviews were audio recorded and transcribed. The themes were derived from the responses that reflected explicit areas of concern or importance for *both* teachers that *spanned* checklist categories and interview questions. We opted for this approach to inform RQ 2. The checklist allowed us to identify areas of concern so "they can be explored more deeply" [13]. Gaining an understanding of *unique* concerns implies a level of understanding of more general concerns, which is not really available at this stage of exploration. Since the teachers were only available to sit in on one pair observation, we then triangulated our themes with the observational notes of the five facilitators and double-checked noted instances in the video data from the other 20 pairs of children who participated in the land use activity. This added rigor by confirming the themes in other instances of authentic activity, as well as by ensuring that multiple observers agreed on the interpretation of the events.

4. Research Instrument Youtopia

The TUI-touch tabletop application used in our study, *Youtopia*, was designed to meet basic BC (Canada) learning outcomes for 5th grade environment and sustainability topics (ages 10-11). This application was demonstrated at IDC '13 in NYC. Sample learning outcomes include:

- Analyze the relationship between the economic development of communities and their available resources;
- Analyze data to determine if a resource is renewable or non-renewable;
- Understand that some resources are constantly available and are considered to be renewable resources (e.g. hydropower);
- Describe potential environmental impacts of using living and non-living resources;
- Analyze how living and non-living resources are used.

The main activity in the system is using physical stamps to designate land use types on an interactive map. The goal of the activity is to support either a small or large population with enough shelter, food and energy without over-polluting the world.

[1] For examples of its use in design and evaluation projects see [12]. Also, the checklist was also used to structure and interpret interview data in a prototyping in game design study [15].

There are different types of shelter, food and energy sources as well as nature reserves, each with different benefits and limitations. The map is of a small area of land including mountains, valleys, grasslands and a river. There are four maps that have similar size and resources. Only the terrain elements are arranged differently. Choosing a new map by touching the maps symbol on the menu restarts the game. Choosing a large population by touching the population symbol on the menu continues the same game with a larger population or restarts depending on which option is selected. Together, the different populations and maps add sufficient complexity to the application so that children can play for long sessions.

Natural resource and human developments are two main land use categories. They are designated with a tree or a wrench on the top of the stamp handle. Each is also labeled with a picture and text to designate the land use type. When stamped in a legal location a larger version of the picture on the label appears on the map. Six stamps can be used to designate natural resources as usable for subsequent human development (e.g. create coal mine from coal reserve, harvest lumber from forest, create river reserve). Seven stamps can be used to designate human developments made from usable natural resources (e.g. create coal plant from coal mines, create house or townhouse from lumber). To help children understand the relationships between the natural resources and their associated developments, the stamp tags are labeled and displayed with like colors.

A child must stamp or designate a natural resource as usable before a shelter, food or energy development that requires that resource can be stamped. For example, since developments like the farm or garden require water from irrigation, irrigation must first be placed on the map adjacent to the river. However, the river's water levels can be depleted so developments that depend on water use may be limited by this constraint. Farms require more irrigation than gardens but produce more food. Building any development requires co-dependent access through the stamps since it is a two-step process in which a natural resource must be designated for use, and then a related human development placed in a suitable location. When natural resource stamps are assigned to one child, and development stamps to the other, a situation of positive interdependence between the two children may result. This is intended to be a co-dependent mode because both children must take action before anything can be built on the map. For example, one child must stamp an area of forest usable (i.e. turned into lumber) before the other child can use their shelter stamp to build housing. In this 'roles' mode, creating any kind of development depends on each child taking action in a coordinated and collaborative manner. In the independent mode, where no 'roles' are assigned, either child may use any stamp. However, specific sequences of stamps (turn forest into usable lumber then build housing) must still occur for successful interaction.

There is a third set of tools that include: *erase*, *information*, and *impact*. Any child can use these tools. The impact stamp tool shows the current state of the world in terms of what percentage of the current population has its needs for shelter, food and energy met, and how polluted the world is. Once the impact tool is placed, the map is frozen and either child can use fingers to touch one or more of the shelter, food, energy or pollution circular displays which then highlights on the map all of the resources and developments that contribute to that state. The circular ring tool provides information about each stamp. Placing a tree or wrench stamp in the ring displays information about the relationships between that and other stamps as well as information about constraints on usage and location of that stamp. For example, placing the apartment stamp in the ring provides information on the amount of lumber required to build an apartment and how many people the structure supports. Information is provided both textually and pictorially. When the ring tool is in use, the map is frozen and greyed out, so the other child cannot continue to interact at that time.

5. Proposed PhD Research

In this section we will discuss the plans for extending our current investigation into contextual classroom concerns.

5.1 Objectives

1. Continue a literature review of existing contextual theories in order to gain a better understanding about which theories are most pertinent for aiding design and evaluation knowledge of tangible user interfaces within primary classroom settings. This builds on the current research discussed Section 3. This exploratory research with *Youtopia*, funded by a SSHERC Scholarship/SFU Graduate Student Research Award, is part of larger research initiative funded by SSHERC, NSERC, and GRAND.
2. Adapt the contextual theoretical knowledge to fit with existing methodologies that can be used within a classroom settings. This is necessary to identify important factors that must be considered in design of TUIs, supporting materials (e.g. teacher materials) and deployment options, etc.
3. Use the tools within in-the-wild classroom studies in order to gain validation for the tools themselves, in addition to creating and validating contextual design sensitivities for multi-touch and tangible user interfaces for educational classroom activities, such as learning about sustainability in a hands-on, collaborative way.

5.2 Questions for Further Exploration

- In what ways can existing contextual theories inform new ways of thinking about tangible user interfaces for educational contexts?
- How can these theories be adapted to create new tools and methods that complement existing evaluation and design methodologies within human-computer interaction for in-the-wild classroom research?
- Since each contextual theory puts more weight on particular aspects of experience than another, how can we adapt existing contextual analytical methods to study factors that will lead to successful integration of TUIs for learning into the classroom?
- How can these factors be used to design and evaluate tangible user interfaces that support in-classroom culture and educational curricular and holistic objectives? What aspects of AT help us focus on classroom needs or problems and how or in what ways can these areas of exploration be turned into executable design-research tools?
- How can multiple theoretical lenses (e.g. AT and Situated Action) be used together and with existing methods to gain a practical understanding of TUI design and classroom needs?
- Specifically, how can a TUI intended for sustainability curriculum facilitate multiple goals (e.g. topic specific knowledge, exploration, flexibility, support for learning styles and personality types, etc) and what role do adapted theories play in gaining this knowledge?

5.3 Exploratory, Mixed Methodology

The primary study instrument will be Youtopia. Objectives 1 and 2 will involve an extension of our current research. This includes an investigation into contextual factors that can aid or hinder TUI integration within preexisting structures (social, cultural, organizational, etc). For Objective 3, we would like to see if our initial findings hold true in actual practice within the classroom and intended curriculum, and to see if new or different themes emerge from this slight change in context. Per the request of our participating school, we have been asked to place the TUI-touch tabletops within authentic 5th grade classrooms, where the teachers will be integrating them with their normally scheduled sustainability unit. In addition, we hope to explore the use of other contextual lenses as tools for in situ system evaluation and in the creation of design knowledge.

6. Contribution

We hope to provide new knowledge about the benefits and limitations of using multi-touch and tangible user interfaces to support collaborative learning in actual (Canadian) classroom contexts. Combining contextual theory and in-the-wild exploratory studies within human-computer interaction research will help expand the domain's available methodologies and tools of inquiry outside of the traditional lab environment. Furthermore, these in-the-wild studies, aided by actual teachers and primary school students, will expand how researchers, designers and practitioners view what's useful and beneficial in emerging educational technologies intended for classroom use.

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